Planning to be Prepared: Assessing Local Level Planning for Climate Change in the United States

by

Melissa A. Stults

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Doctoral Committee:

**Professor Rosina M. Bierbaum, Co-Chair
Associate Professor Larissa S. Larsen, Co-Chair
Assistant Professor Lesli M. Hoey
Professor Maria C. Lemos**

Dedication

This dissertation is dedicated to all the local practitioners who work tirelessly to create more resilient and sustainable local communities. You have taught me more than I could possibly express and I look forward to continuing to work with you to build a more resilient society.

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List of Abbreviations

DMA – Disaster Mitigation Act

EPA – U.S. Environmental Protection Agency

FEMA – Federal Emergency Management Agency

HMGP – Hazard Mitigation Grant Program

HMPs – Hazard mitigation plans

ICLEI – ICLEI – Local Governments for Sustainability, USA

IPCC – Intergovernmental Panel on Climate Change

NGO - Non Governmental Organization

U.S. – United States

USDN – Urban Sustainability Directors Network

Abstract

Climate change is leading to more frequent and intense impacts such as droughts, floods, heat waves, shifting disease patterns, and deteriorating natural systems, all of which are disrupting the ability of local communities to protect the health, safety, and general welfare of their citizenry. In light of this, a growing number of communities are creating stand alone climate adaptation plans that identify their place based vulnerabilities as well as their prioritized actions for preparing for existing as well as projected changes in future weather and long-term climate. In some cases, communities are also embedding climate considerations into other planning domains, such as hazard mitigation planning. To date, however, no systematic and thorough analysis of the processes used to create these plans or their content has been undertaken. This dissertation fills these voids by evaluating the content of 44 stand alone climate adaptation plans and 30 hazard mitigation plans for U.S. local communities in order to answer four interrelated questions:

1. How do existing climate adaptation plans align with emerging principles of plan quality? What community attributes are associated with higher quality plans?
2. How are U.S. local communities framing uncertainty in their climate adaptation planning? What approaches are local communities using to address uncertainty in their climate adaptation planning?
3. What are U.S. local governments planning to do to prepare for climate change? How do these actions align with the risks or vulnerabilities faced by these local governments? Do local governments provide detail to support the implementation of the actions they identify?
4. How could existing Federal Emergency Management Agency hazard mitigation planning guidelines be altered to integrate climate change? How are local communities currently integrating climate change into hazard planning?

Results show that across all stand alone adaptation plans analyzed, plans consistently: have strong factual bases, drawing upon multiple data sources to understand existing and future vulnerabilities; include a wide variety of adaptation actions; identify numerous types of uncertainty related to planning for climate change; and are using, on average, between 4-5 uncertainty reducing approaches promoted in the literature during their planning process. Most plans, however, include extremely limited implementation details, have built out limited adaptive management processes, and continue to use uncertainty reducing approaches that fall within the traditional '*predict and plan*' model of planning. These differences hold regardless of community size or geographical location. These findings raise concerns about whether plans are both flexible enough to deal with the rapidly changing climate and if the actions in the plans will translate into 'on the ground' projects that build a community's resilience to climate change.

Results also validate previous studies by showing that having planners actively engaged in or leading the adaptation planning process and working with elected officials to secure their support, help produce higher quality plans. Results also show that those creating adaptation plans emphasize uncertainty that is outside of the planner's control, with limited attention paid to lingering sources of uncertainty that the planner has the ability to influence.

Contrary to previous studies, results show that communities are including a wide variety of adaptation actions in their plans, with an emphasis on *research and monitoring* actions as well as actions focused on making changes to operational *practices and behavior*. This contrasts with earlier studies showing that adaptation plans disproportionately emphasize *capacity building* actions. This shift to more concrete actions may be a sign that communities are aware of the need to identify a variety of actions in their planning process in order to comprehensively plan for climate change. In addition, results show that two thirds of the communities with stand alone climate adaptation plans have also embedded climate change, in some way, into their hazard mitigation plan. While there is significant room for improving this practice, this finding is a promising sign as it indicates that communities are looking for opportunities to embed or mainstream climate considerations throughout a variety of existing and more institutionalized planning processes.

Cumulatively, these results suggest that the first generation of adaptation planning is more comprehensive than originally documented in the literature. However, much more work is needed to ensure that the next generation of planning improves upon the limitations identified in these first generation plans. In particular, the next generation of adaptation planning: needs to embrace flexible uncertainty reducing approaches, including the creation of adaptive and iterative planning processes; should more fully engage non-traditional stakeholders and elected leaders in the planning process; and include far more details related to how identified actions will transition into real-world adaptation projects.

In conclusion, this research resulted in the creation of an analytical framework[1] and accompanying methodology for evaluating plans, a new conceptual framework[2] for organizing sources of uncertainty relative to the role of the planner, a new conceptual framework for understanding and classifying approaches for managing uncertainty, a comparison of theoretically robust adaptation strategies to those prioritized in local adaptation plans, and the identification of practical ways that communities can embed climate considerations into their hazard mitigation planning. This research also highlighted a tension that is largely missing from the literature: should a community create a stand alone plan or embed climate considerations into other planning domains? The dissertation concludes with policy guidance for practitioners struggling with this question.

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[1] Throughout this dissertation, the term "analytical framework" is used to describe the grouping of related concepts into a conceptual framework (see below) that also includes quantifiable metrics or indicators that can be used to assess the presence or absence of each of the individual concepts. As such, in this dissertation, an analytical framework is something that can be used to measure or analyze the presence of absence of key concepts within or across units of analysis (e.g., stand alone climate adaptation plans).

[2] Throughout this dissertation, the term "conceptual framework" and the accompanying graphical representation is a heuristic to describe potential relationships and interactions between related concepts.

Chapter One
Overview

1. Introduction

Scientists agree that human activity is changing global, regional, and local weather and climate systems (Mimura et al., 2014; The World Bank, 2012). These changes are already evident in more intense and longer droughts, rising sea levels and accompanying increases in coastal inundation and erosion, more and longer heat waves, and more intense and frequent extreme events (Bierbaum et al., 2014; Intergovernmental Panel on Climate Change, 2014). Warming temperatures and increased precipitation are also disrupting ecosystems and causing large-scale species migrations and causing disease vectors and invasive species to move into new territories. These are only some of the impacts already being experienced due to a changing climate, all of which are projected to become more intense as the climate continues to change.

The imminent and far reaching consequences of climate change have made adaptation, or actions to reduce the harm of climate change impacts, an imperative (Bierbaum et al., 2013; IPCC, 2014). Many scales of government are heeding these calls: least-developed countries are developing National Adaptation Programs of Action (The World Bank, 2010), U.S. federal agencies have agency-specific climate adaptation plans, the White House launched the Natural Disaster Resilience Competition and the Resilience Corps program, many U.S. states have voluntary climate action plans (Ray and Grannis, 2015), and some U.S. tribal and local governments are creating climate adaptation plans (Shi et al., 2015; Woodruff and Stults, 2016).

While this progress is laudable, much more needs to be done to ensure that society is effectively planning for climate change (Bierbaum et al., 2013). The need for adaptation planning is perhaps nowhere more acute than at the local level where the impacts of a changing climate are and will continue to be felt most severely (Bierbaum et al., 2013; Cutter et al., 2008; Laukkonen et al., 2009). Thus, there is a growing recognition that local communities need to prepare for existing and projected changes in weather and long-term climate (Berrang-Ford et al., 2011; Shi et al., 2015).

In the United States, the importance of and commitment to local climate adaptation can be seen through things such as the inclusion of local voices in the President's *State, Local and Tribal Leaders Task Force on Climate Preparedness and Resilience,* in the selection of local government stakeholders as *White House Champions of Change*, in the local examples in the 2014 *U.S. National Climate Assessment*, the creation of the Climate Resilience Toolkit, and in the investments that philanthropies are making in local adaptation initiatives (e.g., The Kresge Foundation; Bloomberg Philanthropies; 100 Resilient Cities). The commitment to local climate adaptation can also be seen in the sheer volume of resources devoted to supporting local communities with planning for and implementing climate adaptive actions (Stults et al., 2015; Nordgren et al., 2016).

One of the most common ways local communities are preparing for climate change is through the process of climate adaptation planning. While relatively nascent, climate adaptation planning is a process by which communities identify existing vulnerabilities, explore how changes in climate could exacerbate those vulnerabilities or create new vulnerabilities, and identify actions to reduce those vulnerabilities (Anguelovski and Carmin, 2011; Woodruff and Stults, 2016).

There are three primary ways that local communities can plan for climate change: A) by creating stand alone plans focused exclusively on climate change impacts and actions for adapting; B) by embedding climate change considerations into other community plans and planning processes, commonly known in the literature as '*mainstreaming*'; or C) by combining both A and B. Following path A allows communities to comprehensively understand how climate change could affect their local community and design contextually appropriate actions to respond (Carmin et al., 2012). Investing time and resources into the creation of a stand alone climate adaptation plan also sends a clear message that preparing for climate change is a priority for the community. The major drawback of this approach is that stand alone climate adaptation plans likely lack regulatory authority, which means that they can quickly become plans that '*sit on shelves*' if strong stakeholder and political buy-in does not exist to support plan implementation (Lyles, 2012; Dovers and Hezri, 2010; Frazier, et al., 2013).

In contrast, option B presents a way for communities to integrate climate change into other plans that have more regulatory weight, such as comprehensive or master plans, thereby helping increase the likelihood that the actions identified in the plan get implemented. This approach can also be used in hazard mitigation planning where, by creating a plan, communities make themselves eligible for an array of federal pre-disaster funding (Frazier et al., 2013). Moreover, hazard mitigation planning is designed to help build the resilience of local communities to natural disasters and since natural disaster frequency, intensity, and duration all projected to increase in a climate-altered world, this type of planning presents a logical tool for simultaneously planning for existing as well as future hazards. Embedding climate change considerations into existing planning processes such as hazard mitigation planning may also expose non-traditional stakeholders to the importance of preparing for climate change (Berke and Lyles, 2013). The limitation of this approach is that it can lead to piecemeal adaptation actions that only modestly advance a community's overall preparedness, especially if a community chooses to embed climate change only into select sector based plans (Abunnasr et al., 2013; Swart and Raes, 2007). In worst-case situations, this could lead to individual sectors pursuing maladaptive actions, or actions that are viable for the system in question but create negative consequences for another system (Barnett and O'Neill, 2010; Kates et al., 2012).

Given the strengths and drawbacks discussed above, I speculates that embracing both options A and B may make communities best positioned to holistically plan for climate change. Doing so could enable a community to embed climate change into relevant existing community plans while simultaneously creating a stand alone climate adaptation plan or framework that pieces together all of the content from the individual plans into a holistic package of adaptation action. This approach may be more time and resource intensive, however, thereby limiting its overall utility. To-date, however, the viability of this approach remains unknown for three primary reasons:

1. Little to no research has looked at the strengths and weaknesses of local stand alone climate adaptation planning.
2. Little information exists about how communities are embedding climate change into other planning domains, such as hazard mitigation planning.

3. No studies have looked at communities that have both stand alone climate adaptation plans and hazard mitigation plans that consider climate change in order to understand the strengths and weaknesses of these two approaches.

2. Research Questions and Hypotheses

Given the serious projected impacts of climate change, it is imperative that local communities understand and plan for existing and projected changes in climate. The way that communities plan, however, will likely vary depending on issues such as the local political climate, resource availability, public acceptance of climate change, and staff expertise. The intent of this dissertation is to analyze the strengths and weaknesses of the first generation of local climate adaptation plans in order to generate research-backed recommendations for scaling up and out local adaptation planning and action. Guiding this research are four interrelated questions, each of which is explored in a separate chapter of this dissertation:

1. How do existing climate adaptation plans align with emerging principles of plan quality? What community attributes are associated with higher quality plans? (Chapter 2)
2. How are local communities in the U.S. framing uncertainty in their climate adaptation planning? What approaches are local communities using to address uncertainty in their climate adaptation planning? (Chapter 3)
3. What are local governments in the U.S. planning to do to prepare for climate change? How do these actions align with the risks or vulnerabilities faced by these local governments? Do local governments provide detail to support the implementation of the actions they identify? (Chapter 4)
4. How could existing Federal Emergency Management Agency hazard mitigation planning guidelines be altered to integrate climate change? How are local communities currently integrating climate change into hazard planning? (Chapter 5)

Drawing on knowledge obtained from the literature as well as professional experience working for over a decade with U.S. local governments on climate change and sustainability initiatives, the following hypotheses were generated:

H_1: Stand alone climate adaptation plans have moderately high alignment with principles of plan quality, especially principles focused on fact base, use of future projections, and action identification.

H_2: Communities that are engaged in peer networks, have recently experienced a disaster, and have higher per-capita incomes will create stronger stand alone adaptation plans.

H_3: Stand alone climate adaptation plans will actively discuss uncertainty related to what future weather and climate conditions will be but will also use a variety of uncertainty mitigating approaches (e.g., multiple greenhouse gas emissions scenarios, low-regrets action selection) to help reduce this uncertainty.

H_4: The most commonly promoted adaptation actions in stand alone adaptation plans are those focusing on capacity building, and the least common actions are those focused on land use changes.

H_5: Stand alone adaptation plans have weak implementation guidance and few iterative or flexible planning approaches that align with principles of adaptive management.

H_6: While a number of theoretical approaches exist for integrating climate change into hazard mitigation planning, the highly structured and regulated format of hazard mitigation planning limits the ways that communities are integrating climate change into their hazard mitigation plans.

3. History of Climate Adaptation Planning in the United States

Local level climate change planning emerged in the United States during the mid-1990s (Millard-Ball, 2012; Wheeler, 2008). Historically, this work, also known as climate mitigation or climate action planning, focused on reducing local greenhouse gas emissions that contribute to climate change (Bassett and Shandas, 2010; Wheeler, 2008). A 2009 study found that more than 140 communities in the United States had created stand alone climate mitigation plans (ICLEI, 2009), with the vast majority of these plans focusing on actions to reduce greenhouse gas emissions from buildings and transportation networks (Bassett and Shandas, 2010; Krause, 2011; Stone et al., 2012; Wheeler, 2008). In an analysis of these climate mitigation plans, Wheeler (2008) found that the goals identified in these plans are “too low” to advert significant climate impacts, progress in implementing the plans is slow to non-existent, and proposed measures are inadequate to avoid projected changes in climate. A similar analysis by Bassett and Shandas

(2010) substantiated these claims and found that few of these plans detail actions that will help the community prepare for the impacts of climate change (i.e., climate adaptation actions).

In the last decade, however, more communities have started planning specifically for climate related impacts (Berrang-Ford et al., 2011; Bierbaum et al., 2013; ICLEI, 2013; Shi et al., 2015). This work, known as climate adaptation planning, has commonly resulted in plans focused exclusively on how to prepare for the impacts of climate change (i.e., stand alone climate adaptation plans). The City of Keene, New Hampshire released the first stand alone climate adaptation plan in the United States in 2007. This plan was in response to devastating flooding in October of 2005 that caused millions of dollars' worth of damage, disrupted local businesses and public services, displaced more than 1,000 people, and led to seven deaths (City of Keene, 2007). In response to this disaster, the City partnered with the nonprofit ICLEI-Local Governments for Sustainability, USA (ICLEI) and the University of New Hampshire to develop a plan to prepare for climate change and its effects on future natural disasters. The outcome was the City of Keene's 2007 plan, *Adapting to Climate Change: Planning a Climate Resilient Community*. Since the creation of this plan, more than 40 other communities in the U.S. have created stand alone climate adaptation plans.

Previous research has identified four main factors explaining why some local communities choose to initiate adaptation planning: 1) previous experience with a hazardous event, 2) perception of a future weather-related threat, 3) interest in demonstrating community leadership, and 4) acknowledgement that climate change could inhibit a community's ability to meet its existing goals (Anguelovski and Carmin, 2011; Blanco et al., 2009; Boswell et al., 2012; Preston et al., 2010). More recently, factors such as community per capita income, community education levels, political structure, and engagement in city-to-city peer learning networks have been found to explain why certain communities undertake climate adaptation and mitigation initiatives (both planning and implementation) and others do not (Bedsworth and Hanak, 2013; Boswell et al., 2012; Carmin, et al., 2012; Kalafatis et al., 2015; Lackstrom et al., 2014; Wheeler, 2008; Woodruff and Stults, 2016).

Conversely, one of the most commonly cited barriers to undertaking adaptation action is a lack of funding: 91% of respondents in a 2014 survey conducted by University of Michigan researchers in tandem with nongovernmental organizations, identified this as the most significant barrier to achieving their adaptation goals (Nordgren et al., 2016). This finding has been substantiated in studies done by Moser and Ekstrom (2010), Eisenack et al. (2014), Measham et al. (2011), and the President's State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience (2014), among others. Other high-ranking barriers commonly cited by local practitioners to advancing climate adaptation include: challenges with generating support amongst businesses for adaptation action, allocating adequate staff time to implement actions, and educating and engaging the public in adaptation activities (Nordgren et al., 2016; Stults et al., 2015; President's State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience, 2014).

Another barrier that has recently emerged pertains to a dearth of standardized adaptation planning guidance for U.S. local communities (Stults et al., 2015). This lack of standardized guidance makes it extremely challenging to evaluate the rigor of adaptation planning or to support local practitioners in creating and implementing strong adaptation plans (Stults et al., 2015). Instead of standardized guidance, federal agencies, the scientific community, and boundary organizations have created dozens of 'ad hoc' adaptation planning guides (e.g., IPCC, 2012; University of Washington and ICLEI, 2007; American Planning Association, 2011; California Emergency Management Agency and California Natural Resources Agency, 2012; National Research Council, 2010). These guidebooks often provide conflicting guidance about how best to plan for climate change, leaving practitioners with little clarity about how best to approach adaptation planning, which can translate into weak planning processes, poor plans, or, in worst case situations, communities so confused they choose not to plan (Nordgren et al., 2016).

While standardized adaptation planning guidance does not exist in the U.S., a consensus is emerging regarding the elements of a strong climate adaptation plan and the accompanying planning processes. These elements include the setting of goals, a compilation of projected future changes in weather and climate, a vulnerability or risk assessment, the selection of actions to reduce risk or increase resilience, details that support action implementation, and a plan for monitoring and evaluating progress (ICLEI, 2013; Woodruff and Stults, 2016).[3]

Using these elements as a foundation for analyzing the quality of adaptation plans at national, regional, and local levels in Australia, the United Kingdom, and the United States, Preston et al. (2010) found that the 57 adaptation plans in their sample tend to have strong

[3] More detail about the state of local adaptation planning in the U.S. can be found in Chapters 2 and 4.

assessments of climate related impacts, vulnerability, or risk and have strong discussions of relevant climate drivers (e.g., sea level rise and changing temperature or precipitation patterns). In contrast, Preston et al. (2010) found that plans scored the lowest in areas related to implementation, monitoring and evaluating plan progress, and assessing adaptive capacity. Of all the scales of planning studied (national, regional, multi-jurisdictional, and local), the authors found that local/municipal plans scored better, on average, than those at higher geopolitical scales, suggesting "the more narrowly defined the system of interest, the greater the potential for more detailed planning" (Preston et al., 2010, p. 15).

The study by Preston et al. (2010) also found that a preponderance (72%) of the actions identified in the selected adaptation plans focused on low-risk capacity building. In a similar but more detailed analysis of adaptation actions in the United Kingdom, Tompkins et al. (2010) found that, of 300 adaptation actions examined, the majority related to capacity building. To reach this conclusion, the authors classified all 300 actions into one of eight main types: research, planning, networks, legislation, awareness raising, implemented change, training, and advocacy. They found that the majority of actions fell into one of six categories, which they argue support capacity building: *research*, *planning*, *networks*, *awareness raising*, *training*, and *advocacy*. The priority focus on capacity building as an adaptation action has been further supported by analysis of empirical adaptation work on the Great Barrier Reef, in the agricultural sector in Canada, and in the transportation sector in the U.S. (Eisenack et al., 2011; Fidelman et al., 2013; Preston et al., 2010; Smit and Skinner, 2002).

These results suggest that capacity building—*the practice of enhancing the strengths and attributes of, and resources available to, an individual, community, society, or organization to respond to change* (Intergovernmental Panel on Climate Change, 2014)— is the dominant type of adaptation action included in adaptation planning efforts analyzed to date (Preston et al., 2010; Tompkins et al., 2010). These findings may reflect the nascence of the local climate adaptation field, as the types of actions being planned for and implemented on the ground are what Lesnikoswki et al. (2011, 2013) framed as recognition and groundwork activities. According to the authors, these activities create a foundation that communities can later build upon to implement more aggressive future actions to reduce their vulnerability, such as hardening physical infrastructure, establishing more aggressive building codes, and passing land use ordinances that discourage or prohibit development in vulnerable areas (Lensikoswki et al., 2013).

While capacity building actions tend to be the primary focus of the local adaptation plans studied to date, recent research suggests that communities are pairing capacity building with other types of actions that can lead to tangible reductions in local vulnerability (Abt Associates, 2016; Nordgren et al., 2016). For example, promoting green infrastructure to address stormwater issues, changing organizational procedures and practices to better manage invasive species or extreme heat, and passing more aggressive building codes to ensure that physical infrastructure can withstand climate related impacts are all actions that local stakeholders have recently promoted to prepare for climate change (Bassett and Shandas, 2010; Bierbaum et al., 2013; Dierwechter, 2010; Solecki et al., 2011).[4]

Unfortunately, little information has been assembled to date regarding what types of adaptation actions are included in the first generation of climate adaptation plans in the U.S. Without a more detailed look at U.S. local adaptation planning, it remains unclear exactly what actions U.S. communities are emphasizing as key to building resilience, how they determined that these actions were the most viable, who was engaged in the adaptation planning process and therefore had a say in determining what the community should be doing to prepare, and whether the plans contain detailed information that will support their translation into real-world projects that ultimately reduce the community's vulnerability (Davoudi et al., 2013; Engle, 2011; Measham et al., 2011; Preston et al., 2010).

4. History of Hazard Mitigation Planning

While climate adaptation planning is a relatively new practice, local communities have been planning for natural hazards for centuries (FEMA, 2015). The formalization of hazard planning in the United States began in the 1970s with the passage of the Disaster Relief Act of 1974, which was later amended by the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 2000 (FEMA, 2013). According to the Federal Emergency Management Agency (FEMA), hazard mitigation planning comprises "pre-disaster measures aimed at minimizing or preventing losses and long-term risk to people and property from natural hazard events and their impacts" (FEMA, 2013; Frazier et al., 2013; Godschalk, 2003). Hazard mitigation planning is mandated for any jurisdiction that wishes to be eligible for federal pre-

[4] More information about the types of adaptation actions prioritized at the local level can be found in Chapter 4.

disaster mitigation funds (FEMA, 2013; Schwab and Topping, 2010; Schwab, 2010). As of March, 2016, over 22,600 units of government in the United States, representing over 82% of the total U.S. population, had FEMA-approved local hazard mitigation plans (FEMA, 2016).

To assist in hazard mitigation planning, FEMA provides detailed guidance on what is expected of states, tribes, and localities that wish to create a hazard mitigation plan (FEMA, 2013). FEMA's specific requirements for how local hazard mitigation plans are developed and what they include are set forth in its Plan Review Crosswalk and Local Hazard Mitigation Plan Review Guide (FEMA, 2013). The purpose of these guides is to "help Federal and State officials assess Local Mitigation Plans in a fair and consistent manner, and to ensure approved Local Mitigation Plans meet the requirements of the Stafford Act and Title 44 Code of Federal Regulations §201.6" (FEMA, 2013). As detailed in the guidance material, local hazard mitigation plans must include: documentation of the hazard mitigation planning process; hazard identification and a risk assessment; mitigation actions; details on plan review, evaluation, and implementation; details on plan adoption; and information related to any additional state-level requirements (FEMA, 2013; Frazier et al., 2013; Godschalk, 2003). Approval of local hazard mitigation plans is required by both the respective state hazard mitigation office and FEMA (FEMA, 2013). In order to maintain eligibility for FEMA hazard mitigation project grant funding, local hazard mitigation plans must be updated at least every five years (FEMA, 2013).

Content analyses of hazard mitigation plans find that the actions included in these plans tend to emphasize structural preparedness such as flood defenses, use of culverts, and enhanced building codes (Babcock, 2013; Berke et al., 2012; Burby et al., 2000; Travis, 2010). Some recent work suggests that non-structural actions such as changes in policy and the use of natural systems to lessen the impact of hazards are starting to emerge in local hazard mitigation plans. Overall, however, actions promoted in the hazards community rarely emphasize issues pertaining to capacity building, the use of green infrastructure to manage risk, or retreat-based actions (Committee on Increasing National Resilience to Hazards and Disasters, 2012; Kates et al., 2012; Lyles et al., 2014; Olshansky and Kartez, 1998). In addition, hazard mitigation plans tend to emphasize actions focused on emergency response (Frazier et al., 2013; Kapucu, 2012; Lyles et al., 2012). Given that hazard mitigation is meant to be proactive, researchers note that it is peculiar that emergency approaches, which are inherently reactive, should be emphasized in hazard mitigation planning.

Theoretically, hazard mitigation plans should create roadmaps for increasing a community's preparedness and resiliency in the face of a hazard (FEMA, 2013; Frazier et al., 2013). More commonly, research shows that communities and states undertaking hazard mitigation planning strive to meet the minimum requirements set by FEMA and often overlook critical issues and actions that could protect against future harm (Frazier et al., 2013; Lyles et al., 2012). As Frazier et al. (2013) note, "minimum requirements, as stipulated by the Disaster Mitigation Act of 2000 are all that is needed to qualify for federal mitigation grant funding regardless of plan quality or appropriateness of HMPs to local hazards and risks" (p. 52). The integration of socio-economic vulnerability factors into hazard mitigation planning, the consideration of future changes in climate, and interactive stakeholder engagement techniques are not specifically required by the Disaster Management Act and are therefore not criteria FEMA uses to evaluate hazard mitigation plans (Babcock, 2013; Cutter et al., 2008; Frazier et al., 2013; Solecki et al., 2011).[5]

Because local communities are not required to consider climate change in their hazard mitigation plans (as of 2015, states are now required to consider climate change in their hazard mitigation planning but this requirement does not extend to local communities), thousands of communities throughout the U.S. may be creating plans that leave them ill prepared for climate change and the associated increase in frequency, intensity, and duration of natural disasters. While scholars have called for climate change to be added as an essential element of hazard mitigation planning, to date no analysis has been done to identify how climate change could theoretically and practically be integrated into local hazard planning. Given that over 22,600 U.S. communities have hazard mitigation plans while only approximately 44 communities have stand alone climate adaptation plans, finding ways of incorporating climate change into hazard mitigation planning presents a significant and potentially unique opportunity to rapidly scale up the number of U.S. communities that are simultaneously planning for near-term hazards and long-term changes in climate.

5. Evaluating Plans

Recognizing that hazard mitigation planning often only meets the minimum requirements set by FEMA, a number of researchers have called for a more robust set of criteria to evaluate hazard mitigation planning (as well as other types of planning efforts) (Berke et al., 2011; Frazier

[5] For more information on local hazard mitigation planning, see Chapter 5.

et al., 2013; Lyles et al., 2014, 2012; Waldner, 2004). The call for more stringent evaluation criteria is part of a larger movement towards more robust techniques for evaluating the overall ‘quality’ of local plans (i.e., plan quality evaluation). Behind the call for plan quality evaluation is the idea that “higher-quality plans are more effective than lower-quality plans for promoting such goals as growth management, environmental protection, economic development, disaster resilience, efficient transportation, reduced infrastructure costs, and the reduction of greenhouse gas emissions” (Stevens et al., 2014, p. 1). Implicit in this statement is the concept that higher quality plans are more likely to be implemented than lower quality plans (Berke et al., 2012; Talen, 1996).

The aim of plan quality evaluation is to “identify the specific strengths and weaknesses of plans, evaluate their overall quality, and provide a basis for ensuring that they reach a desirable standard” (Berke and Godschalk, 2009; Stevens et al., 2014, p. 1). The methodology employed in plan quality evaluation research is detailed content analysis, which involves a “systematic reading of a body of texts, images, and symbolic matter” (Krippendorff, 2013). As a field, however, planning has no formal guides that specify the essential elements of ‘good’ plans. This is partly because plan quality is difficult to define (Baer, 1997; Berke and Godschalk, 2009; Brody, 2003), especially when one is trying to evaluate plan quality across varying topics, scales, and levels of formality. Planners and scholars may be able to differentiate high quality plans from low quality plans, but as Baer (1997) notes, “they are hard pressed to explicitly define the key characteristics of plan quality” (p. 329).

This ambiguity about what makes one plan better than another has led many planning scholars to call for standardized plan evaluation criteria. As Alexander and Faludi (1989) note, “if planning is to have any credibility as a discipline or a profession, evaluation criteria must enable a real judgment of planning effectiveness: good planning must be distinguishable from bad” (p. 121). Further elaborating on this point, Stevens et al. (2014) note that there is a compelling “need for a set of rigorous procedures that plan quality researchers can follow to facilitate the production of replicable data that (1) can be meaningfully compared and contrasted across time periods, geographic regions, and substantive contexts and (2) can better promote effective planning practice” (p. 1).

Despite challenges in standardizing plan quality evaluation, some planning scholars have established a set of commonly agreed upon core principles of plan quality, including 1) a strong *factual basis*, 2) clearly articulated *goals*, and 3) appropriately directed *policies* (Berke and Godschalk, 2009; Brody, 2003; Godschalk, 2003; Lyles et al., 2014). The '*fact base'* principle traditionally includes things such as profiling of historic hazards and the use of scientific and indigenous knowledge to assess historic impacts. The '*goals'* principle includes a clear articulation of planning goals or a planning vision and associated objectives. The '*policies*' principle includes actions that specifically focus on achieving the goals/vision articulated in the plan, building upon information gleaned from the fact base analysis.

In addition, planning research, specifically addressing hazard mitigation planning and climate action planning, has found that *public participation* (Berke et al., 2011; Brody, 2003; McGovern, 2013), *inter- and intra-organizational coordination* (Berke et al., 2012; Berke et al., 2011; Measham et al., 2011), clear *implementation guidance* and associated responsibilities (Bassett and Shandas, 2010; Berke et al., 2012; Godschalk, 2003; Lyles et al., 2012; Waldner, 2004), and *monitoring and evaluation* (Bassett and Shandas, 2010; Berke and Lyles, 2013; Berke et al., 2012; Wilby and Vaughan, 2011) are important principles of plan quality. For example, citizen participation "often enhances the planning process and leads to a more desirable outcome that meets the needs of all parties" (Brody, 2003, p. 193). While meeting the needs of all stakeholders may be an unachievable goal due to the heterogeneous nature of stakeholders, research does suggest that when individuals are actively engaged in a process, they are more likely to support the final results (Measham et al., 2011; Norris et al., 2008).

Within the planning literature, plan evaluation studies have been conducted on a diversity of planning types, including hazard mitigation planning (Lyles et al., 2014), affordable housing planning (Hoch, 2007), and sustainability planning (Schrock et al., 2015; Berke and Conroy, 2000). Most plan quality evaluation studies to date, however, have focused on hazard mitigation planning (Berke et al., 2012; Brody, 2003; Burby et al., 2000; Lyles et al., 2014, 2012; Olshansky and Kartez, 1998), with the earliest known plan quality evaluation study (published in 1994) focusing on this topic (Stevens et al., 2014). Since that time, more than forty additional plan quality evaluation studies have been conducted, the majority of which focus on local hazard planning.

In a 2012 study analyzing the quality of 175 local hazard mitigation plans in six coastal states (California, Florida, Georgia, North Carolina, Texas, and Washington), Lyles et al. found that "local hazard mitigation plan quality is moderate to weak overall and varies widely across the principles of plan quality" (p. 18). The highest-scoring principles included goals, participation, and implementation, but even these principles had "considerable room for improvement" (p. 18). The authors also found that climate change was rarely addressed in any of the hazard mitigation plans analyzed.

Since climate change is rarely, if ever, integrated into hazard mitigation planning, only a small number of plan evaluation studies have focused exclusively on climate action planning (Bassett and Shandas, 2010; Boswell et al., 2012; Tang et al., 2010; Wheeler, 2008). To date, the vast majority of these studies have looked at climate *mitigation* planning and not climate *adaptation* planning. For example, Tang et al. (2010) evaluated 40 local climate change action plans in the U.S. against three overarching concepts believed to be important to plan quality: awareness, which "measures the degree to which communities understand the concepts of climate change, climate variability, and global warming"; analysis capabilities, which include an emissions inventory, a vulnerability assessment, and projected future emissions and vulnerabilities; and action approaches, which involve "policies, tools, and strategies to address climate change mitigation and adaptations in the natural environments, built environment, and human health" (p. 44). Aggregating a series of indicators in each of these categories, the authors find that local climate action plans have "a high level of awareness, moderate analysis capabilities for climate change, and relatively limited action approaches for climate change mitigation" (Tang et al., 2010, p. 41). The authors also find that only 15% of all plans discussed the use of a vulnerability assessment to determine appropriate climate adaptation actions (Tang et al., 2010). This general lack of climate adaptation considerations in climate action planning is consistent with similar studies conducted by Wheeler (2008), Bassett and Shandas (2010), Boswell et al. (2012), and Stone et al. (2012).[6]

Overall, plan quality evaluation studies to date have shown that most natural hazard and climate action plans either completely disregard or have fairly weak sections on adapting to climate change (Bassett and Shandas, 2010; Tang et al., 2010; Wheeler, 2008). In addition, existing plan quality studies appear to have overlooked the concept of planning with uncertainty, often focusing instead on evaluating the presence of a rigidly defined set of specific actions that the authors believe are universally important to addressing hazards or advancing sustainable development (Lyles et al., 2014, 2012). This rigidity appears to be displacing emphasis on

[6] More information on previous plan quality evaluation studies can be found in Chapter 2.

flexible and adaptive actions, which are cornerstones of resilience and adaptive management theory (Benson and Stone, 2013; Berke and Lyles, 2013; Folke et al., 2002; Pelling and Manuel-Navarrete, 2011). An important opportunity now exists to integrate concepts related to planning for an uncertain future (e.g., scenario planning, use of future climate projections, no-regrets actions) and adaptive management (e.g., timelines for updating plans and phased implementation schedules) into plan quality evaluation studies, particularly those focusing on hazard mitigation and climate adaptation plans.[7]

6. Summary of Key Findings

The remainder of the dissertation addresses four overarching research questions and their cumulative findings.[8] Chapter 2 explores how local stand alone climate adaptation plans perform against common principles of plan quality. In this chapter, which was co-authored with Sierra Woodruff, the strengths of the first generation of stand alone climate adaptation plans are presented along with opportunities for plan improvement. The foundation of this chapter is content analysis of 44 local adaptation plans in the United States and a comparison of this content with seven principles of plan quality: goals, fact base, actions, public participation, inter-organizational coordination, implementation and monitoring, and uncertainty. Multivariate regression analysis is also used to explore community attributes that are correlated with plan quality, noting the attributes that help explain why some communities create stronger plans than others. In addition, Chapter 2 provides a short history of plan evaluation research, including details about the limited number of previous adaptation plan evaluation studies and indicators known to have previously impacted the quality of local plans. This chapter also highlights some of the prominent adaptation planning guidance available in the grey literature and merges adaptation related concepts from this literature, such as planning with uncertainty, into traditional plan evaluation methodologies. Results from this portion of the dissertation provide important insights for practitioners, policymakers, and scientists wanting to improve the quality—and hence the likelihood of implementation—of local climate adaptation plans.

[7] More information on planning with uncertainty can be found in chapter 3.

[8] Chapters 2 – 5 are presented as stand alone articles, which have each been submitted or published in a peer-reviewed journal. Because of this format, some redundancy is present between the chapters. An effort has been made to reduce this redundancy, where possible, and links are provided to access version of each of the articles that have been successfully published in the peer-reviewed literature.

Chapter 3 looks at how communities are framing uncertainty in their stand alone adaptation plans and how this framing informs the types of uncertainty reducing approaches being used to plan for climate change. Information in this chapter, which is co-authored with Dr. Larissa Larsen, draws simultaneously from the climate literature and the planning literature, which each prioritize different conceptual frames and approaches to address uncertainty. This chapter begins by reviewing the most common types of uncertainty identified within the climate literature and translating these into three categories relative to the role of the planner: 1) uncertainties beyond the planning process, 2) uncertainties within the planning process, and 3) uncertainties that bridge these two realms (bridging uncertainty). Next, using the climate and planning literatures as a foundation, 11 planning approaches commonly recognized as useful practices for reducing the uncertainty associated with climate adaptation planning are identified. These 11 approaches are then categorized by whether they reflect a '*predict and plan*' or an '*adapt and monitor'* approach. Finally, the content of 44 U.S. local climate adaptation plans are evaluated to determine how they frame uncertainty and what approaches adaptation planners are using to address uncertain future climate conditions. This chapter concludes with a call for a transition from a '*predict and plan*' model of planning to one that is based on 'adapting and monitoring.'

Chapter 4, which was also co-authored with Sierra Woodruff, dives more deeply into the types of actions included in 43[9] U.S. local stand alone climate adaptation plans. Content analysis is combined with a modified grounded theory method to categorize the more than 3,700 distinct adaptation actions found in the local plans into one of seventeen types: advocacy, building codes and engineering design standards, capacity building, education and outreach, energy conservation, financing, funding, green infrastructure, land use and zoning, physical infrastructure, planning, policy, practice and behavior, research and monitoring, technology, water conservation, and greenhouse gas mitigation activities. For each plan, the total number of actions, the number of action types, and the proportion of each type of action were calculated. In addition, the total number of actions in each type and the number of plans that included a given type of action was calculated. This chapter also looks at how the proposed adaptation actions align with the risks or vulnerabilities faced by the local community. This was done by first

[9] Satellite Beach, Florida's adaptation plan did not contain any specific adaptation actions. As such, it was removed from this portion of the analysis, taking the total number of plans analyzed in Chapter 4 to 43.

building a list of adaptation actions recommended in the peer-reviewed literature for each of the main types of climate related impacts. Next, a database of the projected climate impacts for each community was created, based on results from the 2014 U.S. National Climate Assessment, and the actions included in each plan were compared against the actions believed to be appropriate given each community's projected future regional climate impacts. Finally, this chapter explores the degree to which the plans provide guidance to support the implementation of identified adaptation actions, thereby helping to ensure that actions listed in plans transition into on-the-ground projects.

Chapter 5 explores the history of hazard mitigation planning and presents a conceptual framework composed of 21 ways that climate change could be embedded into local hazard mitigation planning based on existing FEMA planning requirements. Next, this chapter explore how 30 U.S. local communities have integrated climate change into their hazard planning, using the conceptual framework as an evaluation tool. The results present empirical evidence for how climate change already is and could be more fully embedded into existing hazard mitigation planning processes. This chapter concludes with suggestions on how hazard mitigation planning guidance could be tailored to support more communities in planning simultaneously for existing and future hazards.

Finally, Chapter 6 presents the overarching conclusions from my research, identifying opportunities for scaling up the practice of local level planning for climate change as well as areas for future research. Hopefully, the results from this dissertation contribute to both the scholarship surrounding local adaptation to climate change and the practice of building more resilient local communities.

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Chapter Two
Numerous Strategies but Limited Implementation Guidance in U.S. Local Adaptation Plans[10, 11]

1. Abstract

Adaptation planning offers a promising approach for identifying and devising solutions to address local climate change impacts. Yet there is little empirical understanding of the content and quality of these plans. This paper uses content analysis to evaluate 44 local adaptation plans in the United States and multivariate regression to examine how plan quality varies across communities. Findings show that plans draw upon multiple data sources to analyze future climate impacts and include a breadth of actions. Most plans, however, fail to prioritize impacts and actions or provide detailed implementation processes, raising concerns about whether adaptation plans will translate into on-the-ground reductions in vulnerability. This analysis also finds that plans authored by the planning department and those that engaged elected officials in the planning process were of higher quality than plans authored by others (e.g., nongovernmental organizations, state and federal agencies, or academic partners). The results provide important insights for practitioners, policymakers, and scientists wanting to improve local climate adaptation planning and action.

[10] This chapter has been modified from a version that was published in Nature Climate Change on May 2, 2016, which is accessible via: http://www.nature.com/nclimate/journal/vaop/ncurrent/full/nclimate3012.html.

[11] This chapter was co-authored with Sierra Woodruff at the University of North Carolina.

2. Introduction

Climate change already affects local communities, and these impacts are projected to become more severe and intense in the future (Intergovernmental Panel on Climate Change, 2012; The World Bank, 2012). The growing reality of climate change is leading many local communities to invest in adaptation – actions to limit the negative consequences of climate change – and, in many cases, to create climate adaptation plans (Bierbaum et al., 2013). In the last decade, more than 40 U.S. communities have created stand alone climate adaptation plans. These plans detail how climate change is projected to impact the community and what actions should be taken to prepare (Fussel, 2007; Preston et al., 2010). Adaptation planning represents systematic attention to climate change (Wheeler, 2008) and, as a result, is expected to help prepare communities and lower the cost of climate related impacts (Preston et al., 2010).

Despite the potential value of adaptation planning, few studies have analyzed these plans and none have used plan evaluation methods. Previous adaptation plan studies have analyzed plans using outcome (i.e., impact; Baker et al, 2012) and logic framework (i.e., process; Preston et al., 2010) approaches, which provide insights into how well plan content aligns with processes suggested in adaptation guidance. Plan evaluation, in contrast, assesses how adaptation plans align with agreed-upon criteria of plan quality, allowing the quality of adaptation plans to be compared to the quality of other planning types such as hazard mitigation plans or sustainability plans. Moreover, plan evaluation uses more detailed criteria to analyze the content of adaptation plans and identify specific areas for improvement. A more detailed analysis of local adaptation plans using plan evaluation methods is needed (Engle, 2011; Measham et al., 2011; Millard-Ball, 2012).

In addition, it is important to understand how plan quality varies across communities. Specifically, how are community attributes such as capacity (e.g., access to funding, planning experience), commitment (e.g., dedication to the issue), internal operations (e.g., plan author), and policy diffusion (e.g., involvement in peer networks) associated with plan quality? To help fill these gaps, this paper addresses two questions: 1) How do existing climate adaptation plans align with emerging principles of plan quality? 2) What community attributes are associated with high quality plans?

2.1 Plan Quality

Across the United States, governments and nongovernmental organizations invest millions of dollars and countless hours in planning (Lyles and Stevens, 2014). Due to this large investment, there is a growing interest in evaluating the quality of plans—documenting their content and evaluating their overall strengths and weaknesses in order to better inform practice (Berke and Godschalk, 2009). Behind the call for plan quality evaluation is the idea that high quality plans better advance community goals than lower quality plans because higher quality plans are more likely to be implemented (Stevens et al., 2014).

Over the last two decades, researchers have used plan evaluation methodologies to evaluate plans from multiple domains, including hazard mitigation (Lyles et al., 2014), affordable housing (Hoch, 2007), and sustainability planning (Schrock et al., 2015). As the plan evaluation literature has grown, scholars have built a general consensus on the key principles of plan quality. In meta-analyses of plan evaluation studies, Berke and Godschalk (2009) and Lyles and Stevens (2014) identified six principles commonly used in plan evaluation: 1) goals, 2) fact base, 3) policies, 4) public participation in plan creation, 5) inter-organizational coordination, and 6) details regarding implementation and monitoring. These six principles are increasingly viewed as “standard” principles for plan evaluation (Stevens, 2013) and are considered to be applicable across planning domains and scales (e.g., local, regional, state) (Lyles and Stevens, 2014).

Goals are defined as future desired conditions that establish the breadth of a plan. *Fact base* identifies and prioritizes community issues, providing the empirical foundation on which actions are based. *Actions* provide a guide to decision making to ensure that plan goals are achieved. These first three plan quality principles are frequently referred to as direction setting principles because, while every plan should include these principles, they will look different across planning domains (Berke et al., 2006). For example, the actions identified in a transportation plan will not be the same as those identified in an adaptation plan. Consequently, the evaluation criteria for these principles are tailored to the specific domain being assessed. In contrast, the last three principles – *public participation*, *coordination*, and *implementation and monitoring* – do not differ significantly between planning domains. Whether a transportation or adaptation plan is being evaluated, the plan should provide a description of how the public was engaged in the planning process (*public participation*), how other organizations and government agencies contributed to the planning process (*coordination*), and how the plan will be implemented and monitored in the future (*implementation and monitoring*).

The six standard plan principles correspond to the rational model of the planning process whereby planners are thought to review existing and future conditions, formulate goals, identify potential actions to achieve goals, and select the optimal set of actions for implementation (Lyles and Stevens, 2014). To a large extent, the adaptation planning process proposed in guidance produced by federal, state, and non-governmental organizations follows the rational planning model. For example, California's Adaptation Planning Guide (California Emergency Management Agency and California Natural Resources Agency, 2012) proposes nine steps in the adaptation planning process: identifying 1) exposure, 2) sensitivity, 3) potential impacts, 4) adaptive capacity, 5) risk and time of onset, and 6) prioritizing adaptation needs, 7) identifying actions, 8) evaluating and prioritizing potential actions, and 9) determining implementation details for selected actions. The first five steps correspond to the rational model steps of reviewing existing and future conditions as well as to the fact base plan principle. The last four steps align with the rational model steps of identification and action selection.

The steps in California's adaptation planning process that fall under the fact base principle demonstrate how adaptation planning differs from other planning domains. Adaptation guidance literature emphasizes detailed, science-based analysis of projected changes in climate (*exposure*), as well as the consequences for the community, through the completion of a vulnerability or risk assessment. Because climate change is projected to have broad impacts that affect many governmental sectors, existing adaptation guidance proposes many different types of actions. For example, California's Adaptation Guide (California Emergency Management Agency and California Natural Resources Agency, 2012) recommends actions ranging from "Develop a water recycling program" (p. 7) to "Promote economic diversity" (p. 8). While most adaptation actions are not new, the breadth of actions that should be included in an adaptation plan is unique among planning domains, with the possible exception of sustainability planning.

In addition to the six plan principles commonly used in plan evaluation studies, efforts to prepare for climate change must address uncertainty (Berke and Lyles, 2013; Chakraborty et al., 2011; Haasnoot et al., 2013). Multiple sources of uncertainty, from modeling global climate to estimating the cost of local adaptation options, create a "cascade" of uncertainty (Dow and Carbone, 2007) that can challenge local adaptation planning (Hallegatte, 2009; Moser, 2005).

Planning researchers argue that adaptation planning requires a break from the traditional '*predict and plan*' paradigm and should embrace new approaches that enable discovering, assessing, and addressing uncertainty (Berke and Lyles, 2013; Munaretto et al., 2014). For example, Quay (2010) promotes anticipatory governance, a "model of decision making under high uncertainty based on concepts of foresight and flexibility, [that] uses a wide range of possible futures to anticipate adaptation actions, and then monitors change and uses these actions to guide decision making" (p. 496). Similarly, adaptation guidance emphasizes the need to consider multiple futures and emphasizes actions that provide benefits across a number of potential future scenarios (California Emergency Management Agency and California Natural Resources Agency, 2012; University of Washington and ICLEI, 2007).

To date, plan evaluation studies have not incorporated new approaches of planning under high uncertainty (Berke et al., 2015; Lyles and Stevens, 2014). In our analysis (detailed below), we have included the concept of uncertainty as a core plan principle, thereby extending the plan evaluation literature so that it explicitly measures the extent to which adaptation plans incorporate new planning approaches (Appendix 1).

2.2 Climate Adaptation Planning

To date, few studies have used content analysis, "a systematic reading of a body of texts, images, and symbolic matter," (Krippendorff, 2013) to evaluate whether local adaptation plans adhere to criteria associated with the various plan quality principles. Preston, Westaway, and Yuen (2010) evaluated 57 adaptation plans from a range of geopolitical scales in Australia, the United Kingdom, and the United States against 19 process-based evaluation criteria based on a Logic Framework approach (i.e., process-based) and adaptation guidance materials. Their results indicate that adaptation plan quality is highly variable: plans scored between 16% and 61% of possible points. Overall, however, adaptation plans were relatively weak, scoring on average 37% (Preston et al., 2010). Baker et al. (2012) analyzed seven local adaptation plans in Southeast Queensland, Australia, with similar results. The plans included in these samples exhibited high awareness of climate issues and had strong scores on assessment of climate drivers and impacts (Preston et al., 2010; Baker et al., 2012). They did not, however, include a complete analysis of local conditions such as non-climatic drivers, key financial and natural capital, or existing adaptive capacities that will help the communities prepare for future climatic impacts (Preston et al., 2010; Baker et al., 2012). In addition, few plans provided objectives or success criteria to measure progress, and most failed to include details about implementation (Preston et al., 2010; Baker et al., 2012).

While these studies provide a foundational understanding of adaptation plan content and quality, they fail to integrate the methodologies and lessons learned from the long history of plan evaluation research. As mentioned previously, Preston et al. (2010) use a Logic Framework Analysis (LFA) approach in their assessment, which allows them to evaluate the relationship of program goals to the activities identified to achieve those goals, the inputs required to undertake those activities, and the outputs that emerge. Using this framework, Preston et al. (2010) define four stages of adaptation planning: (1) goal setting, (2) stock-taking, (3) decision-making, and (4) implementation and evaluation. While these four stages overlap with the principles of plan quality, it is extremely challenging to place the results of Preston and colleagues within the larger plan evaluation landscape due to the different evaluation criteria used.

Moreover, the evaluation criteria used by Preston et al. (2010) are skewed towards fact base, with little attention given to other important planning principles; eight of the 19 criteria measure how well plans assess capital, climate drivers, and impacts. Only one criterion is dedicated to public participation and goals. As a result, these important principles, which are typically given equal weight to the other principles in plan evaluation studies, represent only 5% of the plan quality measured by Preston et al. (2010). Because the authors do not use plan principles to organize their evaluation metrics, their results cannot be used to examine how well adaptation plans follow established planning practices such as goal setting, public participation, and inter-organizational coordination. This omission also means that a comparison could not be made between the quality of adaptation plans and the quality of plans from other domains such as hazard mitigation.

Baker et al. (2012) also use distinct evaluation criteria that limit comparison of their findings to those of other plan evaluation studies. For their analysis, Baker and colleagues (2012) created a set of desirable outcome goals and scored plans 0-4 on how well they aligned with these outcome goals. For example, one criterion used by the authors is “the impacts of flooding are minimized or avoided.” Plans were also rated on a scale of 0-4 (low to high) representing how well they performed on five plan principle concepts, including the inclusion of 1) an information base; 2) vision, goals and objectives; 3) options and priorities; 4) actions; and 5) implementation and monitoring. Because Baker et al. do not specify the metrics they used to assign scores for each of the principle components, it is unclear exactly what these scores represent and is challenging to compare their results to those of other studies.

Additionally, both of these previous studies used broad evaluation criteria that lack sufficient detail to identify specific strengths and weaknesses of plans. For example, Preston et al. (2010) include a single code for "articulation of objectives, goals and priorities." This approach groups together four distinct concepts: a vision statement, goals, objectives, and prioritization. Separating these concepts into different codes is necessary to gain the specific knowledge required to understand and improve local adaptation plans and planning processes.

Given these challenges, a number of researchers have called for more detailed analyses of local climate adaptation planning processes and associated planning documents (Engle, 2011; Measham et al., 2011). Moreover, since no existing studies provide a complete analysis of the local stand alone climate adaptation plan landscape in the U.S. (Preston, et al., (2010) analyze only nine local adaptation plans from the U.S., all written before 2009, and Baker et al. (2012) include no plans from the U.S.), a clear need has emerged to comprehensively evaluate all U.S. local climate adaptation plans using best practices from the plan evaluation literature. Doing so will allow U.S. local adaptation plans to be placed within the larger planning landscape, to compare adaptation planning to planning in other domains, and to identify how the current adaptation planning process could be improved.

2.3 Explaining Variation in Plan Quality

In addition to measuring plan quality, many plan evaluation studies explore why some plans are of higher quality than others (Berke et al., 2015; Lyles and Stevens, 2014; Tang et al., 2010). In the adaptation field, a substantial academic literature has developed describing adaptation processes and barriers (Amundesen et al., 2010; Eisenack et al., 2014; Moser and Ekstrom, 2010). This research, however, has predominately focused on providing rich descriptions of adaptation pathways of an individual city or small sets of cities (Burch, 2010; Carmin et al., 2012). Few studies have attempted to use quantitative methods to test theories related to why plan quality varies on a larger scale (Bulkeley et al., 2013). Drawing on past plan quality and local climate adaptation research, four analytical models were identified that have historically affected the quality of local plans: capacity, commitment, policy diffusion, and internal drivers.

2.3.1 Capacity

Theoretically, communities that have more capacity, defined as resources available to dedicate to planning, produce better plans (Brody et al., 2010). Capacity, however, represents only the potential to create a high-quality plan. High capacity does not guarantee the development of a strong plan, nor do deficiencies in resources necessarily preclude it (Baker et al., 2012; Burch, 2010; Conroy and Berke, 2004).

Capacity has garnered significant attention as a precursor for adaptation (Adger et al., 2005; Burch, 2010; Moser and Ekstrom, 2010). Pursuing adaptation requires financial resources to support staff time, acquire technical expertise, build networks, and promote outreach (Carmin et al., 2012). Inadequate resources are the barrier to adaptation most commonly cited by practitioners (Carmin et al., 2012; Moser and Ekstrom, 2010). In a survey of ICLEI-member cities in the U.S., approximately 90% of participants indicated that securing funding was a major challenge to their adaptation efforts (Carmin et al., 2012).

Variables to operationalize capacity such as the presence of funding to create a plan, access to data, provision of technical assistance, and community wealth are commonly included in plan quality studies (Schrock et al., 2015; Tang et al., 2010). These studies also consistently find that state mandates, which build capacity by requiring localities to go through the planning process, are associated with higher plan quality (Berke, 1996; Berke and French, 1994; and Dalton and Burby, 1994). By participating in comprehensive planning, a wide range of local officials can gain knowledge of the planning process and can exchange information, recognize shared goals, and build trust (Lyles et al., 2014). These benefits have been found to translate into stronger hazard mitigation plans and flood control efforts (Brody, et al., 2010; Lyles et al., 2014) and, we postulate, may also positively influence adaptation plan quality.

7.3.2 Commitment

Commitment describes a local government's dedication to an issue, and lack of commitment is often noted as a major impediment to risk reduction (Burby, 2006) and climate adaptation efforts (Eisenack et al., 2014). Hazard mitigation, for example, tends to receive little commitment even when local governments would benefit and have the capacity to implement risk reduction measures – a situation Burby (2006) terms "the local government paradox." Similarly, local governments often find that they are unable to gain widespread public interest and engagement in climate related issues (Anguelovski and Carmin, 2011). Public awareness of climate change and perceptions of the risk generally influence public support for climate change policy (Weber, 2010) and may be important variables in understanding local government commitment to adaptation (Tang et al., 2010).

Disasters are often framed as '*focusing events*' that can be used to increase public awareness and government support for preparedness action, at least temporarily. Even though the science of attributing specific extreme events to climate change is still emerging, disaster experience frequently sparks climate adaptation planning efforts (Anguelovski and Carmin, 2011; Baynham and Stevens, 2014). Firsthand experience with disasters can transform perceptions of climate change from a temporally and spatially remote risk to one that is immediate and personal (Weber, 2010). For example, in Durban, South Africa, climate adaptation efforts gained wide support only after flooding and tornadoes increased awareness and created a sense of urgency (Carmin et al., 2012). Plan quality studies have consistently found that disaster experience is significantly and positively correlated with hazard mitigation plan quality (Berke et al., 2015; Hallegatte, 2009).

Previous climate change and hazard mitigation activities may also indicate local government support for adaptation. In an evaluation of climate change planning in British Columbia, Canada, researchers found that governments with stronger climate change adaptation plans had demonstrated previous commitment to climate mitigation actions (Baynham and Stevens, 2014). Adaptation frequently grows from similar institutional and political roots as mitigation (Adger et al., 2009; Burch, 2010); thus we postulate that previous mitigation activities and involvement in climate networks may indicate commitment to climate adaptation. Similarly, we suggest that the presence of existing hazard mitigation activities may indicate a community's commitment to addressing long-term risk and indicate support for climate adaptation.

2.3.3 Policy Diffusion

Policy diffusion refers to the movement of ideas or actions across jurisdictional lines, often through friendly competition or community networks. Diffusion of information and ideas through professional associations is believed to have helped shape climate mitigation initiatives (Anguelovski and Carmin, 2011; Pitt, 2010; Ryan, 2015) and may similarly influence adaptation efforts (Bulkeley et al., 2013). In particular, membership organizations such as ICLEI-Local Governments for Sustainability (ICLEI) and the Urban Sustainability Directors Network (USDN) provide opportunities for municipalities to share lessons learned and promising practices with their peers, which, we postulate, may stimulate more innovation and overall climate action. In addition, the year of plan publication has also been found to influence the quality of local plans, presumably because plans published later build on and benefit from lessons learned from earlier planning efforts (Lyles et al., 2014; Schrock et al., 2015).

2.3.4 Internal Operations

The fourth model/variable discussed within the literature relates to internal operations, which almost always relates to plan author. Authorship, and the involvement of planners specifically, is known to influence hazard mitigation and adaptation plan quality (Baker et al., 2012; Lyles et al., 2014). While previous studies have not included funding source, we suspect that different funders have different priorities and requirements for the planning process, which may lead to plans of varying quality.

Most of the individual variables within these four analytical models have been tested in hazard, comprehensive, and climate mitigation (also known as climate action) plan quality studies, but they have yet to be evaluated in the context of climate adaptation planning. Given these omissions, a more detailed look at U.S. local climate adaptation planning is needed in order to understand what variables, if any, help explain why some communities create stronger plans than others (Engle, 2011; Measham et al., 2011).

3. Methods

3.1 Sample Selection

This analysis focuses on local adaptation in the U.S. because local communities in the country generally have a higher capacity to adapt than those in many other countries due to things such as greater economic assets, higher levels of government transparency, and relatively high levels of data and resources to support action. And yet, in spite of this, little formal adaptation action has emerged (Moser and Ekstrom, 2010; Burton, 2005). To understand this paradox, focus is placed on what adaptation planning has occurred in order to more fully understand the scale of local adaptation planning in the country and identify opportunities for improvement.

Plans included in this analysis were selected based on three criteria: (1) the central topic of the plan was adaptation, resilience, or preparedness; (2) the plan was written by or for a U.S. city or county government; and (3) the plan took a comprehensive approach to adaptation by focusing on more than just one or two topics (i.e., sector-based adaptation plans were excluded). These criteria excluded plans that integrate adaptation components but do not focus entirely on adaptation (e.g., climate action plans and sustainability plans that dedicate a chapter to adaptation), plans that are written by regional entities (e.g., the Southeast Florida Regional Climate Change Compact), and plans that are written without local government involvement (e.g., plans written by local environmental non-profits). These criteria ensure a relatively homogeneous and comparable sample.

All U.S. plans that met these criteria and were released between 2007, when Keene, NH published the first adaptation plan in the U.S., and 2014, were evaluated. The sample was developed based on a search of three adaptation clearinghouse websites: the Georgetown Climate Center, the Climate Adaptation Knowledge Exchange (CakeX), and the Center for Climate and Energy Solutions. In addition, plans were collected through three 100-page Google searches for the terms “local adaptation plan,” “local resilience plan,” and “local preparedness plan.” While no entity has a complete list of all adaptation plans in the United States, we are confident that the vast majority of U.S. local adaptation plans were captured through this process. In total 85 plans were collected, of which 44 met the above criteria for evaluation (Figure 1). Of the 41 not included in the final sample, 16 were other types of plans that included only a chapter on adaptation, 8 were written by regional agencies, and 17 were sector specific.

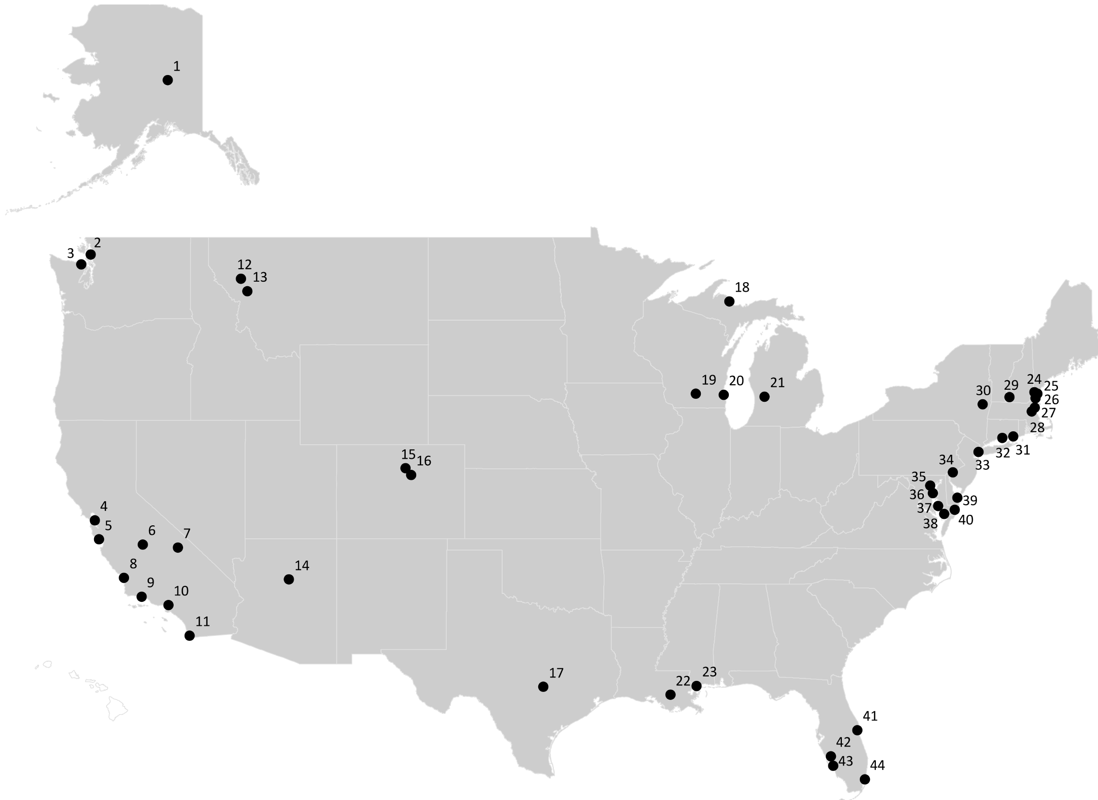

Figure 1. Communities with stand alone climate change adaptation plans included in the sample.

6.2 Coding protocol and procedures

A coding protocol was developed to assess seven principles of plan quality. In addition to 1) goals, 2) fact base, 3) actions, 4) public participation in plan creation, 5) inter-organizational coordination, and 6) details regarding implementation and monitoring, which are all commonly used in plan evaluation studies, a seventh principle for how plans deal with 7) uncertainty was added by the authors in order to reflect the importance of this issue in the adaptation literature (Table 1 and Appendix 1).

To ensure that the protocol captured the most current theory on adaptation, metrics for each principle were based on an analysis of nine *adaptation planning* guidance documents published by international, federal, state, and non-governmental organizations (IPCC, 2012; University of Washington and ICLEI, 2007; American Planning Association, 2011; Center for Climate Strategies, 2011; California Emergency Management Agency and California Natural

Resources Agency, 2012; Global Programme of Research on Climate Change Vulnerability, Impacts, and Adaptation, 2013; National Research Council, 2010; Burton, 2005; Institute for Sustainable Communities, 2010). All of the adaptation planning guidance documents focused on holistically planning for climate change. The adaptation planning guidance documents referenced vary in focus and prescriptiveness. For example, the American Planning Association's "Policy Guide on Planning for Climate Change" is tailored to planners and focuses on describing potential impacts and adaptation actions. ICLEI's "Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments" focuses on process, rather than actions or policy options. In contrast, the IPCC's "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" assesses the current knowledge on risk management and adaptation to climate extremes in a way that is policy relevant but not policy prescriptive. These guidance documents were reviewed using an inductive approach to identify key processes associated with adaptation planning. Despite the diversity in guidance documents considered, there was a high level of agreement on adaptation processes and factors that should be considered in climate adaptation planning. From this analysis, process recommendations and considerations that are present across multiple adaptation guidance instruments and therefore could serve as evaluation metrics, were extracted for inclusion in our coding protocol.

These metrics were grouped into one of the seven plan quality principles. In addition, existing coding protocols (Berke et al., 2013; Berke and Godschalk, 2009; Lyles and Stevens, 2014) were used to increase the specificity of metrics from the adaptation guidance literature. For example, many of the adaptation materials analyzed indicate that stakeholders should be engaged in the adaptation planning process but do not provide details about which stakeholders should be involved or how they should be engaged. Stakeholder engagement corresponds to the public participation plan principle, which in many plan quality studies is measured with detailed metrics such as a discussion on how the plan was developed, who was involved, and tools used for public engagement.

Adaptation guidance and established planning practices led us to expect plans to provide greater depth and analysis on some topics than others. For example, a large focus of climate adaptation guidance is identifying climate impacts and vulnerabilities; consequently, we expected plans not only to discuss impacts but also to provide further analysis about where these impacts might occur. Similarly, within the planning field there is an extensive literature on stakeholder engagement, so we expected plans to discuss not only who was involved in the planning process but also how they contributed. Other concepts, such as discussing adaptation barriers and recognizing the need for transformational change, are less agreed upon in the literature and push the boundaries of adaptation planning. As such, detailed metrics for these concepts were not included in the coding protocol. By drawing on both adaptation guidance materials and existing protocols, we developed a protocol with 124 metrics (Appendix 1). These metrics were applied to U.S. local adaptation plans in the sample, but they are applicable to other countries and scales.

Metrics included in the protocol are intended for adaptation plans that take a comprehensive approach to adaptation, not plans that focus on a specific sector. For example, in the fact base principle there are codes for identifying impacts to natural systems, built environments, and human health, all of which may not be considered by a plan focused on a single sector, such as transportation. Similarly, the actions principle includes 15 categories of actions, including advocacy, land use, and financing. While plans that focus heavily on preparing for climate change by undertaking one type of action may be penalized under this approach, the coding protocol was designed to evaluate comprehensive, stand alone adaptation plans that prepare a community for a range of future climate conditions. In these plans, having different types of adaptation actions (e.g., policies, practices, and outreach efforts) is important to ensure that a community is preparing politically, economically, socially, and physically. Moreover, this coding approach allows this methodology to be applied across geographic areas and between communities facing different climate impacts. For example, whether one is analyzing the plan of Anne Arundel County, MD, which focuses exclusively on sea level rise, or the plan of Boulder County, CO, that focuses on drought and wildfire, researchers expect both to explore how these changes will affect different community sectors and consider a breadth of actions to address these wide-ranging vulnerabilites. Thus the coding protocol designed is intended to establish an ideal standard of adaptation planning: by comparing a sample of plans to this standard, we hope to identify common strengths and areas in need of improvement. Going forward, the coding protocol can be edited and adapted over time, particularly as more details emerge regarding which components of plans are the most instrumental in guiding plan implementation.

The protocol was pre-tested on eight local adaptation plans from Europe and Australia. The pre-testing allowed for the training of three coders and the refinement of metrics and coding instructions so that they captured the intended concepts. Each plan was coded independently by two of the trained coders in line with recommendations from the communications literature on content analysis (Krippendorff, 2013) and recommendations from the plan evaluation literature on methodology (Berke and Godschalk, 2009; Lyles and Stevens, 2014). Before coding plans within the sample, researchers calculated inter-coder reliability to ensure that the coders fell within an appropriate range of inter-coder agreement (0.80 or greater) (Lyles et al., 2014).

Coders used the *NVivo version 10* qualitative analysis software package (QSR, 2012) to link coding items with the content of plans. After the coders completed a plan, their quantitative data was compared to identify disagreements on a metric-by-metric basis. All disagreements were discussed and reconciled by referring to the qualitative plan content, and the final, agreed-upon codes were integrated into a master dataset.

Inter-coder reliability scores for each plan and code were calculated using two measures: percent agreement and Krippendorff's[12] alpha. Because of their theoretical importance and researcher confidence in the reconciliation process, all items in the dataset were kept and included in plan quality calculations, regardless of the inter-coder reliability score. To achieve equal weighting of the codes for each principle, index scores were calculated for each plan principle by summing the reconciled scores for the principle and dividing by the number of codes in that principle. Researchers calculated total plan quality by averaging index scores for each plan principle. Additionally, descriptive statistics were calculated to assess the overall quality of the plans included in the sample, as well as how well each plan scored on the seven plan quality principles.

3.3 Assessing Plan Quality Variability

Four causal analytical models explaining plan quality were developed, each composed of previous metrics known to influence plan quality: local capacity, commitment, policy diffusion, and internal processes (for a detailed discussion regarding the theoretical grounding for these four models, see section 2.3). Based on previous studies, five variables were included in the capacity model (three variables related to financial capacity and two related to state mandates): 1) funding provided to create the plan, 2) median household income in the community, 3) the

[12] Krippendorff's alpha is a reliability coefficient that measures the agreement amongst coders.

municipal operating budget, 4) the presence of a local land use planning mandate, and 5) the presence of a state hazard planning mandate.

Based on previous studies, seven variables were included in the commitment model. The concept of public support was operationalized with 1) percentage of public concerned about climate change and 2) previous experience with a disaster. Four measures were used to capture previous climate change and hazard mitigation experience: 3) whether a local government is a member of ICLEI-Local Governments for Sustainability, 4) whether the local government is a signatory of the U.S. Mayors Climate Protection Agreement, 5) whether the local government is a signatory to the Resilient Communities for America pledge, and 6) whether the community participates in the Community Rating System. Finally, 7) whether the plan was formally adopted by an elected body, a direct measure of political support for the adaptation process, was included in the commitment model.

Policy diffusion refers to the movement of ideas or actions across jurisdictional lines, often through friendly competition or community networks. Given previous research, the policy diffusion model included four variables: 1) year of plan publication, 2) presence of a state adaptation plan, 3) membership in ICLEI-Local Governments for Sustainability USA, and 4) membership in the Urban Sustainability Directors Network.

The fourth model developed was an internal operations model, which includes two variables: 1) plan author and 2) source of funding. For plan author, a separate dummy variable for different internal authors, specifically planners, environmental agencies, or a taskforce, was included. For source of funding, dummy variables for federal, state, or non-governmental organization funding were included. While previous studies have not included funding source, we theorize that different funders have different priorities and requirements for the planning process, which may lead to plans of varying quality (see Appendix 2 for a complete list of independent variables included in the analysis and sources of data).

For each analytical model, a separate ordinary least square (OLS) regression with plan quality as the dependent variable was run. Lubell (2009) uses a similar approach of running differing analytical models separately through a regression analysis due to a small sample size. The use of OLS regression is a common practice in plan evaluation studies, especially when trying to understand what factors are statistically significant predictors of a given outcome (in this case, plan quality) (Brody et al., 2012; Tang et al., 2011; Zahran et al., 2008). In addition to running OLS regressions, researchers constructed a best-fit model consisting of variables from the individual analytical models significant at a 0.1 level. To ensure that this method of variable selection was effectively explaining the variation in the data, we used the leaps package (Lumley, 2009) within the software R to identify the best model. The leaps package performs all sub-sets regression or an exhaustive search of all models of each size. In almost every case, the leaps package identified the model with the significant variables from the individual analytical models as having the most explanatory power. This procedure was repeated with each of the seven plan principles as the dependent variable. Diagnostic procedures found no violation of regression assumptions. All analyses were conducted using the software R (R Core Team, 2013).

4. Results: Adaptation Plan Quality

Adaptation plans in the sample scored an average 40.6% of all possible points. The highest-scoring plan received 76.6% and the lowest scoring plan received 12% of all possible points. Only 12 plans scored above 50%, which suggests that the adaptation plans evaluated do not provide comprehensive coverage of plan quality principles.

Plans scored highest on the actions principle (average score 62%), indicating that they include a diversity of actions to prepare for climate change (Table 1). The actions most frequently included in plans were *practice and behavior* (e.g., changing operations and maintenance schedules, opening cooling centers) and *research and monitoring* (e.g., conducting more studies), which were found in 42 of the 44 plans (95%; Appendix 1). Other than one plan that did not include any actions, all plans proposed at least five of the fifteen types of actions coded during analysis (more detail on the actions included in the various plans can be found in Chapter 4). This finding starkly contrasts Baker and colleagues (2012) conclusion that local governments have not developed specific adaptation actions. The high score on the actions principle in this study suggests that U.S. local communities may be ‘hedging their bets’ against future climate impacts by including a variety of adaptation options in their plans.

Table 1. Plan quality evaluation principles used in this analysis and summary statistics. The first column lists each of the seven principles of plan quality assessed in this analysis. Column two provides the authors definition for each of the principles of plan quality. Column three provides examples of criteria used to measure each of the plan quality principles. Column four presents the number of criteria used to measure each of the principles' quality. The variation in the number of criteria included in each principle (column four) is related to the amount of guidance provided in the grey and peer-reviewed literature (see methods for more details). Mean (column five) refers to the average score on the principles across plans in the sample. Columns six and seven provide the standard deviation and the range, respectively, of scores received on each principle during the plan quality assessment.

Principle	Definition	Example Criteria	Total Criteria	Mean	Std Dev	Range
Goals	Future desired conditions	Plan purpose, vision, goals, and objectives	6	0.40	0.22	0.00 – 0.67
Fact Base	Empirical foundation that identifies and prioritizes issues to ensure that actions are well informed	Data sources, analysis of current conditions, climate change exposure, vulnerability and risk assessment	44	0.51	0.14	0.25 – 0.86
Actions	Guide to decision making to ensure that plan goals are achieved	Capacity building, land use, green infrastructure, etc.; cost and co-benefits of action options; prioritization of actions	23	0.62	0.18	0.00 – 0.96
Uncertainty	Recognition of and approaches to overcome uncertainty in future climate projections	Recognize sources of uncertainty; consider multiple future scenarios; flexible, robust, or no-regret actions	13	0.28	0.16	0.00 – 0.69
Public participation	Recognition of and actions for engaging actors in preparing the plan	Description of planning process and techniques to engage stakeholders; identification of individuals involved in preparation of the plan	9	0.44	0.28	0.00 – 1.00
Coordination	Recognition of the interdependent actions of multiple organizations and the need for coordination	Engagement of local universities, state agencies, businesses, neighboring jurisdictions, etc. in the planning process	9	0.36	0.24	0.00 – 0.89
Implementation and monitoring	Guidance to translate plan actions into action and track progress towards goals	Organizational responsibilities, timelines, and funds for implementation and monitoring	16	0.29	0.24	0.00 – 0.88

Within the actions principle, plans scored lowest on *cost of implementing* each action (7 plans, 16%) and a detailed explanation of how actions were *prioritized* (9 plans, 20%). Generally, adaptation plans include a breadth of actions but provide little analysis of *co-benefits*, *costs*, and *priorities*. For example, Austin, TX's plan (*Toward a Climate Resilient Austin*) includes 11 of the 15 different types of actions included in this analysis, but it includes none of the metrics related to *co-benefits*, *costs*, and *priorities*.

Plans also scored well on the *fact base* principle, mostly by drawing on multiple data sources and having strong analyses of future climate exposure and potential impacts to community *infrastructure*, the *economy*, *natural systems*, *public health*, and *cultural assets*. Few plans, however, provide details about where impacts to these systems will occur. For example, only one plan in the sample included maps or detailed identification of the location of potential health impacts associated with climate change (the Confederated Salish and Kootenai Tribes' *Climate Change Strategic Plan*). Similar to Preston et al.'s (2010) analysis, plans in the sample did a poor job of prioritizing impacts, providing detailed analysis about where impacts will occur, and discussing how non-climatic drivers, existing social, economic, and financial capacities, and underlying causes of vulnerability will impact future vulnerability. In contrast to Preston et al. (2010), however, many plans in this sample provided detailed and rigorous climate analyses, often through considering multiple climate scenarios and looking at regional climate projections.

The lowest scoring plan quality principle was uncertainty (average score 28%). Failing to address uncertainty may cause adaptation plans to be ineffective or maladaptive. Consequently, significant attention has been dedicated within the scholarly literature to developing new and refining existing planning approaches to manage uncertainty through approaches such as scenario planning, selecting robust and flexible actions, and using adaptive management (Quay, 2010). While most plans (33 plans, 75%) explicitly acknowledge the uncertainty associated with planning for future changes in climate, few employ approaches that account for uncertainty. Considering *multiple scenarios* was the approach most commonly used: 31 plans (70%) mention that multiple greenhouse gas emission scenarios were considered in the planning process. Most plans used emission scenarios generated by the Intergovernmental Panel on Climate Change, but there was wide variation in which scenarios were considered. Many plans that considered multiple scenarios (19 of 31) failed to provide details about how scenarios were developed and how they differ in future impacts. Those that did provide details tended to use a low- and high-emissions scenario to demonstrate the range of projections and then plan for some average of the two. *No-regrets*, *flexible*, and *robust actions* (see Appendix I for definitions of key terms) were not frequently discussed as options to address uncertainty (13 (30%), 10 (23%), and 4 (9%) plans, respectively), and specific actions are rarely labeled as no-regrets, flexible, or robust (1 (2%), 2 (5%), and 0 plans, respectively).

Additionally, no plan in this sample undertook structured scenario planning exercises, which are heavily advocated for in the scholarly literature. Only one plan developed local scenarios to consider the opportunities, constraints, and trade-offs of different growth patterns (Lafourche Parish, LA's *The Lafourche Parish Comprehensive Resiliency Plan*). Several plans used different disaster and climate scenarios to solicit input about vulnerabilities and priorities from stakeholders (Baltimore, MD's *Disaster Preparedness and Planning Project*), but, most commonly, only one greenhouse gas emission scenario was used as a basis for action selection.

The adaptation literature also emphasizes learning by continuously monitoring indicators and scientific evidence in order to update plans and policies in real time (Abunnasr et al., 2013). While 43% of the adaptation plans analyzed mention adaptive management (under the *uncertainty principle)*, only 18% establish a process to incorporate new information from experience, monitoring, and science into decision-making. Plans that mention adaptive management typically reference the need for an iterative process to incorporate new knowledge (see Chapter 3 for more discussion about uncertainty reducing approaches used in local adaptation plans).

The second-lowest scoring principle was implementation and monitoring (average score 29%). Here, the highest-scoring criteria was *mainstreaming,* the concept of integrating climate change into other plans or policies, which was discussed in 37 of the 44 plans (84%). This finding suggests that local stakeholders are aware of the value of integrating climate change into other planning processes, but does not imply that such integration has happened. The weakest components of this principle were *evaluation methods* (3 plans, 7%) and *metrics* (7 plans, 16%), with few plans describing how the plan would be evaluated or what metrics would be used to measure progress. No plans included both evaluation metrics and methods. Chula Vista, CA's plan provides strong evaluation metrics to measure progress, but fails to describe how or who will track these metrics. Similarly, in the goals principle, plans scored lowest on the identification of *objectives*. Only seven plans include objectives, which are defined as tangible, measurable outcomes to track progress towards goals (Berke et al., 2006).

5. Results: Variation in Plan Quality

As demonstrated above, quality among adaptation plans varies greatly. To help understand this variation, multivariate regression was used to examine whether four analytical models (capacity, commitment, policy diffusion, and internal operations) are correlated with plan quality. Of the four models, the internal operations model, consisting of plan author and funding source, accounted for the most variation in plan quality (adjusted $R^2 = 0.30$; Table 2). The capacity, commitment, and policy diffusion models each explained less than 10% of the variation in plan quality.

Three variables are significantly correlated with plan quality: formal adoption of the adaptation plan ($b = 0.09$, $t = 3.04$, $p < 0.01$), whether the plan was written by the planning department ($b = 0.14$, $t = 3.31$, $p < 0.01$), and whether a plan received state funding ($b = -0.14$, $t = -4.01$, $p < 0.001$). State funding decreased plan quality, while the other two variables had a positive relationship with plan quality. The best-fit model, including these three variables and the year the plan was published, on the assumption that more recent plans build on lessons learned from earlier planning processes (Lyles et al., 2014; Schrock et al., 2015), explains 50% of the variation in plan quality (Table 3).

Regression analyses with the seven plan principles as the dependent variable demonstrate that community variables are not uniformly associated with plan principles (Table 3). Formal adoption of the adaptation plan, for example, positively correlates with the quality of plans' goals ($b = 0.12$, $t = 2.38$, $p < 0.05$) and implementation and monitoring ($b = 0.22$, $t = 3.68$, $p < 0.001$) but does not have a significant effect on uncertainty, participation, and inter-organizational coordination. Adaptation plans

c.

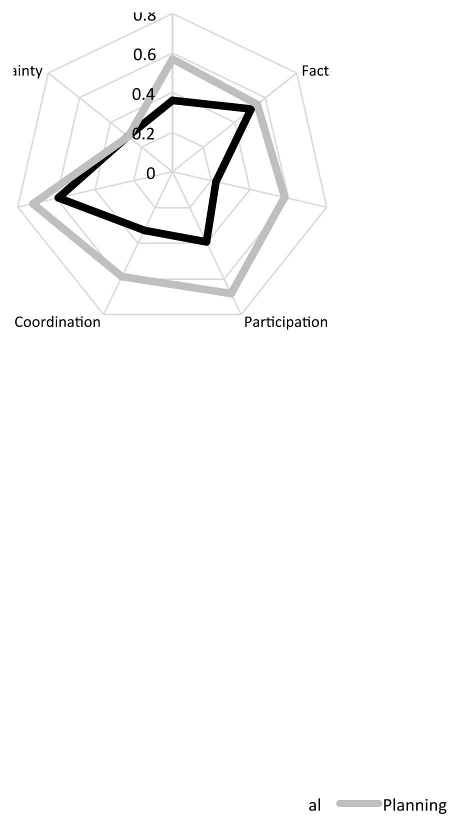

Figure 2. Variation in plan quality principles. Demonstration of how the quality of individuals plan principles vary depending on (a) different funding sources, (b) adoption by an elected body, and (c) different types of plan author. Lines indicate how well plans in the sample scored for each of the principles.

written by the planning department on average have significantly stronger goals (b = 0.20, t = 2.59, $p < 0.05$), actions (b = 0.19, t = 2.71, $p < 0.01$), implementation and monitoring (b = 0.23, t = 2.66, $p < 0.05$), and inter-organizational coordination (b = 0.17, t = 2.20, $p < 0.05$). State funding has a significant negative effect on participation (b = -0.29, t = -2.03, $p < 0.05$) and inter-organizational coordination (b = -0.28, t = -4.52, $p < 0.001$; Figure 2).

Table 2. Results of multivariate analysis on overall plan quality. The four analytical models tested include capacity, commitment, policy diffusion, and process. Under each of the models are the variables used to operationalize them. More detail about each of these models can be found in the methods section. Variables found to be statistically significant at 0.1 are marked by '.'. Variables significant at 0.05 are marked by '*'. Variables significant at 0.01 are marked by '**'. BIC stands for Bayesian Information Criterion, a criterion frequently used to help select models. BIC is based on the likelihood function and number of parameters in the model.

	Capacity Model		**Commitment Model**		**Policy Diffusion Model**		**Process Model**		**Best Fit Model**	
	Coef.	**S.E**	**Coef**	**S.E.**	**Coef**	**S.E.**	**Coef**	**S.E.**	**Coef**	**S.E.**
Constant	0.60	0.26*	0.31	0.25	-38.56	22.2	0.41	0.04**	-27.5	15.99
Capacity										
Funding	-0.05	0.05								
Budget	-0.003	0.03								
HH income	-0.00	0.00								
St plan mandate	-0.04	0.05								
St haz mandate	0.03	0.05								
Commitment										
Public perception			0.002	0.005						
Mitigation plan			0.02	0.06						
Signatory of CPP			0.05	0.05						
Resilient cities			-0.05	0.06						
CRS			0.03	0.04						
Adoption			0.11	0.04*					0.09	0.03**
Disasters			-0.009	0.01						
Policy Diffusion										
Year					0.02	0.01 .			0.01	0.007 .
State plan					-0.02	0.05				
USDN member					-0.002	0.05				
ICLEI					0.03	0.05				
Process										
Federal funding							0.03	0.04		
State funding							-0.15	0.05**	-0.14	0.04**
NGO funding							0.03	0.06		
Taskforce							-0.003	0.05		
Env author							-0.008	0.08		
Planning author							0.16	0.05**	0.14	0.03**
N		44		44		44		44		44
Adjusted R2		-0.03		0.06		0.002		0.30		0.50
BIC		-29.18		-28.29		-33.3		-43.94		-63.72

Table 3. Best-fit model for each individual principle of plan quality. Variables found to be statistically significant at 0.1 are marked by '.'. Variables significant at 0.05 are marked by '*'. Variables significant at 0.01 are marked by '**'. BIC stands for Bayesian Information Criterion, a criterion frequently used to help select models.

Dependent Variable	**Goals**		**Actions**		**Uncertainty**		**Implmentation**		**Participation**		**Coordination**	
	Coef.	**S.E.**	**Coef.**	**S.E.**	**Coef.**	**S.E.**	**Coef.**	**S.E.**	**Coef.**	**S.E.**	**Coef.**	**S.E.**
Constant	-93.4	27.8**	0.54	0.04**	0.15	0.04**	0.17	0.04**	0.53	0.04**	0.80	0.11**
CAPACITY MODEL												
Funding	-0.02	0.06										
Budget												
HH income											-0.00	0.00**
St plan mandate	-0.11	0.06										
St haz mandate	0.14	0.06*			0.11	0.04*						
COMMITMENT MODEL												
Public perception												
Mitigation plan			0.13	0.05*								
Signatory of CPP	0.03	0.06										
Resilient cities												
CRS												
Adoption	0.12	0.05*	0.08	0.05			0.22	0.06**				
Disasters												
POLICY DIFFUSION MODEL												
Year	0.05	0.01**										
State plan					0.08	0.05						
USDN member			-0.13	0.06*								
ICLEI			0.04	0.05							0.07	0.06
INTERNAL PROCESS MODEL												
Federal funding												
State funding			-0.10	0.06					-0.29	0.09**	-0.28	0.06**
NGO funding												
Taskforce												
Env author	0.15	0.11										
Planning author	0.20	0.08*	0.19	0.07*			0.23	0.09*			0.17	0.08*
N		44		44		44		44		44		44
Adjusted R2		0.46		0.31		0.23		0.33		0.26		0.52

BIC	-9.2	-18.1	-32.4	-7.5	11.6	-14.4

Researchers also found that communities with a climate mitigation plan score significantly higher on actions ($b = 0.14$, $t = 2.59$, $p < 0.05$). Counter to one of the initial hypotheses, median household income is negatively correlated with inter-organizational coordination ($b = -0.000007$, $t = -3.81$, $p < 0.001$), and communities that are members of the Urban Sustainability Directors Network have significantly lower scores on the actions principle ($b = -0.13$, $t = -2.21$, $p < 0.05$). These may be spurious relationships, but how capacity and networks influence planning decisions and processes warrant further exploration.

6. Improving Adaptation Plans

Due to the recent emergence and highly contextualized nature of adaptation planning, there are no standardized precedents, guidelines, or frameworks for the content of adaptation plans (Anguelovski and Carmin, 2011; Measham, 2011).[13] Consequently, innovation has occurred at the local level, leading to a diversity of planning approaches. This is reflected in the large variance in adaptation plan quality in the sample. Despite this, local adaptation plans share common strengths and weaknesses that expose critical gaps in current planning processes and research.

Adaptation plans scored highest on the actions and fact base principles but lacked clear mechanisms and prioritization for translating plans into on-the-ground projects. Although it is difficult to compare scores across plan evaluation studies because of differing coding protocols and methodologies (Lyles and Stevens, 2014), results suggest adaptation plans may have stronger actions but weaker implementation components than plans in other domains, especially hazard mitigation plans (Berke and Godschalk, 2009). In a meta-analysis of 16 plan evaluation studies published between 1997 and 2007, Berke and Godschalk (2009) found that plans scored relatively low in goals, fact base, and actions, as compared to organizational coordination, implementation, and monitoring. In contrast, the adaptation plans in this sample scored well in the fact base and actions principles but were much weaker in implementation and monitoring. Plan principle scores in this sample, ranging from 28 to 62% of possible points, are comparable

[13] Since the inception of the first local climate adaptation plans, significant process has been made at national (e.g., National Adaptation Programmes of Action), state (e.g., California Climate Adaptation Plan), and agency levels (e.g., federal agency adaptation plans) to create adaptation plans. These plans, however, vary significantly and do not necessarily provide guidance for local stakeholders looking to plan for climate change.

to studies included in Berke and Godschalk's (2009) meta-analysis, which produced scores ranging from 3 to 91%.

Consistent with previous analyses of adaptation planning (Preston et al., 2010; Lyles and Stevens, 2014), plans in this sample do a poor job of prioritizing impacts and actions. The lack of priorities is compounded by the failure to include details found to be important in motivating plan implementation (Laurian et al., 2004) such as the co-benefits of adaptation actions, associated costs, and implementation responsibilities. To improve future plans, practitioners should include details such as implementation responsibilities, cost (to the extent that it can be estimated), potential funding sources, and timetable for each action, as well as how to measure implementation progress. The dearth of goals and tangible objectives to achieve those goals, as well as evaluation metrics by which to measure progress suggests that practitioners still do not have a clear idea of what adaptation looks like or how it can be measured: an uncertainty that is mirrored in the academic literature (Adger et al., 2005; Ford et al., 2013).

Results also indicate a gap between theories for planning under uncertainty and the incorporation of these approaches into plans. While planning approaches such as adaptive management, that account for high uncertainty are important in making long-lasting plans that produce desirable outcomes (Berke and Lyles, 2013; Measham, 2011), very few plans contain these elements. This finding aligns with previous studies, which indicate that identifying approaches to addressing uncertainty is a weakness of adaptation planning (Berke and Lyles, 2013; Preston et al., 2010). This omission may, in part, be due to limited resources for planning and high cost, time, and technical requirements of many approaches to managing uncertainty. Considering multiple futures and including no-regret actions in planning are easy ways to begin managing climate related uncertainty. In addition, local practitioners need to establish a process for incorporating lessons learned into future planning and implementation thereby ensuring that planning is adjusting to real-time changes in science and policy (Quay, 2010; Berke and Lyles, 2013).

The alignment of these findings with studies in different nations (Preston et al., 2010; Baker et al., 2012) and at different scales (Preston et al., 2010; Stevens, 2013) suggests that the shortcomings identified in the sample of local U.S. plans are characteristic of adaptation planning more broadly. Detailed approaches to uncertainty and metrics for monitoring and evaluation appear to be persistent challenges that require additional attention.

The finding that plans authored by the planning department have stronger goals, actions, implementation and monitoring, and inter-organizational coordination is consistent with recent work on hazard mitigation planning, which found that the involvement of planners improves the quality of actions and the implementation components of these plans (Lyles et al., 2014). Results also support findings from studies demonstrating the importance of local elected officials in the creation of climate adaptation plans and policies (Measham, 2011; Bedsworth and Hanak, 2013; Brody, 2003; Eisenack et al., 2014; Tang et al., 2010). To improve future adaptation planning, a wide array of individuals should be involved in the planning process, especially representatives from the planning department and elected officials.

Regression analyses with the seven plan principles as the dependent variable demonstrate that community variables do not uniformly influence plan principles and also highlights additional community variables that may influence the planning process and the quality of plans. Specifically, counter to our hypotheses, median household income has a significant negative relationship with inter-organizational coordination ($b = -0.000007$, $t = -3.81$, $p < 0.001$), and communities that were members of the Urban Sustainability Directors Network (USDN) were found to have significantly lower scores on the actions principle ($b = -0.13$, $t = -2.21$, $p < 0.05$) than non-members.

Initially researchers thought USDN members might score lower on the actions principle because they produce more focused plans that include a smaller set of well-supported actions, but additional analysis shows that USDN members tend to include fewer types of actions and less discussion of co-benefits, costs, and priorities in their adaptation plans (although these differences are not significant). One possible explanation is that USDN members may focus on mainstreaming or embedding climate adaptation into other community plans such as hazard mitigation and sustainability plans. If true, this may mean that adaptation plans in these communities are designed to document the community's vulnerability and adaptation priorities, as opposed to being stand alone plans for adaptation action. Again, as Preston et al. (2010) suggest, action scores likely reflect the plan purpose since adaptation "plans" may act as preliminary strategy documents or consultation papers. More work is needed, however, to understand whether this hypothesis is true.

In previous studies of plan quality, household income has been used as a proxy for community capacity. In this analysis, it was found that household income has a negative relationship with plan quality, suggesting that community wealth and a larger tax base does not necessarily translate into higher quality plans. One possible explanation for this negative relationship is that communities with greater wealth are those that have a higher adaptive capacity, or a higher ability to adapt to climate related impacts. In these communities, the impetus for holistic adaptation planning might be weaker than in more resource constrained communities where climate related vulnerabilities are pervasive. More research is needed, however, to see if this hypothesis holds.

The negative relationship between state funding and plan quality may, in part, be due to states selectively funding communities that are particularly vulnerable to climate change impacts. For example, Maryland funded four local adaptation plans, all in counties extremely vulnerable to sea level rise: about 60% of Dorchester County lies in the 100-year floodplain and many properties and roads are flooded during spring high tides and in Somerset County 58% of the land area and 44% of the structures are within the 100-year floodplain. The State of New Hampshire funded two local plans in the sample: Seabrook, which has experienced nine presidential disaster declarations in the last ten years, and Durham, which has experienced seven. Extremely vulnerable communities may engage in adaptation planning but lack the capacity, even with state funding, to produce high quality plans. For example, a community extremely vulnerable to sea level rise, but with an extremely small planning department, may receive state support to create a plan but lack the technical knowledge, time, or staffing capacity needed to provide a strong and contextually relevant plan. State funded plans may focus more on identifying vulnerabilities to start the adaptation process, but fail to engage community members and organizations in the plan creation, thereby leading to lower plan quality scores. If true, this suggests that additional measures of vulnerability are needed in future analyses, since different types of vulnerability may directly affect plan quality.

State funded plans may also be driven by state interests and, consequently, fail to develop meaningful local participation or buy-in. For example, State’s may strongly encourage grantees to emphasize certain topics or use specific data in their analyses, thereby coloring the local adaptation planning process. The extent to which this is true, however, is unclear. As such, additional research is needed to explore the role of funders in the planning process. Although this analysis did not measure these factors directly, other forms of state support of local adaptation, such as providing technical data and planning guidance, likely enhance local adaptation efforts.

The next step in this work is to assess whether and how adaptation plans translate into the implementation of adaptation actions. Specifically, what types of adaptation actions are being implemented? And why? Additionally, more work is needed to understand how uncertainty shapes the adaptation planning process and influences the types of actions being selected and implemented to prepare for climate change. Finally, more research is critically needed on how adaptation plans inform implementation decisions and how effective implemented actions are at building resilience.

While this analysis helps identify strengths and opportunities for improving adaptation planning, a limitation is that the sample only includes communities with stand alone adaptation plans. The growing movement towards mainstreaming climate change into other types of planning initiatives (Friend et al., 2013) means that there are likely hundreds of other communities planning for climate change. Exploring the content and quality of these plans would allow for a richer understanding of different approaches to planning for climate change and highlight which are most effective for creating more resilient communities. This analysis also focuses on how plan quality varies across communities, not why some communities engage in adaptation planning and not others. The distribution of communities in the sample, however, is clearly geographically uneven begging the question: what motivates climate change adaptation planning?

Adaptation will continue to garner greater attention as the impacts of climate change are realized. This paper provides a baseline assessment of stand alone, local climate adaptation planning in the U.S. Consistent with past research on adaptation planning, it was found that plans lack approaches to address uncertainty, implementation priorities and details, and metrics for monitoring and evaluation. These persistent shortcomings raise concerns about whether plans will translate into actions that reduce community vulnerability. Results also suggest that the involvement of planners and elected officials may improve adaptation plan quality. As adaptation becomes more prevalent, it is hoped that practitioners, scientists, and policy makers reflect on and learn from the strengths and weaknesses of existing plans and use these lessons to craft future plans that help foster the creation of more resilient communities.

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Chapter Three
Tackling Uncertainty in U.S. Local Climate Adaptation Planning[14, 15]

1. Abstract

Global climate change presents an array of uncertainties that planners must address as they work to build more resilient communities. Scholars from both climate and planning disciplines have categorized different sources of uncertainty and identified different planning approaches suited for climate adaptation planning. No systematic comparison of these two literatures, however, exists. Moreover, little is known about how planners conceive and frame climate related uncertainties and what approaches they are using relative to those recommended in the literature. To bring clarity to these issues, this paper begins by reviewing the most common types of uncertainty identified within the climate literature and organized into those within and outside the control of local planners. Next, 11 planning approaches recognized as useful for reducing climate related uncertainty are categorized by whether they reflect a '*predict and plan*' or an '*adapt and monitor'* approach. Finally, the content of 44 U.S. local climate adaptation plans are evaluated to determine how they frame uncertainty and what uncertainty reducing approaches they use. Results show that local planners disproportionately focus on *uncertainty beyond the planning process* as well as *bridging uncertainty*. Local planners are also using a number of uncertainty reducing approaches in their planning with the four most common being: 1) the use of multiple climate scenarios, 2) vulnerability assessments, 3) monitoring changing climate conditions, and 4) acknowledging the importance of adaptive management. The first two approaches fall within the "*predict and plan*" model of planning and the later within an "*adapt and monitor*" model. These results suggest that while planners are beginning to recognize the importance of flexible uncertainty reducing approaches, significantly more work is needed to operationalize these approaches. This research provides planners with an understanding of how

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[15] This chapter was co-authored with Dr. Larissa Larsen.

they can work directly to reduce uncertainty associated with planning for climate change, thereby helping to ensure they are flexibly planning for a future plagued by climate change.

2. Introduction

Uncertainty, broadly defined as “a perceived lack of knowledge, by an individual or group, which is relevant to the purpose or action being undertaken and its outcomes” (Abbott, 2012), is a common barrier to planning activities in nearly all disciplines and fields. While uncertainty has always been a concern for urban and regional planners (Abbott, 2005; Abbott, 2012), climate change introduces new dimensions that compound and complicate existing sources of uncertainty (Hallegatte, 2009; Styczynski, et al., 2014). For example, in a world plagued by climate change, infrastructure will need to withstand wide fluctuations in precipitation and temperature, including changes in both averages and extremes, which will likely make “design more difficult and construction more expensive” (Hallegatte, 2009; 240). In light of this, Walker et al. (2013) designated climate change an issue associated with ‘deep uncertainty’, defined as “the condition in which analysts do not know or the parties to a decision cannot agree upon (1) the appropriate models to describe interactions among a system’s variables, (2) the probability distributions to represent uncertainty about key parameters in the models, and/or (3) how to value the desirability of alternative outcomes” (p. 957).

When planning for situations cloaked in deep uncertainty, planners must discard the traditional ‘*predict and plan/act*’ or rational model of planning in favor of more flexible approaches (Lempert and Collins, 2007). To replace traditional planning processes, Quay (2010) calls for plans that can ‘*adapt and monitor*’ as more information about changing climate conditions and relevant impacts emerge. This means that traditional planning approaches that use the past as an analogue for the future must be revised and complimented with approaches that acknowledge that planning efforts can move forward despite some types of uncertainty (Bierbaum et al., 2013; Styczynski et al., 2014).

While a great deal of attention has been paid to the various sources of uncertainty in the climate literature, these issues are just emerging in the planning literature as the increasing challenge of things such as planning for extreme weather and climate variability is recognized. To help equip planners with the information and tools they need to begin planning for climate change, three analyses are undertaken in this paper. First, the main sources of climate related uncertainty from the climate change literature are reviewed and organized into those within and outside the control of local planners. In the second section, 11 planning approaches commonly discussed in the planning or climate change literatures as useful for reducing the uncertainty associated with climate change are identified. Next, these approaches are grouped into one of two categories: those reflecting a '*predict and plan'* approach and those reflecting an *'adapt and monitor*' approach to uncertainty reduction. Finally, in the third section the academic literature on contemporary planning practice is grounded through a content evaluation of 44 U.S. local climate adaptation plans to determine what sources of uncertainty are identified and what planning approaches were used to lessen uncertainty. This research offers insights to local and regional planners looking to transition from a '*predict and plan*' model of planning to an '*adapt and monitor*' model, one that will be of increasing importance in a world plagued by climate change.

3. Uncertainty in the Planning Literature

In 2001 Myers wrote that uncertainty and disagreement are the twin hazards of planning; a sentiment shared by Baum (2015) who stated that, "people fear uncertainty, defeat, embarrassment, and blame," (p. 68). Although planning, as a profession, regularly engages with uncertainty, relatively few planning scholarly articles directly address the issue. Some notable exceptions include the work of Friend and Jessop (1969), Mack (1971), Christensen (1985), Kartez and Lindell (1987) Abbott (2005, 2012), Hopkins and Zapata (2007), Quay (2010), Chakraborty et al (2011), Abunnasr et al. (2013), and Walker et al. (2013).

Of the planning literature that addresses uncertainty, we find that Abbott's (2005; 2012) conceptual model is the most intuitive and holistic. In this model, Abbot organizes sources of uncertainty based on whether they are 1) beyond the planning environment, 2) at the intersection of the planning environment and planning process (bridging uncertainty), or 3) beyond the planning environment (Figure 3).

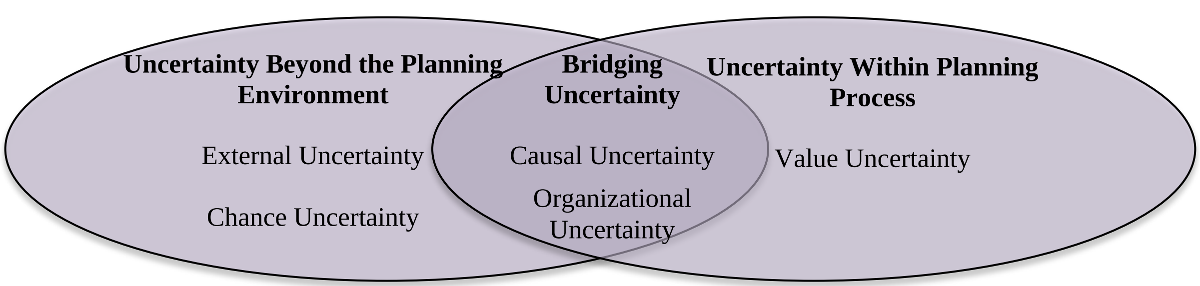

Figure 3. Dimensions of environmental and process uncertainty modified from Abbott 2012.

In the sphere of uncertainty beyond the planner's influence, Abbott situated external and chance uncertainty. External uncertainty pertains to a lack of information "about the wider social environment and how it relates to and influences the [planning] situation" (Mack, 1971: p. 68). Factors such as human migration, future human behavior, shifts in the political climate, and technological advances are examples of external factors that are beyond the planning process and planner's influence. Chance events, another form of uncertainty beyond the planner's influence, are truly unknowable, one-off events that can occur at any time. Extreme weather events or acts of violence are chance events that can have lasting impacts on a community.

In the sphere of uncertainty within the planning process Abbott identifies value uncertainty, which "relates to unknown social views and values about a situation or area, about where it is heading, and about its possible futures" (p. 573). Value uncertainty also includes uncertainties about the views and values of politicians, residents, businesses, and other community stakeholders (Abbott, 2005). According to Abbott, value uncertainty is within the planner's influence as it is part of the planning process. As such, it can be managed through an effective planning process where the planner endeavors to reveal any different, and potentially conflicting, priorities. In regards to climate change, minimizing value uncertainty also necessitates navigating differences in acceptable levels of risk and the end goals that stakeholders may bring to a climate planning initiative.

In the bridge of Abbott's diagram are causal and organizational uncertainties. Causal uncertainty pertains to a lack of knowledge about cause and effect relationships (Abbott, 2005) and addresses a lack of understanding regarding how physical, social, and economic factors that may emanate from beyond will combine to create a local impact or planning 'problem' (Lau, 2015). Organizational uncertainty, in contrast, deals with a lack of knowledge or an inability to predict the future intentions, policies, plans, and actions of organizations within and relevant to the planning environment (Abbott, 2005; 2012; Mack, 1971). For the planner this means thinking about how other local entities or organizations may react to particular conditions or events and coordinating public, private, and non-profit actions where possible.

With Abbott's conceptual framework in mind, sources of climate related uncertainty commonly discussed within the climate change literature were reviewed and organized into a conceptual framework that characterizes these types of uncertainty in relationship to the planner's roles and responsibilities. Doing this allows one to identify strategic locations where planners can work to reduce climate related uncertainty while also acknowledging that certain sources of uncertainty are beyond their influence.

4. Uncertainty in the Climate Change Literature

Exactly what future weather and climate conditions will be is uncertain (Walker et al., 2013; Lemos and Rood, 2010), although there is greater certainty at larger spatial scales (e.g. globally). Despite this reality, it is accepted that the climate is already changing, leading to local impacts such as an increase in heavy precipitation events in the Midwest, a decrease in overall rainfall in the Southwest, rising seas along the coast, thawing permafrost in the far north, and more tumultuous weather in the south (Walsh et al., 2014). Hence, local and regional stakeholders urgently need to plan for and implement actions to reduce their vulnerability to climate related impacts (Woodruff and Stults, 2016).

Since planners are broadly recognized as being charged with protecting the health, safety, and general welfare of citizens (Heathcott, 2005; U.S. Department of Commerce, 1928), it is important that they understand how climate change could affect their communities and integrate this knowledge into their planning. To do this effectively, however, necessitates that planners understand the myriad sources of uncertainty related to planning for climate change and embrace appropriate uncertainty reducing approaches. Within the climate change literature, a significant amount of attention has been devoted to identifying sources of climate related uncertainty. To help condense these sources of uncertainty, the most commonly identified sources of climate uncertainty have been organized into five overarching categories and their constituent subcategories (Table 4). The following section summarizes and defines what is included in these five categories: 1) uncertainty in *future climate conditions*, 2) *socio-economic and political* uncertainty, 3) uncertainty in *effective response options* for local communities, 4) uncertainty in the local community's *coping capacity*, and 5) uncertainty in the *local impacts*.

Table 4: Main sources of climate-related uncertainty, categorized by the authors into one of five types. Underneath each main type of uncertainty are sub-types relevant to the broader heading.

1. Uncertainty in Future Climate Conditions
    a. Uncertainty in future greenhouse gas emissions
    b. Uncertainty in future climate conditions
    c. Uncertainty in direction of change
    d. Uncertainty in intensity and severity of change
    e. Uncertainty in timing of change

f. Uncertainty in location of change g. Uncertainty inherent in modeling h. Uncertainty associated with climate variability
2. Socio-Economic and Political Uncertainty o Uncertainty in human behavior and responses to weather/climate o Uncertainty related to actions of other entities o Uncertainty related to state, national, or international policies or agreements
3. Uncertainty in Local Impacts
4. Uncertainty in Local Coping Capacity
5. Uncertainty in Effective Response Options

4.1 Uncertainty in Future Climate Conditions

The most frequent type of uncertainty discussed in the climate change literature relates to not knowing what future climate and weather conditions will be (Cai, et al., 2011; Dessai and Hulme, 2007; Hallegatte, 2009; Lemos and Rood, 2010). Included within this broader concept are: 1) uncertainty related to future greenhouse gas emissions; which is related to 2) uncertainty in what future climate conditions will be; 3) uncertainty in the direction of change for climate conditions, especially for precipitation (i.e., more or less); 4) uncertainty related to the intensity and severity of change; 5) uncertainty related to when changes will occur, including uncertainty related to the return frequency of changes (Abunnasr et al., 2013; Mearns and Norton, 2010; van Aalst, et al., 2008); 6) uncertainty related to where changes will occur (Dessai and Hulme, 2007; Mearns and Norton, 2010); 7) uncertainty related to the ability of global climate models to replicate the climate system and adequately project future conditions (Lemos and Rood, 2010); and 8) uncertainty inherent in the climate system, including uncertainty related to climate variability (Lemos and Rood, 2010). Combined, these sources of uncertainty address the temporal and spatial nature of future climate related changes.

4.2 Uncertainty in Socio-Economic and Political Conditions

The second source of uncertainty relates to uncertainty beyond the local planning process (socio-economic and political uncertainty), but which potentially influence local actions. Within the climate literature, these sources of uncertainty generally include actions, behaviors, or policies enacted by higher levels of government that will directly or indirectly affect the ability of local communities to adapt (Dessai and Hulme, 2007; Intergovernmental Panel on Climate Change, 2012; Mearns and Norton, 2010; Refsgaard et al., 2013; Stone, et al., 2012). Uncertainty related to socio-economic and political factors can broadly be grouped into three sub-categories: 1) broad uncertainty related to human behavior and responses to weather and climate conditions, specifically greenhouse gas emissions and technological adaptation; 2) uncertainty related to the actions of other entities at different scales (e.g., neighboring municipalities); and 3) uncertainty related to state, national, or international policies, funding programs, or agreements (Dilling et al., 2015; Lemos and Rood, 2010). This type of uncertainty includes policies established at state and national levels that impact local level decision making as well as decisions made in the private and non-profit sectors that will directly or indirectly influence local circumstances. Inherent in this category of uncertainty are nuances related to municipal funding, which often flows from state and federal entities to local communities for specific projects or program work.

4.3 Uncertainty in Future Local Climate Impacts

The third category of uncertainty relates to what future climate impacts will be at the local or regional level. Uncertainty related to future climate impacts is one of the most commonly discussed sources of uncertainty related to climate change (Adger and Vincent, 2005; Cai et al., 2011; Gersonius, et al., 2014). This type of uncertainty is influenced by uncertainty in both future weather and climate conditions as well as uncertainty in the socio-economic and political conditions. To project future climate impacts, climate models are run to identify what future variables such as temperature, surface pressure, wind, humidity, and precipitation may be like at a global and regional level. While climate models can help provide insight into what potential future average weather or climate conditions may be like, they cannot tell local decision-makers exactly how these changes will manifest into local impacts (i.e., how climate change will be felt at the local level).

4.4 Uncertainty in Local Coping Capacity

A fourth type of uncertainty relates to a community's current capacity to cope or adapt to changing climate conditions. This source of uncertainty deals with a lack of knowledge regarding how a community has responded or been affected by historic weather/climate impacts, thereby informing what type of coping capacity a community may have for future climate impacts (Dessai and Hulme, 2007; Lau, 2015). Further complicating this type of uncertainty is a lack of understanding or agreement on what constitutes coping. Nelson et al. (2007) refers to coping as the "pre-conditions necessary to enable adaptation, including social and physical elements, and the ability to mobilize these elements" (p. 397). Knowing the pre-conditions necessary to enable adaptation offers insights into whether or not a community and its residents have the resources necessary to adapt to changing climate conditions (Engle, 2011; Brown and Westaway, 2011).

4.5 Uncertainty in Effective Local Response Options

This final source of climate related uncertainty concerns the question, what are the most effective response options/actions to lessen the negative local impacts of climate change (Chakraborty et al., 2011; Kates et al., 2012; Quay, 2010). Unlike climate mitigation where energy efficiency is a common starting point, climate adaptation actions are inherently local and not easily transferable across locations. This means that what is a good practice in one location, may be less relevant or appropriate in another. For example, the outcome achieved by a technology solution in one community may be more effectively achieved through a green infrastructure or land use action in another community (Eriksen and Brown, 2011).

Building off of Abbott's (2005; 2012) planning uncertainty model, the five sources of climate related uncertainty discussed above have been organized into three categories: 1) uncertainty within the planner's influence, 2) uncertainty beyond the planner's influence, and 3) uncertainty within the bridges the two previous types of uncertainty (Figure 4). This categorization allows researchers and practitioners to identify which sources of uncertainty planners can influence, and which they cannot. Sources of uncertainty that emerge within the planner's influence necessitate the application of appropriate uncertainty reducing approaches. Sources of uncertainty outside of the planner's influence likely need to be acknowledged, but should not derail local climate adaptation efforts. The next section looks at a variety of approaches available to reduce uncertainty associated with planning for climate change, including techniques that can help reduce all of the types of uncertainty noted below, as well as how these approaches are or are not being used in practice.

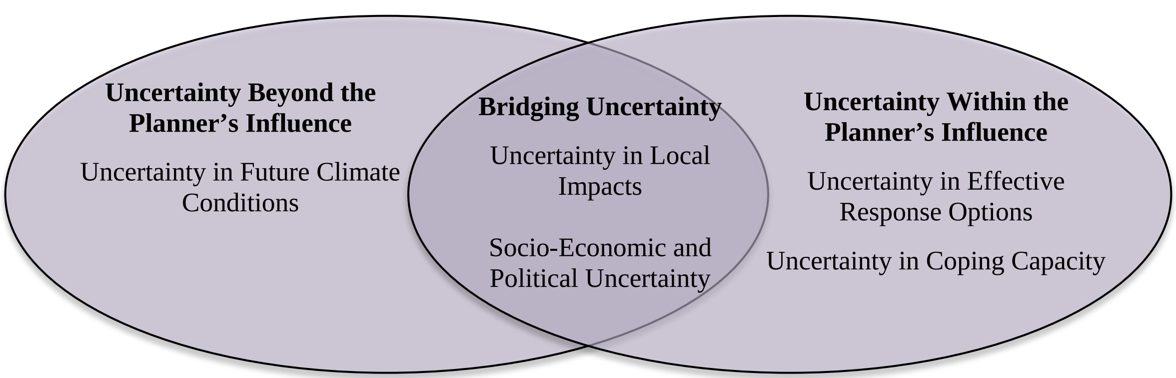

Figure 3. Proposed dimensions of climate change related uncertainty, categorized by the authors based on the planner's ability to influence each source.

5. Approaches to Lessen Uncertainty in Climate Adaptation Planning

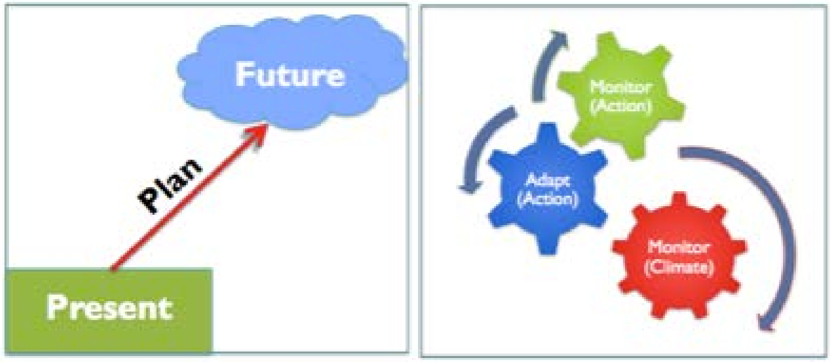

Figure 5: Model of the *'predict and plan'* (left) and *'adapt and monitor'* (right) approaches to planning.

In light of the significant role uncertainty plays in planning for climate change, a number of uncertainty reducing approaches have emerged within the peer-reviewed and grey literature. After reviewing the literature, we determined that these approaches broadly fall into one of two categories: 1) those that support a '*predict and plan'* approach to planning; and 2) those that support an '*adapt and monitor'* approach (Table 6; Figure 5).

The '*predict and plan'* model of planning, also known as the rational model of planning, emphasizes the use of predictions of the future as a baseline from which to plan (Quay, 2010). As Quay (2010) notes, '*predict and plan'* is based on "forecasts [of a] future trend or a future desired state and then identif[ying] the infrastructure needed to serve or create this future" (p. 498). This model of planning was first formalized within the planning discourse by Chicago School planners' Meyerson and Bainfield (1955) but gained traction in population and employment forecasts done in the 1960s (Chapin 1965; Kent 1964). Today it continues to be commonly used in all areas of planning (e.g., transportation, water system, economic development, sustainability). The '*predict and plan'* model of planning works well when social and environmental systems are "stable and predictable over short periods of time" (Quay, 2010, p. 468).

Unfortunately, climate change creates situations that are unstable, uncertain, and not fully predictable. This means that the '*predict and plan*' model may have limited utility when planning for climate change (Hallegatte, 2009). An alternative, more flexible approach to planning for climate change may be needed (Quay, 2010; Meerow et al., 2016). This is termed the '*adapt and monitor'* approach. This approach is based on calls for flexible and iterative adaptation planning that intrinsically builds in mechanisms to evaluate progress and readjust activities as new information emerges or local situations and context evolve (Boyd and Juhola, 2014; Hughes, 2015; Mimura et al., 2014). Within the planning literature, a number of scholars have acknowledged the importance of iterative/adaptive approaches to planning, including Lindblom and Cohen (1979) and Rittel and Weber (1973). These concepts have also been heavily discussed in the natural resources literature (Holling, 1973), but the degree to which they are being implemented in practice, remains unknown.

While both the '*predict and plan*' and '*adapt and monitor*' approaches are discussed within the planning literature (as well as within other domains), to the best of our knowledge, no one has attempted to organize uncertainty reducing planning approaches based on their alignment with each of these approaches. As such, we conducted a detailed review of the peer reviewed and gray climate adaptation literature to identify the most commonly promoted uncertainty reducing approaches (a detailed description of this methodology can be found in Woodruff and Stults, 2016; Chapter 2). Through this review, eleven approaches were identified and classified based on whether they most closely align with the traditional '*predict and plan*' model of planning or the more nuanced '*adapt and monitor*' approach.

As shown in Table 5, five approaches were identified that are either fully grounded or partially grounded in the '*predict and plan*' model of planning: 1) conducting a vulnerability assessment; 2) using multiple climate change scenarios; 3) downscaling global or regional climate scenarios; 4) using no regrets and low-regrets actions; and 5) planning for multiple time frames.

Table 5. Approaches identified within the planning and climate literatures for addressing climate related uncertainty. The 11 approaches are grouped by the authors based on whether they more closely align with a 'predict and plan' or an 'adapt and monitor' approach to planning.

Table 5: Approaches for Addressing Uncertainty

Type of Uncertainty	Sub-Categories of Uncertainty
Predict and Plan	1. Conducting a vulnerability assessment 2. Using multiple climate change scenarios 3. Downscaling global or regional climate scenarios 4. Using no regrets or low-regrets actions 5. Planning for multiple time frames
Adapt and Monitor	6. Using adaptive management 7. Scenario planning 8. Selecting robust actions 9. Using incremental or flexible actions 10. Using thresholds or tipping points 11. Monitoring changing climate conditions

5.1 Vulnerability Assessments

A vulnerability assessment is a technique to assess how climate change could affect a local community (Fussel 2007; Luers, 2003). Once a vulnerability assessment is complete, stakeholders are able to produce a relative weighting of where or who within their community are the most vulnerable to changing climate conditions (Berkhout et al., 2014; Smit and Wandel, 2006). At their core, vulnerability assessments are based on using models or predictions of future climate in order to determine future vulnerability. As such, we posit that vulnerability assessments fall into the traditional '*predict and plan*' model of planning and, if used without being paired with approaches identified in the '*adapt and monitor*' category, could lead to communities being under-prepared for potential changes in climate, especially if future changes are outside the range used to guide the vulnerability assessment process.

5.2 Use of Multiple Climate Scenarios

In climate change science, projections of future climate change are based on an array of future greenhouse gas emissions scenarios. These scenarios include wide ranging variables for future land use, demographic developments, socio-economic developments, and technological change, as well as assumptions about consumption patterns. The most commonly cited scenarios are those used by the Intergovernmental Panel on Climate Change (IPCC) (Füssel, 2007; Styczynski et al., 2014). In climate change planning, practitioners are often encouraged to look at multiple climate scenarios. This frequently includes looking at projected impacts associated with a low-or-medium emissions scenario as well as looking at the impacts associated with a high emissions scenario. Using multiple emissions scenarios affords planners insight into a potential range of impacts associated with climate change. Despite their utility however, no one scenario is likely to be fully predictive of future conditions (Kirshen et al., 2012), meaning that planning based explicitly on a single emissions scenario or a very small set of scenarios could lead to ill-prepared practitioners (Quay, 2010).

5.3 Downscaling Climate Information

Statistical and dynamic downscaling are two different approaches that take data from global climate models and use it to project future climate conditions at regional and local scales (National Research Council, 2010). In dynamic downscaling, "empirical relationships between past observations of local- and regional-scale climate variations are used to translate large-scale projections from global climate models to smaller space scales and shorter time scales" (National Research Council, 2010, p. 220). Statistical or empirical downscaling, in contrast, develops "statistical relationships that link the large-scale atmospheric variables with local/regional climate variables" (Intergovernmental Panel on Climate Change Working Group II, 2014, p. 10). Similar to above, downscaling tends to focus on predicting a single or a small set of futures upon which to plan. As such, we posit that this technique is in alignment with the traditional 'predict and plan' approach to planning.

5.4 No Regrets and Low Regrets Actions

No regrets actions are those that "generate net social and/or economic benefits irrespective of whether or not anthropogenic/[human]-induced climate change occurs" (IPCC, 2007: p. 878), and are frequently touted uncertainty reducing techniques (Biesbroek et al., 2010; Hallegatte, 2009; Heltberg et al., 2009; Dilling et al., 2015). Examples of no regrets actions include increasing green infrastructure, increasing public and non-motorized transportation, and improving the livelihood of the poor and disenfranchised (Abunnasr et al., 2013; Heltberg et al., 2009), all of which are well-established goals and practices in urban planning.

Low-regrets actions are those that "provide benefits under current climate and a range of future climate change scenarios" (IPCC 2014). These actions are generally low cost and have a high possibility for benefit, meaning that if they are later found to be unnecessary, the opportunity cost is minimal (Kettle and Dow, 2014). Examples of low-regrets actions include building in extra margins in infrastructure designs to allow for increases in precipitation, restricting development in floodplains, and creating additional water storage facilities.

As noted by the United Kingdom Climate Impacts Programme (n.d.), no-regrets and low-regrets options are "particularly appropriate for the near term as they are more likely to be implemented (obvious and immediate benefits) and can provide experience on which to build further assessments of climate risks and adaptation measures" (15). They are not, however, cost-free (Wilby, 2008). These approaches can also prove ineffective in the long-term if stakeholders only embrace these actions without also selecting more challenging actions that may take more time to implement due to the need to generate political will, public support, or identify appropriate financing (Abunnasr et al., 2013). Because low and no-regrets actions tend to disproportionately focus on immediate and short-term benefits, we posit that their utility under a wide range of climate futures is uncertain, making them best suited as a technique within the 'predict and plan' approach to planning.

5.5 Multiple Time Frames

The final technique identified as falling within the '*predict and plan*' model of planning is the selection of actions that cover multiple time frames. By selecting actions for immediate implementation as well as those that will be implemented five to ten years in the future, stakeholders can prepare for immediate concerns while also setting a foundation to address future threats and risks (Hallegatte, 2009). Maintaining the momentum to implement longer-term actions, however, can prove challenging, especially at the local level where political environments, public interests, and financial resources are constantly fluctuating. The use of multiple time frames, if paired with a technique such as adaptive management, could produce a solution that falls within the '*adapt and monitor*' category. However, we postulate that stakeholders do not regularly revisit actions that are slated for implementation in future time frames, meaning that they are selecting actions that cover multiple time frames based on what they assume to be a relatively predictable set of future climate conditions.

Adapt and Monitor

Accepting that the future can no longer be predicted with precision, the '*adapt and monitor*' model of planning emphasizes taking action that is adjustable as new information emerges (Quay, 2010; Walker, 2012). Based on a review of the climate and planning literatures, six climate relevant planning approaches that are either fully grounded or partially grounded in the '*adapt and monitor*' model of planning were identified (Table 6): 1) use of adaptive management, 2) scenario planning, 3) selecting robust actions, 4) using incremental or flexible actions, 5) using thresholds or tipping points, and 6) monitoring changing climate conditions.

5.6 Adaptive Management / Adaptive Planning

Adaptive management, with its routes in adaptive policy, stems from the mid-1920's when John Dewey (1927) proposed that "policies be treated as experiments, with the aim of promoting continual learning and adaptation in response to experience over time." Since then, the concept of adaptive management has gained traction in the ecosystems management, planning, climate, and resilience fields (Engle and Lemos, 2010; Holling, 1973; Nelson, et al., 2007). The concept of adaptive management or adaptive planning means being able to change course (e.g., policy, management practices, or planning approaches) based on changing and unforeseen future conditions (Walker et al., 2013). At the core of adaptive management is the concept of learning by doing in which actions are viewed as experiments that can be learned from, replicated, and improved upon as needed (Walters, 1997; Miles, 2013; Tompkins and Adger, 2004). Because of its explicit focus on continual learning and revision, we identified adaptive management as a strategy within the 'adapt and monitor' approach to planning.

5.7 Scenario Planning

Scenario planning is a “process of positing several informed, plausible and imagined alternative future environments in which decisions about the future may be played out, for the purpose of changing current thinking, improving decision making, enhancing human and organizational learning and improving performance’’ (Chermack, 2004: p. 16). More generally, scenario planning is a process to construct possible narratives about what the future could be (Evans, 2011) and then selecting options that are viable across all of these potential futures. Scenario planning does not allow stakeholders to predict the future or select an optimal future to plan for (Varum and Melo, 2010). Instead, scenario planning provides a tool to explore multiple plausible futures by bringing together diverse stakeholders to co-construct possible narratives about their future and then use these scenarios to assess “strategic options and capabilities” that will serve across a range of plausible futures (Evans, 2011). Because scenario planning focuses on planning for a range of futures as opposed to a single or small subset of futures, and the assumption that it will require continual learning, we framed scenario planning as a viable technique with an ‘adapt and monitor’ approach to planning.

5.8 Robust Decision Making and Action Selection

Robust decision making uses multiple views of the future to identify actions that “perform well enough across a broad range of plausible futures, but may not perform optimally in any single future” (Walker et al., 2013; p. 960). To generate actions that are robust, planners must think through multiple different future scenarios (e.g., through scenario planning) and avoid selecting a single or small sub-set of future scenarios upon which to base their planning (Hallegatte, 2009; Lempert et al., 2007; Walker et al., 2013). Similar to scenario planning, because robust actions are specifically designed to perform well across an array of futures and, as such, should be regularly revisited as new information becomes available, we categorized them as a viable technique within the ‘adapt and monitor’ approach.

5.9 Incremental and Flexible Actions

Incremental actions are those that can be phased in over time. Often seen as modular actions that can be sequenced so as to minimize risk, incremental actions are touted as being able to address immediate concerns while leaving options open to deal with changes in the magnitude and timing of climate impacts (Quay, 2010: Hallegatte, 2009; Easterling et al., 2004).

Incremental actions allow stakeholders to spread out costs and reduce losses if the investment or adaptation action must be abandoned or proves unnecessary (Quay, 2010).

Flexible adaptation actions, also commonly described as reversible actions, are those that are capable of being adjusted, tailored, or tweaked as circumstances change (Hallegatte, 2009; Quay, 2010). Examples of flexible and reversible adaptation actions include the modular building of a sea wall, climate proofing buildings, or limiting development in potentially vulnerable areas (Hallegatte, 2009). All of these approaches can be modified or forgone quickly if climate impacts prove to be less than expected.

Kates et al., (2012) note that incremental and flexible actions are frequently extensions of existing actions and behaviors that emphasize doing slightly more of what is already being done to deal with variation in climate. As such, the major limitation of incremental or flexible actions is that the magnitude and intensity of climate change may exceed the capacity of these actions to cope. Moreover, some actions simply cannot be done incrementally or in a flexible manner, such as increasing the capacity to treat wastewater. Finally, incremental and flexible actions necessitate the continual monitoring of climate conditions so as to ensure that one is ready to implement the next module or change course if needed. We posit, however, that both incremental and flexible actions are specifically designed to be tailored and adjusted as new information or knowledge becomes available, thereby justifying their inclusion as a technique viable within the 'adapt and monitor' approach to planning.

5.10 Tipping Points or Thresholds

Defined as the "boundary conditions where acceptable technical, environmental, societal, or economic standards may be compromised" (Haasnoot et al., 2013), the identification of adaptation tipping points represents an alternative mechanism for dealing with uncertainty. Contingent only upon magnitude, not time (Gersonius et al., 2014), adaptation tipping points represent when the magnitude of climate change exceeds current management actions, thereby necessitating that new actions be implemented (Abunnusar et al., 2013; Walker and Salt, 2006). Once identified, thresholds or tipping points can be modeled to give an estimate of the likelihood of that threshold being exceeded in the future or monitored so that stakeholders can be ready to act when a threshold is reached. If stakeholders rely solely on modeling thresholds and using those modeling results as a basis for decision-making, then this approach would fall within the '*predict and plan*' model of planning. However, if used as a means to monitor changing climate conditions, thresholds and tipping points can be useful within the '*adapt and monitor*' model of planning, which is how we anticipate they are being used.

5.11 Monitoring Climate Conditions

The final technique within the '*adapt and monitor*' approach is the regular monitoring of climate conditions. In this case, signposts or triggers can be set that indicate when additional action is needed such as revisiting a plan, the scaling up of a promising practice, or a change of policy (Quay, 2010; Walker et al., 2013). Generally, monitoring of climate conditions is promoted in two situations: 1) a plan exists for how best to prepare once a signpost or trigger is hit and one is monitoring to determine when to implement that plan; or 2) no action or plan is needed yet, but one would be warranted once a certain signpost or trigger is met. Since monitoring is inherently about collecting new information that, ideally, should be used to inform decision making, we placed it within the 'adapt and monitor' approach to planning.

The above sections summarized both the different types of uncertainty relevant to climate adaptation and the recommended planning approaches to reduce these sources of uncertainty. The following section describes the process undertaken in this paper to evaluate whether these types of uncertainty and planning approaches are commonly identified and used by local adaptation practitioners. To do this, the most common types of uncertainty cited within 44 U.S. local climate adaptation plans are identified and analyzed based on community size (small, medium, or large) and location (coastal vs. inland). Next, the uncertainty reducing approaches discussed above are compared against those used during local adaptation planning.

6. Methods

6.1 Sample Selection

Three criteria were used to select plans for the sample: (1) the central topic of the plan, as defined by the author, was adaptation, resilience, or preparedness; (2) the plan was written by or for a U.S. city, town, or county government; and (3) the plan took a comprehensive approach to adaptation (i.e., sector-based adaptation plans were excluded). These criteria excluded plans that attempted to integrate or mainstream climate adaptation into other planning processes (e.g., sustainability or master plans) and regional or multi-jurisdictional plans (e.g., San Diego Bay, Metropolitan Washington Council of Governments).

Researchers attempted to evaluate all plans in the U.S. released before 2015 that met these criteria. The sample was developed based on a search of three adaptation clearinghouse websites: the Georgetown Climate Center, the Climate Adaptation Knowledge Exchange, and the Center for Climate and Energy Solutions. In addition, plans were collected through three 100-page Google searches for the terms "local adaptation plan", "local resilience plan", and "local preparedness plan". In total 85 plans were collected, of which 44 met the established criteria for evaluation (Figure 6). Of the 41 not included in the final sample 16 were other types of plans that only included a chapter on adaptation, 8 were written by regional agencies, and 17 were sector specific (see Woodruff and Stults, 2016 for a detailed description of the sample selection process; Chapter 2).

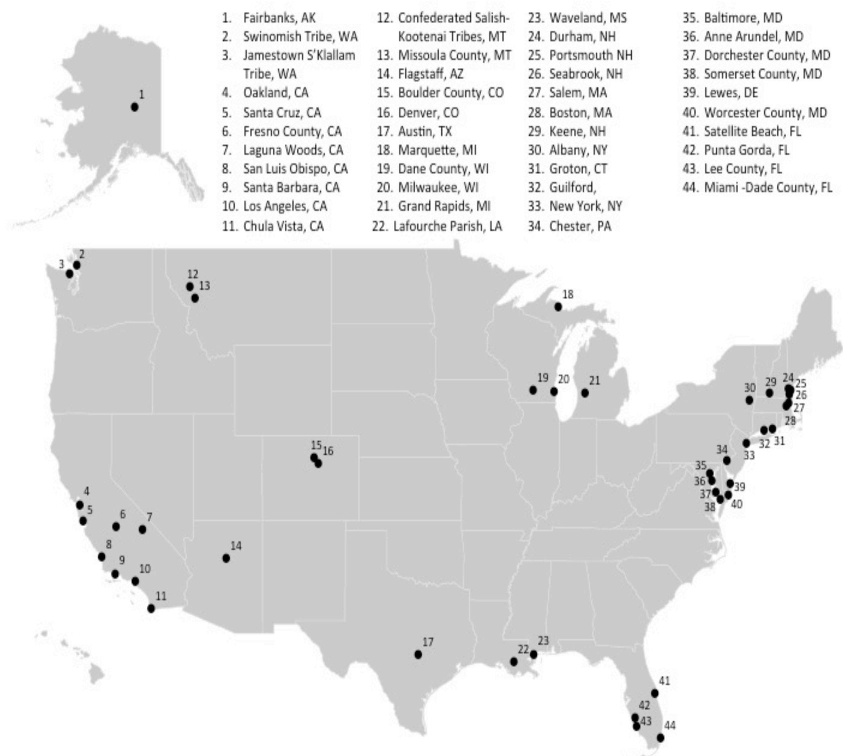

Figure 6. Communities with climate adaptation plans analyzed to see how they frame uncertainty and what uncertainty reducing techniques are being used.

6.2 Coding Protocol and Procedures

Based on the material discussed in the preceding sections, a coding protocol was developed to identify the presence of uncertainty as well as approaches for reducing uncertainty in the local adaptation plans in the sample. In total, 21 codes were developed to assess uncertainty: two codes centered on the *identification of uncertainty* and nineteen codes focused on identifying *specific approaches to overcome uncertainty* (Appendix 3). For actions, each had to be explicitly labeled as being *no regrets*, *low regrets*, *incremental*, *flexible*, or *robust* in the plan in order to receive these codes: researchers did not interpret whether actions could be considered as meeting any of these criteria. The twenty-one codes were pre-tested on eight local adaptation plans from Europe and Australia to ensure that the codes captured the intended concepts.

Each plan in the sample was coded independently by two trained coders in line with recommendations from the communications literature on content analysis and methodological recommendations from the plan evaluation literature (Krippendorf, 2013). Before coding plans within the sample, inter-coder reliability was calculated to ensure that the coders fell within an appropriate range of inter-coder agreement (0.80 or greater).

Coders used *NVivo version 10* qualitative analysis software package to link coding items with the content of plans. Once coders completed a plan, researchers compared coders' quantitative data to identify disagreements on a metric-by-metric basis. All disagreements were discussed and reconciled by referring to the qualitative plan content, and final agreed upon codes were integrated into a master dataset.

After all codes had been reconciled, a qualitative analysis of the text associated with the ***type or source of uncertainty*** codes was undertaken, grouping similar types of uncertainty together. Aggregate data was grouped based on two variables to see if any trends existed: community population size and coastal versus non-coastal communities.

7. Results

7.1 Types of Uncertainty in Climate Adaptation Planning

Roughly three-quarters of the plans in the sample identify the presence of uncertainty when planning for climate change (33 out of 44 plans). Categorizing this uncertainty into the five types discussed in Figure 4 shows that the most common type of uncertainty was associated with *knowing what the future climate will be* (present in 29 out of 44 plans; Figure 7). Boulder County's plan provides a summary of this type of uncertainty

> "Adding to the complexity of managing the impacts of climate change is the uncertainty inherent in climate science. Although scientists are reasonably confident in the direction of temperature changes, the magnitude of change remains uncertain. For other changes, like precipitation, both the direction and magnitude of change are uncertain. This means that Boulder County and its municipalities are facing an uncertain range of possible future climate conditions with ensuing complications in identifying proactive management responses that are robust yet cost-effective across a potentially wide range of future climate conditions and design requirements" (Boulder County, p. 13).

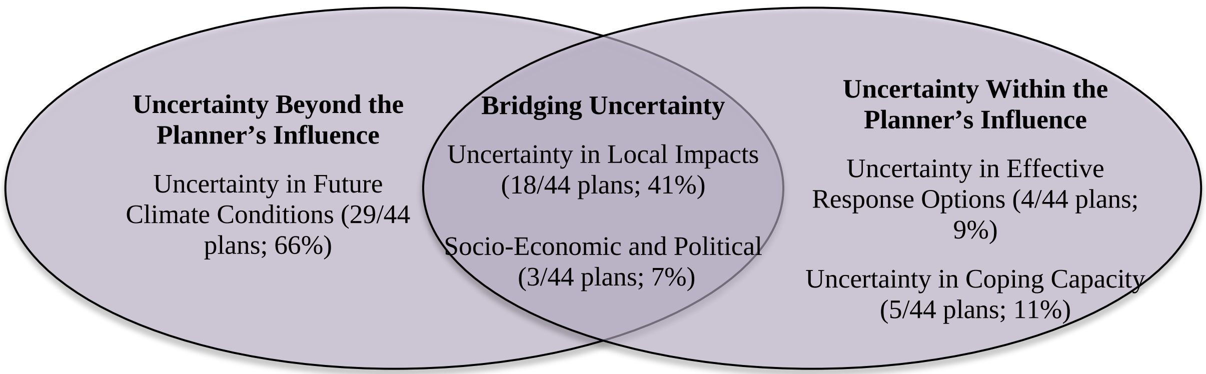

Figure 7. Types of climate related uncertainty and the number and percentage (in parenthesis) of plans in sample that identified each type of uncertainty.

The second most common type of uncertainty relates to *what the local impacts of climate change will be* (found in 18 out of 44 plans). As demonstrated in the following quote from the City of Santa Barbara, CA, this form of uncertainty was almost always followed by a statement about the need to act in the face of an uncertain future: “While uncertainty remains when it comes to determining the exact way that climate change will affect California, uncertainty should not result in paralysis or a lack of action” (Santa Barbara, p. 10).

In aggregate, the most common type of uncertainty identified within the sample was uncertainty *beyond the planner’s influence* (found in 29 of the 44 plans). *Bridging uncertainty*, which was found in 18 of the 44 plans, was the second most common type of uncertainty. The least common type was uncertainty deemed *within the planner’s influence*, which was found in 9 of the 44 plans analyzed.

The least common specific form of uncertainty identified in plans related to socio-economic and political uncertainty, with only Austin, TX, Boulder County, CO, and Los Angeles, CA identifying this type of uncertainty. In all three cases, this type of uncertainty framed around lack of information regarding how humans will respond to changing climate conditions. Also infrequent in plans in the sample was uncertainty related to appropriate responses to dealing with climate related impacts (4 out of the 44 plans). Only Boulder County, CA, Los Angeles, CA, New York City, NY, and Punta Gorda, FL identified this source of uncertainty. Uncertainty in appropriate responses commonly dealt with lack of clarity about either what to do to prepare for changes in climate or uncertainty pertaining to the effectiveness of proposed actions. For example, Punta Gorda, FL’s plan identifies the uncertainty associated with the effectiveness and potential side effects of large-scale beach nourishment: “As with statewide seawall construction, beach nourishment on this scale would be a mammoth engineering project, with uncertain environmental impacts of its own" (Punta Gorda, p. 214). Uncertainty related to the coping capacity of a community was also infrequent in the sample, appearing in only 5 out of the 44 plans analyzed.

On average, each of the 33 plans that acknowledged uncertainty identified 1.3 types of uncertainty. Two plans, Boulder County, CO and Los Angeles, CA, identified 4 of the 5 types of uncertainty. Austin, TX, Baltimore, MD. Punta Gorda, FL, and Santa Barbara, CA all identified three types of uncertainty. Eleven plans did not mention uncertainty.

Plans from small communities (i.e., populations under 50,000) identified, on average, less than 1 type of uncertainty each (0.89). Medium sized communities (populations between 50,001 – 250,000) and large communities (population over 250,001) identified, on average, 1.6 and 1.7 types of uncertainty in their adaptation plans, respectively. There was little difference between the number of uncertainties identified by coastal communities (average of 1.7) and noncoastal communities (average of 1.8) (Table 6 and Table 7).

Table 6. Percent of plans in sample that contained each category of uncertainty, grouped by community population size (small communities are those with a population 50,000 and under; medium communities have a population between 50,001 – 250,000; large = 250,001+)

	Percent of Plans that Contained Each Category of Uncertainty					**Average Number of Uncertainties Identified in each plan**
Number of Communities in Each Size Category	Future Conditions	Soc-Eco Factors	Local Impacts	Coping Capacity	Effective Actions	
Small (18)	56%	0%	6%	22%	6%	0.9
Medium (9)	78%	0%	67%	11%	0%	1.5
Large (17)	71%	18%	47%	18%	18%	1.7

With fewer than five cases in some cells, researchers were unable to use Chi-Square approaches to statistically analyze results. However, the results in Table 6 show that only large communities identified socio-economic sources of uncertainty and large and medium communities disproportionately discussed uncertainty related to local impacts.

Table 7. Percent of plans that contained each category of uncertainty, grouped based on if the community is coastal or non-coastal.

	Percent of Plans that Contained Each Category of Uncertainty					Average Number of Uncertainties Identified in each plan
Number of Coastal or Non-Coastal Communities	Future Conditions	Soc-Eco Factors	Local Impacts	Coping Capacity	Effective Actions	
Coastal (28)	64%	4%	39%	14%	11%	1.7
Non Coastal (16)	69%	13%	44%	6%	6%	1.9

Results from Table 7 suggest that no significant differences exist in regards to the number or sources of uncertainty identified based on whether a community is coastal or noncoastal. While coastal communities, combined, identified a total of 48 types of uncertainty, this averaged out to just under 2 types per plan, which is comparable to the average total number of uncertainties in non-coastal communities (1.7).

7.2 Approaches for Addressing Uncertainty

The two most common uncertainty reducing approaches were both in the '*predict and plan*' category of planning, and included the use of multiple greenhouse gas emissions scenarios (used in 34 out of 44 plans) and the conducting of vulnerability assessments (discussed in 32 out of 44 plans) (Table 8). In regards to the use of multiple scenarios, there was wide variation in the types and numbers of scenarios used during the planning process, but nearly every community used greenhouse emissions scenarios developed by the Intergovernmental Panel on Climate Change (IPCC). Four communities, Baltimore, MD, Los Angeles, CA, Jamestown S'Klallam Tribe, and Lafourche, LA developed their own suite of scenarios. In the case of Baltimore, Los Angeles, and Jamestown, these scenarios were informed by the IPCC. For Lafourche, it was unclear what role, if any, IPCC scenarios played in their generation of place-based scenarios. Importantly, the use of multiple scenarios did not translate into scenario planning: instead, plans in the sample used multiple scenarios to provide a range of potential future climate conditions and then communities chose one, possibly two, scenarios (often a high and low emissions scenario) upon which to base their planning.

Nearly three-quarters of the communities in the sample (32 out of 44 plans) also noted using a vulnerability assessment to help inform their planning process. Vulnerability within the built environment, natural systems, and public health were frequently evaluated across all plans (see Woodruff and Stults, 2016 for more details). Twelve out of the 44 plans had no content about whether or not a vulnerability assessment was conducted as part of the local planning process. This could mean that a few additional communities conducted a vulnerability assessment as part of their planning process, but did not detail that process in their adaptation plan.

The large use of vulnerability assessments in climate adaptation planning is not surprising given the amount of emphasis placed on this technique in the peer-reviewed and grey literature. As demonstration, one of the organizations that helped to champion the importance of local adaptation planning, ICLEI-Local Governments for Sustainability, strongly encourages all local communities to conduct a climate vulnerability assessment. While we were unable to determine which communities were members of ICLEI during their adaptation planning process, consultation with membership staff at ICLEI determined that 24 out of the 44 communities in the sample either are or were members of ICLEI at one point within the last five years. Sixteen of the communities that are or have been ICLEI members in the sample noted having conducted a climate vulnerability assessment, yet it is likely that many of the remaining eight communities also undertook some form of vulnerability assessment as part of their adaptation planning process.[16]

Table 8. Uncertainty reducing approaches used in local climate adaptation plans, grouped based on whether they most closely align with a 'predict and plan' or an 'adapt and monitor' approach to planning, as well as the percentage of plans in the sample that used each technique.

Predict and Plan	
1. Multiple Scenarios	n = 34 (77.3%)
2. Vulnerability Assessments	n = 32 (72.7%)
3. No Regrets Actions	n = 13 (29.5%)
4. Multiple Time Frames	n = 11 (25%)
5. Downscaling	n = 10 (22.7%)
6. Low Regrets Actions	n = 3 (6.3%)
7. Low Regrets Actions Detailed	n = 0 (0%)
8. No Regrets Actions Detailed	n = 0 (0%)
TOTAL	**103**
Adapt and Monitor	
9. Monitoring Changing Conditions	n = 24 (54.5%)
10. Adaptive Management	n = 22 (50%)
11. Flexible Actions	n = 16 (36.4%)
12. Signposts / Thresholds	n = 12 (27.3%)
13. Adaptive Management Detailed	n = 8 (18.2%)
14. Incremental Actions	n = 6 (13.6%)
15. Robust Actions	n = 5 (11.4%)
16. Flexible Actions Detailed	n = 2 (4.5%)
17. Incremental Actions Detailed	n = 0 (0%)
18. Robust Actions Detailed	n = 0 (0%)
19. Scenario Planning	n = 0 (0%)
TOTAL	**95**

The third and fourth most common approaches found in the sample are both from the '*adapt and monitor*' category of planning: monitoring changing climate conditions and adaptive

[16] No information about whether or not these remaining 8 ICLEI members completed a vulnerability assessment as part of their adaptation planning process could be identified. As such, these communities were not included in the count of communities that used a vulnerability assessment.

management. Twenty-four out of the 44 plans in the sample included content about continuing to monitor how the climate was changing and the impacts associated with that change. Half of the plans analyzed (22 out of 44) mention the importance of adaptive management in planning for climate change. Terms such as “learning”, “iterative”, “evolving”, and “dynamic” were commonly used to describe the concept of adaptive management. While over half of the plans included language emphasizing the importance of adaptive management, only eight plans built out an approach to adaptively manage the plan (Anne Arundel, MD, Boulder County, CO, Confederated Salish and Kootenai Tribe; Guildford, CT, Lee County, FL, Los Angeles, CA, Santa Cruz, CA, and Satellite Beach, FL).

No plans in the sample identified specific actions as being robust, incremental, low-regrets, or no-regrets. Only two plans used actions labeled as flexible (Punta Gorda, FL, and New York City, NY). Also uncommon was any discussion about the importance or value of low-regrets actions (3 out of 44), robust actions (5 out of 44), or incremental actions (6 out of 44).

Finally, despite the importance of scenario planning in the peer-reviewed literature (e.g., Evans 2011), no plan in the sample used a scenario planning process to inform their planning and action selection. This suggests an important disconnect between what is suggested as a promising practice in theory and what is viable in practice.

The average number of approaches to address uncertainty in each plan in the sample was 4.5 out of 19: 2.3 from the ‘*predict and plan*’ category, and 2.2 from the ‘*adapt and monitor*’ category. Small (those with a population under 50,000) and medium-sized communities (population between 50,001 and 250,000) used roughly 3.9 to 4 uncertainty-reducing approaches each. Large communities (population over 250,001) used, on average, 5.4 approaches per plan for addressing uncertainty. This suggests that large communities may have more capacity to undertake an array of uncertainty reducing approaches when compared to smaller communities. Tables 9 and 10 show the total number of uncertainty reducing approaches grouped by community population size and whether a community is coastal or not. Appendix 4 and 5 provide summaries, by community, of the types of uncertainties identified and the uncertainty reducing approaches used.

Table 9. Average number of uncertainty reducing approaches used in each plan in the sample, grouped by community population size (small communities are those with a population 50,000 and under; medium communities have a population between 50,001 – 250,000; large = 250,001+) and whether they fall within a 'predict and plan' or 'adapt and monitor' approach to planning.

Number of Communities in Each Size Category	Predict and Plan	Adapt and Monitor	Total
Small (18)	2.22	1.78	4
Medium (9)	2.33	1.56	3.9
Large (17)	2.47	2.88	5.4

Table 10. Average number of uncertainty reducing approaches used in each plan in the sample, grouped by whether a community is coastal or non-coastal and whether they fall within a 'predict and plan' or 'adapt and monitor' approach to planning,.

Number of Coastal or Non-Coastal Communities	Predict and Plan	Adapt and Monitor	Total
Coastal (28)	2.25	2.32	4.6
Non Coastal (16)	2.5	1.88	4.4

8. Discussion

This paper presented two conceptual frameworks for understanding the different sources of uncertainty related to planning for a climate altered future and how those sources of uncertainty relate to the role of the planner. Results indicate that local communities are aware of the myriad types of uncertainty related to planning for climate change but are not discussing that uncertainty within their climate adaptation plans. What uncertainty was discussed nearly always focused on issues *beyond the planner's influence* (54% of uncertainty references) as well as what we define as *bridging uncertainty* (with uncertainty in local climate impacts being the most dominant type in this category; 31% of uncertainty references). The dominance of these two types of uncertainty within the sample is not surprising given the frequency with which the peer-reviewed and grey literature discuss them, especially uncertainty related to future climate conditions and uncertainty related to future climate impacts (NCA, 2014, IPCC). In contrast, plans in the sample placed little emphasis on uncertainty categorized as *within the planner's influence* (15% of total uncertainty references).

Surprisingly, no relationship was found between the size of a community or its proximity to the ocean, and the number of uncertainties discussed. This suggests that regardless of size or geographical location, communities are concerned about a similar number of uncertainty types. One notable exception is that only large communities identified uncertainties related to socio-economic and political factors as being relevant to their adaptation planning process. This could be because large communities regularly interact with state and federal colleagues and may be more affected than smaller communities by legislative, funding, or policy changes at these scales of governance.

Overall, each plan in the sample included an average of 4 of the 19 uncertainty reducing approaches. There was no relationship between the number of uncertainties identified in a given plan and the number of uncertainty reducing approaches used during the planning process. As illustration, Baltimore, MD's and Los Angeles, CA's plans both identified four out of the five types of uncertainty and both used six uncertainty reducing approaches. In contrast, the City and County of Denver, CO's plan only identified one type of uncertainty, but included nine uncertainty reducing approaches. This suggests that other extraneous factors (e.g., possibly municipal capacity, political support for adaptation) may influence how many and which uncertainty reducing approaches are employed during adaptation planning.

Overall, 198 uses of uncertainty reducing approaches were identified in the 44 plans in the sample: 103 from the traditional '*predict and plan*' approach to planning and 95 from the '*adapt and monitor*' approach. The two most common uncertainty reducing approaches were multiple scenarios (present in 74% of plans) and vulnerability assessments (present in 73% of plans), both of which are from the '*predict and plan*' approach. The two most popular techniques from the '*adapt and monitor*' approach were monitoring changing climate conditions (present in 55% of plans) and a discussion regarding the need for adaptive management (present in 50% of plans). Despite the slight dominance of '*predict and plan*' approaches, it is promising that 35 out of the 44 plans include at least one uncertainty reducing technique from the '*adapt and monitor*' approach. These approaches, however, tend to disproportionately focus on monitoring or discussing the value of adaptive management as opposed to changing planning processes or selecting adaptation actions that will perform well across multiple possible futures.

One uncertainty reducing technique that is highly praised in the peer-reviewed literature – scenario planning - was absent from plans in this analysis. In theory, scenario planning is a technique that can help reduce or ameliorate all the types of uncertainty identified in this paper. With its focus on "improv[ing] our understanding of the future through systematic analysis of available information and ideas while highlighting, through the presentation of multiple possible outcomes or scenarios, how open the future is and how limited our knowledge of it remains," (Rickards, 2013; p. 34), scenario planning is uniquely positioned to help address the various types of uncertainty associated with planning for climate change. More to the point, scenario planning was designed specifically to address issues that do not lend themselves to simple prediction; issues such as climate change (Dessai et al., 2009; Rickards, 2013).

The dearth of scenario planning approaches in the sample may be associated with the cost, time, and staffing commitment necessary to undergo a complete scenario planning process (Chakrobarty 2011; Zapata and Kaza, 2015; Quay et al., 2011). This disconnect between what theory says should be a readily embraced technique and what local practitioners are using clearly speaks to a mismatch between theory and practice that we believe warrants much further study.

The mismatch between theory and practice can also be seen when looking at the lack of communities embracing robust and flexible actions. According to research discussed in this paper, these types of actions lend themselves to an '*adapt and monitor*' approach to planning and can help reduce nearly all the sources of uncertainty identified in this paper. Yet, no community in the sample labeled actions as being robust and only two labeled actions as being flexible. Moreover, only five communities in the sample discussed the importance of robust actions. However, all of these references used the term robust as a synonym for '*hard'* or '*strong'*. This differs fundamentally from how the term robust is used in the planning and climate literatures, where it is meant as a technique that is viable across multiple different futures (Chakraborty, 2011).

This lack of robust and flexible actions within the sample may be due to political, cultural, and economic considerations or differences in language that limit the viability of these approaches. For example, a robust action is designed to be viable across multiple different futures (Quay, 2010; Walker et al., 2013). If a community does not use scenario planning in their planning process, then it is unlikely they will identify robust actions that are capable of performing across multiple different futures. Similarly, the dearth of flexible actions may be attributable to the rigid nature of local governance in which specific ideas and plans must be created in order to secure the financing needed for implementation. This rationale could also explain why so few communities identified incremental actions in their planning processes.

In contrast, plans within the sample frequently used monitoring and adaptive management to address uncertainty, both of which are touted in the peer-reviewed literature as essential for preparing for climate change (Carpenter, et. al., 2001; Chakraborty et al., 2011; Quay, 2010). While only eight plans in the sample had specific adaptive management processes, 22 discussed the importance of the concept, suggesting that the concept of adaptive management is in the process of being translated from theory to practice.

Additionally, 16 plans in the sample discussed the importance of both no-to low-regrets actions and flexible actions as approaches for addressing uncertainty. Interesting, only two plans specifically labeled an action as being flexible and only one plan labeled an action as being no- or low-regrets. This suggests that planners are increasingly aware of the utility of using no- and low-regrets actions as well as flexible actions, but are either not prioritizing actions that fit this description or do not feel the need to label actions as meeting these requirements.

Findings also showed that ten communities (nearly one quarter) used downscaled climate data in their adaptation planning process. This data was almost always regional, not local, in nature but it does suggest that more communities are looking for and using data at finer resolutions to guide their decision-making processes. The use of information at this scale is mirrored by a call for the production of more downscaled climate data within the scholarly literature (Dessai and Hulme, 2007; Hallegatte, 2009). Given the limitations of downscaling, especially its potential to increase certain types of uncertainty, we are reluctant to emphasize this approach as being instrumental in reducing climate related uncertainty.

9. Conclusion

In aggregate, research findings suggest that planners are still relying on uncertainty reducing approaches that fall within the traditional '*predict and plan*' model of planning. On the positive, flexible approaches from the '*adapt and monitor*' approach do exist within local climate adaptation plans. Significantly more time and investment is needed, however, to ensure that existing as well as future flexible planning approaches are embraced by and integrated into local planning. The impetus for this is clear: the global climate is changing and accurately predicting future climate conditions is impossible. This necessitates that local planners get equipped with the tools and approaches they need to use flexible planning approaches, such as those promoted under the '*adapt and monitor*' approach in order to address the five types of uncertainty identified in this paper.

To help make this transition, it is important that planners understand the various sources of climate related uncertainty as well as the approaches available to help them reduce that uncertainty. The two conceptual frameworks provided in this paper can help the local planner understand the various sources of climate related uncertainty and their ability to reduce it. While not every uncertainty reducing technique will be appropriate, planners should carefully evaluate their local context, and determine which approaches will help to address the uncertainties plaguing their adaptation planning process. More to the point, planners should take caution not to let uncertainty that is *beyond their influence* prevent them from acting. Instead, emphasis should be placed on reducing uncertainty deemed as lying *within the planner's influence* and *bridging uncertainty*. Fortunately, techniques such as scenario planning, the use of robust, incremental, and flexible actions, and continuing to monitor changing climate conditions are all techniques that can help the planner reduce a variety of sources of uncertainty while still actively planning for a climate altered future.

As argued by Abbott (2005; 2012), the planning field exists because of uncertainty. As such, uncertainty is something planners regularly deal with (Hallegatte, 2009). However, the types and complexity of uncertainty associated with problems such as climate change necessitates that planners retool their planning toolkits. Using scenario planning, adaptive management, monitoring, and incremental and robust actions are just some of the tools that need to find their way into the planner's climate adaptation toolbox. To make this happen, however, scholars and practitioners will have to work together to understand why these tools are not currently being used and what is needed to increase their application in local adaptation planning. This may necessitate changes in the broader cultural, environmental, and institutional structures of local government. Regardless, it is the job of scholars and practitioners to ensure that uncertainty does not become an excuse for allowing communities to remain vulnerable to climate change.

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Chapter Four
Looking under the Hood of Local Adaptation Plans: Shedding Light on the Actions Prioritized to Build Local Resilience to Climate Change[17, 18]

1. Abstract

In the face of a changing climate, many U.S. local governments are creating plans to prepare. These plans, often called climate adaptation, climate preparedness, or climate resilience plans, lay out how a local community is vulnerable to existing and future changes in climate as well as what actions they propose taking to prepare for climatic impacts. The actions included in these plans provide insight into what local governments feel they have the ability to undertake, as well as what actions they believe are important to ensure they are building resilience to climate change. To date, little to no analysis has been conducted on the content of these plans, which leaves scholars, practitioners, and those supporting communities with limited understanding of what gaps need to be filled or how best to support locally prioritized climate adaptive action. This paper analyzes the content of 43 stand alone climate adaptation plans from U.S. local communities to identify what types of actions are proposed and prioritized in existing plans and how those actions compare to what scholars indicate the communities should be prioritizing based on regional climate projections. The results indicate that local communities include numerous and varied actions in their adaptation plans and that the majority of communities are selecting actions that are theoretically appropriate given projected changes in regional climate. This suggests that communities are recognizing the far-reaching impacts of climate change and looking to use their full authority to create more resilient communities. Yet some types of actions, such as building codes and advocacy, are not being used to their full potential. These results contrast with those of previous studies, which found that local communities focus primarily on capacity building approaches. Findings also demonstrate that plans rarely contain

[17] This chapter is modified based on an article currently under review for publication in the Journal Mitigation and Adaptation Strategies for Global Change

[18] This chapter is coauthored with Sierra Woodruff.

significant details about how actions will be implemented, which raises the question about whether plans will translate into real-world projects. In summary, findings suggest that communities are selecting a wide variety of actions in order to help them prepare for climate change. More work, however, is needed to support the translation of these actions into implemented projects that foster resilient local communities.

2. Introduction

The imminent and far-reaching consequences of climate change have made adaptation, or actions to reduce the harm of climate change impacts, an imperative (Bierbaum et al., 2013; IPCC, 2014). Most of the least-developed countries have developed National Adaptation Programs of Action (The World Bank, 2010), some U.S. states are creating voluntary climate action plans (Ray and Grannis, 2015), and many U.S. tribal and local governments are creating climate adaptation plans (Shi et al., 2015; Woodruff and Stults, 2016). These plans generally profile physical and social vulnerabilities to existing and future changes in climate and identify actions to build resilience to projected impacts (Woodruff and Stults, 2016).

While action at all scales is needed, the urgency of climate change is most pronounced at the local level where the majority of climate impacts are felt (Baker et al., 2012; Moser and Pike, 2015). This reality, combined with the fact that more than 80% of the U.S. population currently lives in urban areas (Bureau, 2012), means that any effort to prepare for climate change must emphasize action at the city level. In the United States, the importance of city level adaptation to climate change can be seen in the inclusion of local voices in the President's *State, Local and Tribal Leaders Task Force on Climate Preparedness and Resilience*, in the local examples in the 2014 U.S. National Climate Assessment, and in the investments that philanthropies are making in local adaptation initiatives (e.g., The Kresge Foundation; Bloomberg Philanthropies; 100 Resilient Cities). Since 2005, more than 40 communities in the United States have created stand alone climate adaptation plans, with potentially hundreds more embedding climate considerations into other planning approaches (e.g., sustainability plans, drought or water management plans, climate action plans; Quay, 2010; Shi et al., 2015; Woodruff and Stults, 2016).

Despite the growing awareness of the importance of local climate adaptation, few analyses have explored what actions U.S. local governments are including in their climate adaptation plans and, therefore, what actions they are prioritizing to prepare for climate change (Fidelman et al., 2013). Without knowledge about locally prioritized adaptation actions, scholars, practitioners, and those seeking to help local communities adapt to climate change will continue to have limited understanding of the state of practice and how to effectively assist in implementing adaptive actions. This research addresses this need by answering three questions: 1) what are U.S. local governments planning to do to prepare for climate change, 2) how do these actions align with the risks or vulnerabilities faced by these local governments, and 3) do local governments provide details that will support the implementation of actions they identify?

The following section begins by looking at the state of local adaptation planning in the United States and abroad, paying particular attention to studies that identify the types of adaptation actions prioritized in local adaptation plans. Next, existing typologies of adaptation action are identified in order to help organize proposed actions into a conceptual framework that permits multi-site comparison. Following this is a brief discussion of proposed impact-specific adaptation actions identified in both the peer-reviewed and gray literature in order to understand what actions are recommended for addressing placed based vulnerabilities, as well as a discussion of factors known to influence plan implementation. Next, research methods and findings from an analysis of adaptation actions contained in 43 stand alone climate adaptation plans from U.S. local communities are described. This paper concludes with a discussion about what findings indicate about the state of local adaptation planning in the U.S. and what opportunities exist to improve the next generation of climate adaptation planning and action.

2.1 The State of Local Adaptation Planning

Over the last several years, scholars have proposed a strategic process to plan for climate change that includes five main steps: 1) identifying risks and vulnerabilities; 2) planning, assessing and selecting options; 3) implementing a plan; 4) monitoring and evaluating; and 5) revising strategy and sharing lessons learned (Figure 8) (Bierbaum et al., 2014; Mimura et al., 2014). Scholars have undertaken surveys and detailed case studies to more deeply understand how communities are progressing through this cycle. For example, a 2011 survey of local communities' adaptation initiatives from around the world found that nearly 40% of the 468 local respondents had conducted or were in the process of conducting a vulnerability or risk assessment (Carmin et al., 2012). Of the U.S. respondents (156), 27% were in the vulnerability analysis or planning phases, and only 9% were in the implementation phase (Carmin et al., 2012; Shi et al., 2015). The authors concluded, “most cities are still at the earliest stages of planning, having just started to discuss or think about the best way to proceed” (Carmin et al., 2012 p. 28).

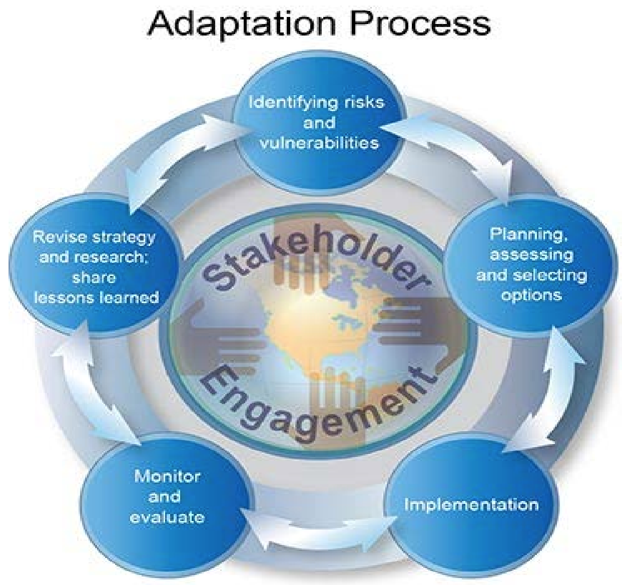


Figure 8: General Adaptation Process (per the Adaptation Chapter of the 2014 U.S. National Climate Assessment; Bierbaum et al., 2014)

To a large extent, the academic literature reflects communities’ progress in the adaptation planning process, with the first phase (conducting a vulnerability or risk assessment) receiving significantly more attention than the later phases (Stults et al., 2015). Specifically, most of the literature on adaptation discusses methodologies for identifying vulnerabilities or the results of specific vulnerability assessments (Berrang-Ford et al., 2011; Eakin and Luers, 2006; Maru, Langridge, Lin, 2011; Smit and Wandel, 2006). Less attention has been dedicated to discussing adaptation actions that local practitioners are undertaking, and even less attention has been paid to profiling the implementation and evaluation of specific adaptation actions (Bierbaum et al., 2014; Mimura et al., 2014).

The research that does exist on adaptation actions and implementation tends to focus on adaptation actions in a specific place (i.e., case study analysis), or high-level comparisons of single adaptation actions across a small subset of communities. For example, in a multi-site analysis, Abt Associates (2016) conducted interviews and desktop research to understand how 17 communities were preparing for climate change. The authors created detailed case studies highlighting a single action each community had undertaken to prepare for climate change or climate variability. They concluded that local communities are using a wide variety of tools to address local vulnerabilities, such as implementing land use regulations to avoid climate related exposure, installing green and physical infrastructure to reduce climate related sensitivity, and using education to increase adaptive capacity (Abt Associates, 2016).

In an analysis of flood management in 169 municipalities in the State of Connecticut, Boyer et al. (2016) found that the average community has roughly eight zoning policies in place that provide climate adaptation value. The most commonly used policies related to water quality, wetlands conservation, and restricting development in flood-prone areas. Capital improvements and capital-related policies were also pervasive, with the most common type focusing on improving drainage infrastructure (e.g., cleaning, maintenance, replacing pipes, installing larger culverts). While Boyer et al. (2016) did not look for capacity building activities during their analysis, qualitative interview data indicated that local stakeholders placed a significant emphasis on capacity building actions such as education, garnering political support, and public engagement in climate planning and decision making (Boyer et al., 2016). In fact, cumulative results from the Boyer et al. (2016) and Abt Associates (2016) studies show that nearly all communities analyzed included at least some dimension of capacity building in their adaptation activities.

Capacity building is defined as "*the practice of enhancing the strengths and attributes of, and resources available to, an individual, community, society, or organization to respond to change*" (Intergovernmental Panel on Climate Change, 2014, p. 1759). The emphasis on capacity building in local adaptation planning has repeatedly been cited in detailed place-based case studies (Fidelman et al., 2013; Moloney and Fünfgeld, 2015; Petersen et al., 2014; Welsh et al., 2013), in multiple-site case studies (Berke et al., 2011; Biagini et al., 2014; Engle, 2013; Quay, 2010), and in adaptation meta-analyses (Bierbaum et al., 2013; Hansen et al., 2013; Hughes, 2015). For example, in an analysis focused on the United Kingdom, Tompkins et al. (2010) identified over 300 examples of "adaptation practice" (p. 627), with the most frequently used type being capacity building actions. The authors defined capacity building as actions focused on research, planning, networking, awareness raising, training, or advocacy. In similar research looking at climate adaptation actions prioritized in 57 federal, state, and local plans in Australia, the United Kingdom, and the United States, Preston et al. (2010) found that the majority of actions (72%) focused on “low-risk capacity-building,” with the most frequent action being “gathering and sharing more information” (p. 423).

2.2 Typologies of Adaptation Action

While capacity building is a commonly discussed strategy, there are a variety of other types of adaptive actions that can help communities prepare for climate change. In the last several years, scholars from the climate, planning, and disaster fields have created typologies to organize the types of actions that can help reduce vulnerability or increase resilience to natural disasters and climate change (Biagini et al., 2014; Cutter et al., 2008; Felgenhauer and Webster, 2013; Ford et al., 2013; Smit and Skinner, 2002; Tompkins et al., 2010). These typologies generally group actions based on one of several attributes: 1) the timing of activity relative to the impact (e.g., anticipatory versus reactive), 2) the intent associated with the action (e.g., autonomous versus planned), 3) the geospatial scope of the action (e.g., local versus regional), 4) the form of the action (e.g., financial versus physical infrastructure), or 5) the degree of change in existing systems associated with the action (e.g., incremental versus transformational; Biagini et al., 2014; Smit and Skinner, 2002).

Form-based typologies (#4 above) are the most prevalent (Biagini et al., 2014), but a great deal of variation exists in regards to how existing typologies classify form-based adaptation actions. Berrang-Ford et al. (2011) used the categories of “intention to act” and “action” to classify adaptation activities found in English language peer-reviewed articles. In this approach, the authors classify things such as the assessment of vulnerability or risk as intention to act, as these do not directly lead to reductions in vulnerability (Berrang-Ford et al., 2011). In contrast, things such as monitoring, increasing awareness, building partnerships, and retreating were considered adaptation actions. Taking a similar approach, Lesnikowski et al. (2011) and Lesnikowski et al. (2013) classify adaptation activities into three categories: recognition, groundwork, and adaptation action. Recognition activities demonstrate that an entity is aware of a climate related impact but has not yet taken action. Groundwork activities are preliminary steps that inform and prepare stakeholders for action but do not constitute actual changes in policy, programs, or the delivery of services; they include activities such as the assessment of vulnerability, adaptation research, and stakeholder networking – all actions typically considered to be capacity building (Lesnikowski et al., 2013). Adaptation actions, according to Lesnikoswki et al. (2011), are tangible actions taken to "alter institutions, policies, programs, built environments, or mandates in response to experienced or predicted risks of climate change" (p. 1155). This includes legislative change, public awareness and outreach, surveillance and monitoring, infrastructure and technology enhancements, program or policy evaluations, financial support for autonomous adaptation, and medical interventions.

Building on these existing typologies, Biagini et al. (2014) classify 158 distinct adaptation activities financed through the Global Environment Facility into ten categories: 1) capacity building, 2) management and planning, 3) changes in or expansion of practice or behavior, 4) policy, 5) information, 6) warning or observing systems, 7) physical infrastructure, 8) green infrastructure, 9) financial, and 10) technology. Similar to Tompkins et al. (2010) and Preston et al. (2010), the authors found that the majority of activity was related to capacity building: nearly every project analyzed in the GEF adaptation portfolio included an action focused on capacity building. Unlike other research, however, the authors also found a significant number of activities focused on management and planning and changing practice and behavior (Biagini et al., 2014). These assessments suggest that much of the adaptation planning to date has focused on capacity building and laying the foundation for future adaptations such as policy changes, shifts in operational procedures, and changes in zoning and land use policy.

2.3 Selecting Impact-Appropriate Adaptation Actions

While capacity building is critical to enable and enhance future adaptation efforts, it is not sufficient to address the climate impacts that many communities are already experiencing. There are a variety of other types of adaptation actions such as land use changes and infrastructure enhancements that directly reduce vulnerability. In a study of adaptation activity in the State of California, Bedsworth and Hanak (2010) identified 49 potential adaptation actions to reduce the vulnerability of six sectors to climate change. Similarly, a number of other scholars and policymakers have identified adaptation actions to respond to climate impacts across a variety of sectors (Boswell et al., 2012; Fu and Tang, 2013; Jenerette et al., 2011; Juhola et al., 2013; Neill et al., 2009; Pincetl and Hogue, 2015; Welsh et al., 2013). Eisenack et al. (2011) identify 245 adaptation actions recommended in the peer-reviewed and grey literature for transportation. They note that the grey literature provides more concrete actions aimed at responding to specific climate impacts than the peer-reviewed literature (Eisenack et al., 2011). Indeed, international organizations, federal agencies, state governments, non-profits, professional organizations, and foundations have all developed adaptation guidance and tools to help local governments identify actions to address their place-based vulnerabilities.[19] While the most appropriate actions vary from community to community, these guides and tools provide a comprehensive overview of the types of actions that should be considered for different climate impacts and sectors (Table 11).

Table 11. Summary of proposed climate adaptation actions based on guidance provided in the grey and peer-reviewed literatures.[14] Column one denotes the six major climate drivers, column two the local impacts most likely to occur due to those drivers, column 3 examples of commonly promoted actions within the peer-reviewed and gray literature to adapt to those impacts, and column four denotes the type of action, based on the categorization used in the analysis. This table is not meant to identify every possible potential action, only the types (column four) proposed to respond to projected climate impacts (column two).

Climate Driver	Impact	Suggested Actions	Type
Temperature change	Extreme heat	Open additional cooling centers during extreme heat	Practice and behavior
		Improve early warning systems for extreme heat	Technology
		Use urban greening to reduce temperatures	Green infrastructure
		Install cool roofs	Physical infrastructure
		Update heat response plan in light of climate change	Planning
	Vector-borne disease	Increase monitoring of disease	Research and monitoring
		Enhance vector-control management practices	Practice and behavior
	Ecosystem impacts	Assist migration of flora and fauna	Practice and behavior
		Purchase upland ecosystems to allow species to migrate	Land use
	Ocean acidification	Remove CO2 from oceans	Technology
		Continue to monitor changes to ocean pH and ecosystem impacts	Research and monitoring
	Air quality	Improve early warning systems	Technology
		Advocate for stricter air quality standards	Advocacy
		Install air quality monitoring stations	Research and monitoring
		Change timing of behaviors, such as sports team practices, during days with poor air quality	Practice and behavior
		Increase urban forest and greening	Green infrastructure
	Energy demand	Conserve energy	Energy conservation
		Implement green building codes	Building codes and design standards
	Infrastructure damage	Use alternative materials that are resistant to heat damage	Physical infrastructure
		Establish stricter building codes	Building codes and design standards
		Conduct maintenance more frequently	Practice and behavior
Sea level rise	Inundation	Facilitate managed retreat from areas at risk of inundation	Land use

[19] The United Nations Environment Program's Guidance on Assessing Vulnerability, Impacts and Adaptation to Climate Change; The Environmental Protection Agency's Being Prepared for Climate Change: A Workbook for Developing Risk-based Adaptation Plans; The National Institute of Standards and Technology's Community Resilience Planning Guide; New York Climate Smart Communities Toolkit; California Adaptation Planning Guide; ICLEI's Preparing for Climate Change: A Guidebook for Local, Regional and State Governments; Institute for Sustainable Communities' Promising Practices in Adaptation and Resilience; and The American Planning Association's Policy Guide on Planning and Climate Change.

		Preserve undeveloped shoreline	Land use
		Mandate real-estate disclosures	Practice and behavior
		Educate homeowners and members of the private sector	Education and outreach
		Protect structures	Physical infrastructure
		Maintain or restore coastal wetlands	Green infrastructure
		Create a 'no-build' zone or district	Policy
		Plan for relocation	Planning
		Elevate and strengthen buildings against more frequent flooding	Building codes and design standards Physical infrastructure
	Ecosystem impacts	Assist migration of flora and fauna	Practice and behavior
		Establish transfer of development rights program	Land use
	Salt water intrusion	Relocate wells and septic tanks	Land use
		Install a desalinization plant	Technology
		Expand water and sewer infrastructure	Physical infrastructure
Decreased precipitation	Reduced water supply	Expand and diversify water supply	Practice and behavior
		Increase water storage	Physical infrastructure
		Enhance rainwater infiltration	Green infrastructure
		Conduct water management planning	Planning
		Reduce water demand	Water conservation
		Increase water reclamation and purple pipes	Physical infrastructure
		Update landscape ordinance	Policy
		Improve information used for water management	Technology
	Ecosystem impacts	Initiate water conservation programs	Water conservation
	Reduced water quality	Enhance water treatment processes	Practice and behavior
		Protect and restore riparian buffers	Green infrastructure
			Land use
Increased precipitation	Flooding	Increase stormwater management capacity	Physical infrastructure
		Encourage low-impact development	Land use
		Capture stormwater where it falls	Green infrastructure
		Reduce number of properties at risk of flooding and stormwater damage	Land use
		Plan for relocation	Planning
		Create a 'no-build' zone or district	Policy
		Make properties and infrastructure more resilient to flooding	Physical infrastructure Building codes and design standards
		Promote the purchase of flood insurance	Education and outreach Financing
	Infrastructure damage	Strengthen buildings to prevent damage	Physical infrastructure
		Install or restore green infrastructure to help lessen flood damage to built infrastructure	Green infrastructure
		Relocate vulnerable infrastructure	Land use
		Strengthen building codes	Building codes and design standards
	Ecosystem impacts	Maintain natural vegetation for stormwater retention	Green infrastructure
	Reduced water quality	Make adjustments to water treatment processes	Practice and behavior
		Capture stormwater where it falls	Green infrastructure
		Protect and restore riparian buffers	Land use
Extreme events	Storm surge	Preserve natural shorelines	Land use
		Protect and enhance natural breakwaters	Green infrastructure
		Install floodgates and other structural protection	Physical infrastructure
		Educate homeowners and members of the private sector	Education and outreach
		Create a 'no-build' zone or district	Policy
		Strengthen buildings to prevent damage	Building codes

	Power outages	Create renewable energy systems for back-up power	Technology
		Strengthen energy infrastructure	Physical infrastructure
	Hurricanes / coastal storms	Conduct evacuation planning	Planning
		Strengthen building codes	Building codes and design standards
		Educate homeowners and members of the private sector	Education and outreach
		Maintain or restore natural systems to serve as a storm buffer	Green infrastructure
		Convert land adjacent to coastline into parks	Land use
		Ensure that evacuation routes are usable during disaster	Physical infrastructure
	Erosion	Restore wetlands and dunes	Green infrastructure
		Install revetments or other pieces of hard infrastructure	Physical infrastructure
	Thunderstorms / winter storms	Implement ice and snow removal programs	Practice and behavior
		Retrofit homes and businesses to withstand extreme weather	Physical infrastructure
		Strengthen building codes	Building codes and design standards
		Educate homeowners and members of the private sector	Education and outreach
	Ecosystem impacts	Purchase less vulnerable land and create migration corridors	Land use
		Establish transfer of development or purchase of development rights programs	Land use
	Infrastructure damage	Strengthen building codes	Building codes and design standards
		Maintain or restore natural systems to serve as a storm buffer	Green infrastructure
		Harden physical infrastructure	Physical infrastructure
	Extreme wind	Strengthen building codes to address extreme winds	Building codes and design standards
		Conduct regular tree maintenance	Practice and behavior
Wildfire	Infrastructure and property damage	Design buildings and infrastructure to minimize vulnerability to fire	Building codes and design standards Physical infrastructure
		Educate homeowners about tree maintenance and vegetation cover	Education and outreach
		Promote fuel breaks and defensible space	Practice and behavior
		Regulate development in the wildland-urban interface	Land use
		Manage fuel load through thinning and brush removal	Practice and behavior
	Air quality	Improve early warning systems	Technology
		Change timing of outdoor activities to correspond to times with better air quality	Practice and behavior

2.4 Plan Implementation

Identifying sector- and impact-specific adaptation actions is an important step in planning for climate change. But a community can build resilience only if the actions identified during the planning phase are implemented. Unfortunately, time and resource constraints limit the ability to assess the implementation of adaptation actions in all U.S. communities. Consequently, scholars within the planning and policy domains have devised a series of criteria that are frequently used to gauge the likelihood that a plan will be implemented, including the following:

1. Identification of parties responsible for action implementation (Bassett and Shandas, 2010; Berke and Lyles, 2013; Berke et al., 2012; Brody and Highfield, 2005).
2. Identification of parties responsible for monitoring and evaluating implementation of actions as well as the overall plan (Berke et al., 2012).
3. Articulation of a measurable target and indicator to measure the successful implementation of each action (Bassett and Shandas, 2010).
4. Establishment of a timeline for implementing each action (Berke et al., 2012; Brody and Highfield, 2005; Horney et al., 2012).
5. Identification of costs and funding source to implement each action (Bassett and Shandas, 2010; Hughes, 2015; Lyles and Stevens, 2014).
6. Provision for updating the plan as new information becomes available, including a timeline for when updates need to be made (Berke et al., 2012; Brody and Highfield, 2005; Highfield and Brody, 2013).
7. A strategy to monitor the plan's overall effectiveness (Brody and Highfield, 2005).

Using a combination of these criteria, scholars have evaluated hazard mitigation, sustainability, and climate action plans, finding that plans regularly omit important implementation details. For example, in a meta-analysis of plan quality studies, Berke and Godschalk (2009) found that plans consistently "specify organization responsibility and timelines for actions for implementation and monitoring" but omit other important elements associated with plan implementation, such as funding source. Lyles et al. (2014) found similar results, noting that while plans generally identify the majority of the criteria associated with implementation, they often fail to identify the costs of the proposed actions and the potential sources of funding to finance prioritized actions. Similarly, in an analysis of state-level drought mitigation plans, Fu et al. (2013) found that most plans included implementation responsibility details but omitted details pertaining to financial and/or technical support, details regarding future plan updates, and timetables for implementation. Omissions such as these raise concerns about whether plans will translate into on-the-ground, vulnerability reducing actions.

3. Methods

To understand which adaptation actions local governments prioritize, how these actions align with expected climate impacts, and the likelihood that actions will be implemented, content compiled during a previous plan evaluation study was reviewed and analyzed (Woodruff and Stults, 2016; Chapter 2). In the earlier study, content analysis was used to evaluate 44 stand alone, local adaptation plans in the U.S. against seven principles of plan quality: 1) goals, 2) fact base, 3) actions, 4) public participation, 5) inter-organizational coordination, 6) implementation and monitoring, and 7) uncertainty. For each principle, metrics were developed by reviewing and identifying commonalities across adaptation guidance literature published by academics and international, federal, state, and nongovernmental organizations. Plans were then scored on the presence or absence of each metric, in effect converting the qualitative text in the plan to a quantitative measure. Converting text to quantitative scores allows comparison across plans and statistical analysis. For the purpose of this paper, only data within the *actions* and *implementation and monitoring* principles and associated metrics are analyzed (for a full review of the methodology used in this paper, see Woodruff and Stults, 2016; Chapter 2).

The *actions* principle includes 23 metrics (Appendix 6), and the *implementation and monitoring* principle includes 16 (Appendix 7). Metrics within the *actions* principle fall into two categories: 1) those that describe the type of adaptation action being proposed (e.g., policy, green infrastructure), for which 15 metrics were initially included, and 2) those that help justify the need for the adaptation action (e.g., cost of inaction, co-benefits), for which eight metrics were used (Appendix 6). The original 15 types of adaptation actions were based on the types previously used during adaptation action analyses discussed in the peer-reviewed literature (Biagini et al 2014; Tompkins et al 2010; Travis 2010; Appendix 6). Within the *implementation and monitoring* principle, eight metrics focus on providing information that theoretically supports plan implementation, and eight metrics focus on monitoring plan implementation and outlining a process to improve the plan over time (Appendix 7). These metrics also stem from the peer-reviewed literature, most notably from work on plan quality evaluation (Lyles et al., 2014; Berke et al., 2015).

To ensure that the plans in the sample were comparable, only plans that were completed between 2007 and 2014, focused on adaptation, resilience, or preparedness, were written by or for a U.S. city or county government, and took a comprehensive approach to adaptation, were included in the sample (for more details on on sample selection, see Woodruff and Stults, 2016; Chapter 2). One plan in the original sample, Satellite Beach, FL, did not include adaptation actions, so it was removed, taking the sample size for this paper to 43 (Appendix 8). Each plan was coded independently by two trained coders consistent with recommendations from the communications literature on content analysis (Krippendorff, 2013) and recommendations from the plan evaluation literature on methodology (Berke and Godschalk, 2009; Stevens et al., 2014).

Coders used the *NVivo version 10* qualitative analysis software package (QSR International Pty Ltd, 2012) to link metrics with the content of plans. After the coders completed a plan, their quantitative data was compared to identify disagreements on a metric-by-metric basis. All disagreements were discussed and reconciled by referring to the qualitative plan content, and the final, agreed-upon codes were integrated into a master dataset.

Once all 43 plans had been analyzed, all of the text related to the type of adaptation action was extracted and re-analyzed using a modified Grounded Theory Method (Thornberg, 2012). Each author independently reviewed and classified actions, moving actions to more appropriate types and creating new types of actions, if necessary, to more accurately reflect what the local plans were proposing. To be consistent, all actions were coded based on the action being proposed, not the intent of the action. This meant that if an action was a policy change that would incentivize more resilient building codes, it was coded as being a policy action and not a building code action. By doing this, researchers were able to code the actions as presented by the plan authors, avoiding the need to interpret the plan authors' intent.

When appropriate, adaptation actions were co-tagged as multiple types. For example, Baltimore MD's action to "encourage the development of integrated flood protection systems that use structural (engineering) and non-structural (wetlands) measures" was double tagged as being both a physical infrastructure action and a green infrastructure action. All differences were collaboratively reconciled by referring back to the adaptation plan and looking for similarities between the action in question and other actions.

Through this review, four new types of adaptation actions were created: water conservation, energy conservation, funding, and actions focused exclusively on greenhouse gas mitigation. The original *conservation* action type was also removed and actions initially classified within this category were reclassified as either *land use* or *green infrastructure* actions. Finally, the actions that were originally tagged as being too *general* to classify were grouped into one of the other types of actions, as appropriate.

In the end, each adaptation activity was classified as one of seventeen types (Table 12).[20] For each plan, the total number of actions, the number of action types, and the proportion of each type of action was calculated. In addition, the total number of actions in each type and the number of plans that included a given type of action was calculated.

To address how these actions align with the climate impacts that communities face, the 2014 U.S. National Climate Assessment was used to determine climate impacts for each of the 43 communities based on its region of the country. For each climate impact identified for the local community or region, a literature review of adaptation action guidance materials developed by international, federal, state, and non-governmental organizations was conducted to identify recommended adaptation actions for the different climate impacts and drivers (Table 11). We then determined how those actions would be classified in the draft typology. For example, the *California Adaptation Planning Guide* recommends that a community facing significant sea level rise should consider managed retreat and preserving undeveloped shoreline (CEMA, 2012), both of which could be coded as land use. The U.S. Environmental Protection Agency, recommends communities consider the maintenance and restoration of wetlands to address sea level rise, which was coded as green infrastructure (Environmental Protection Agency, 2014). While not all actions identified during the literature review are included, the actions included in Table 11 demonstrate the types of actions the literature recommends communities consider for each climate driver. Using the material in Table 11, we then determined whether the types of actions proposed in each community's plan aligned with the types of adaptation actions recommended in the peer-reviewed literature based on the projected regional climate impacts.

To discover whether local governments provide detail to support the implementation of adaptation actions, the aggregate results from the coding of implementation criteria as well as the supporting text from each plan was reviewed. Descriptive statistics were calculated to identify similarities and differences across plans.

[20] All of types of adaptation action identified by Biagini were used in our analysis, with the exception of warning or observing systems. In addition, we added *advocacy*, *building codes and engineering design standards*, *energy conservation*, *funding*, *land use*, *research and monitoring*, *water conservation*, and *greenhouse gas mitigation*. This took the total number of strategies types coded for in this paper to 17.

Table 12. The final seventeen types of adaptation actions included in this analysis. Column one lists the type of action, column two briefly describes the action, and column three indicates the source of the action type, including if it has previously been identified as an important adaptation action within the peer-reviewed literature.

Action Type	Description	Source
Advocacy	Actions to encourage regional partners, state agencies, and other organizations to take adaptation-appropriate actions.	Tompkins et al., 2010
Building codes and engineering design standards	Actions to improve physical infrastructure's response to changing climate through improved standards or engineering.	Travis 2010
Capacity building	Actions to develop human resources, institutions, and communities, equipping them with the capability to adapt.	Biagini et al. 2014; Tompkins et al., 2010
Education and outreach	Actions focused on increasing public knowledge.	Tompkins et al. 2010; Biagini et al. 2014
Energy conservation	Actions to reduce energy consumption.	Grounded Theory Analysis
Financing	Actions that use financial (dis)incentives or budget mechanisms to encourage adaptation.	Biagini et al. 2014
Funding	Actions focused on securing capital to implement adaptation-related activities.	Grounded Theory Analysis
Green infrastructure	Actions that use natural systems or processes to advance adaptation.	Biagini et al. 2014
Land use and zoning	Actions that determine how land will be used and where development will occur.	Travis 2010
Physical infrastructure	Actions to create new physical infrastructure, remove physical infrastructure, or modify how physical infrastructure is built.	Biagini et al. 2014; Travis 2010
Planning	Actions that incorporate understanding of climate science, impacts, vulnerability and risk into government and institutional planning processes, efforts, or existing initiatives.	Tompkins et al. 2010; Biagini et al. 2014
Policy	Actions to create new or revise existing regulations and legislation.	Biagini et al. 2014; Tompkins et al., 2010
Practice and behavior	Actions to modify or expand on-the-ground behavior, operations, management, or programs that affect resilience.	Biagini et al. 2014
Research and monitoring	Actions that focus on gathering information and creating reports, maps, or models; monitoring includes observation or repeated measurements over time.	Tompkins et al. 2010; Biagini et al. 2014; Travis 2010
Technology	Actions to develop or expand climate-resilient technologies such as technologies to improve water use, renewable energy, communications, and early warning systems	Biagini et al. 2014; Travis 2010
Water conservation	Actions focused on reducing water consumption.	Grounded Theory Analysis
Greenhouse gas reductions	Actions that explicitly focus on reducing greenhouse gas emissions.	Grounded Theory Analysis

4. Results

4.1 Types of Adaptation Actions

Across the 43 adaptation plans in the sample, researchers identified 3,375 discrete actions. On average, each plan included 93 actions. The median number of actions in a plan was

54. Lee County, FL included the most actions (447), followed by Lafourche Parish, LA (337) and New York City, NY (323). Milwaukee, WI had the fewest actions (14). However, what qualifies as an action and the level of detail provided about each action varied significantly across the plans in the sample. While Lee County, FL had the most actions, the plan's authors provided little detail about their proposed actions, many of which were very general (such as "increase public awareness"). Punta Gorda, FL similarly included many actions that are too general to provide direction on implementation (e.g., "limit development," "use flexible planning," and "stormwater retention"). In contrast, Baltimore, MD and New York City, NY provided extensive detail on each action, discussing the motivation for the action, details about what the action entails, and action-specific implementation information.

On average, each plan in the sample included 12 of the 17 adaptation action types. Baltimore, MD, Denver, CO, Keene, NH, and Lee County, FL included at least one of each of the 17 types of adaptation actions. Fresno County, CA, New York City, NY, Oakland, CA, Punta Gorda, FL, and San Luis Obispo, CA all included 16 out of the 17 types of adaptation actions. Two plans included only seven of the seventeen types of actions: Guilford, CT and Seabrook, NH (Figure 9).

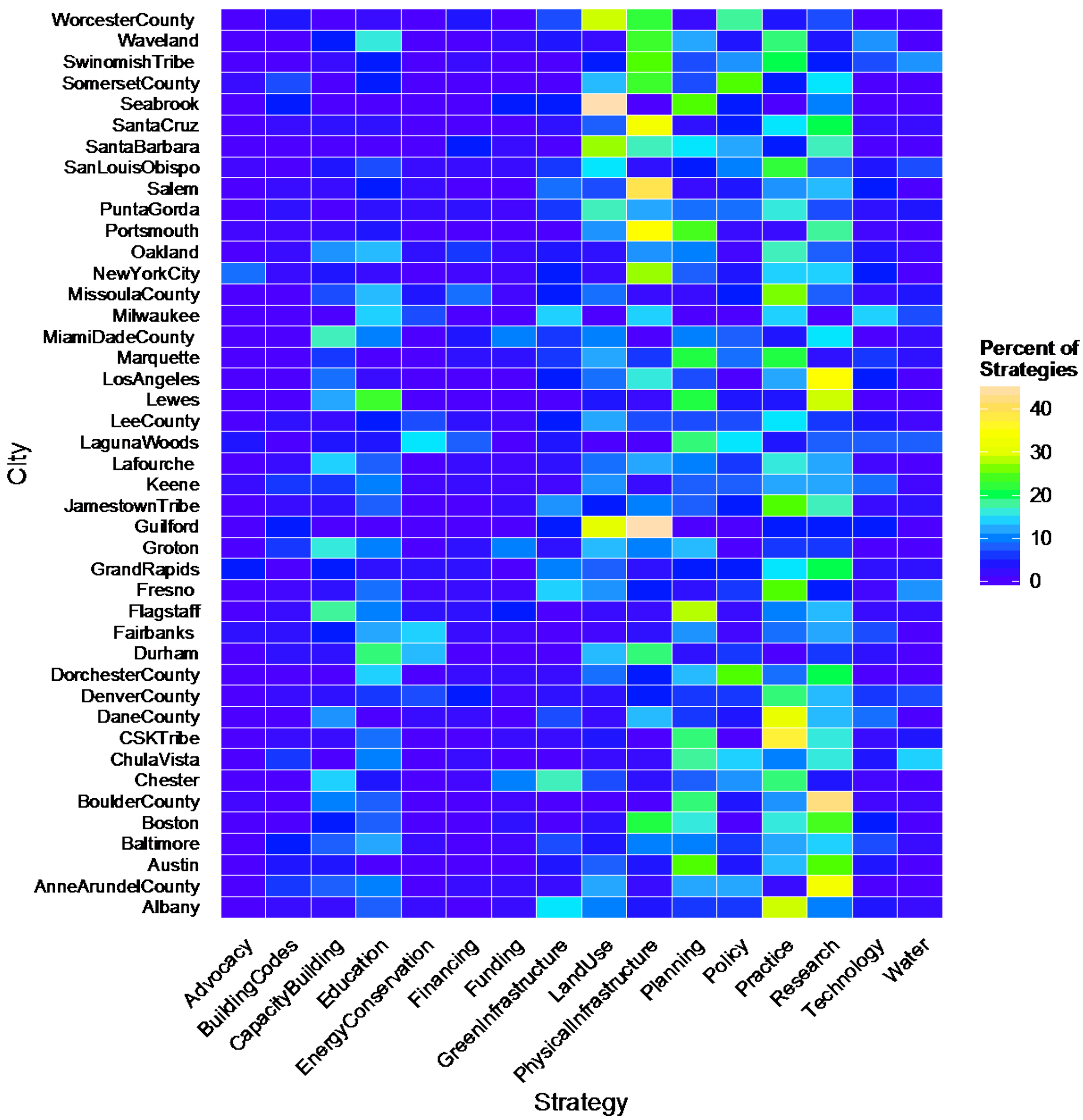


Figure 9. The distribution of actions across action types for each plan in the sample. If an action type makes up a large percent of the actions in a plan, it is lighter in color.

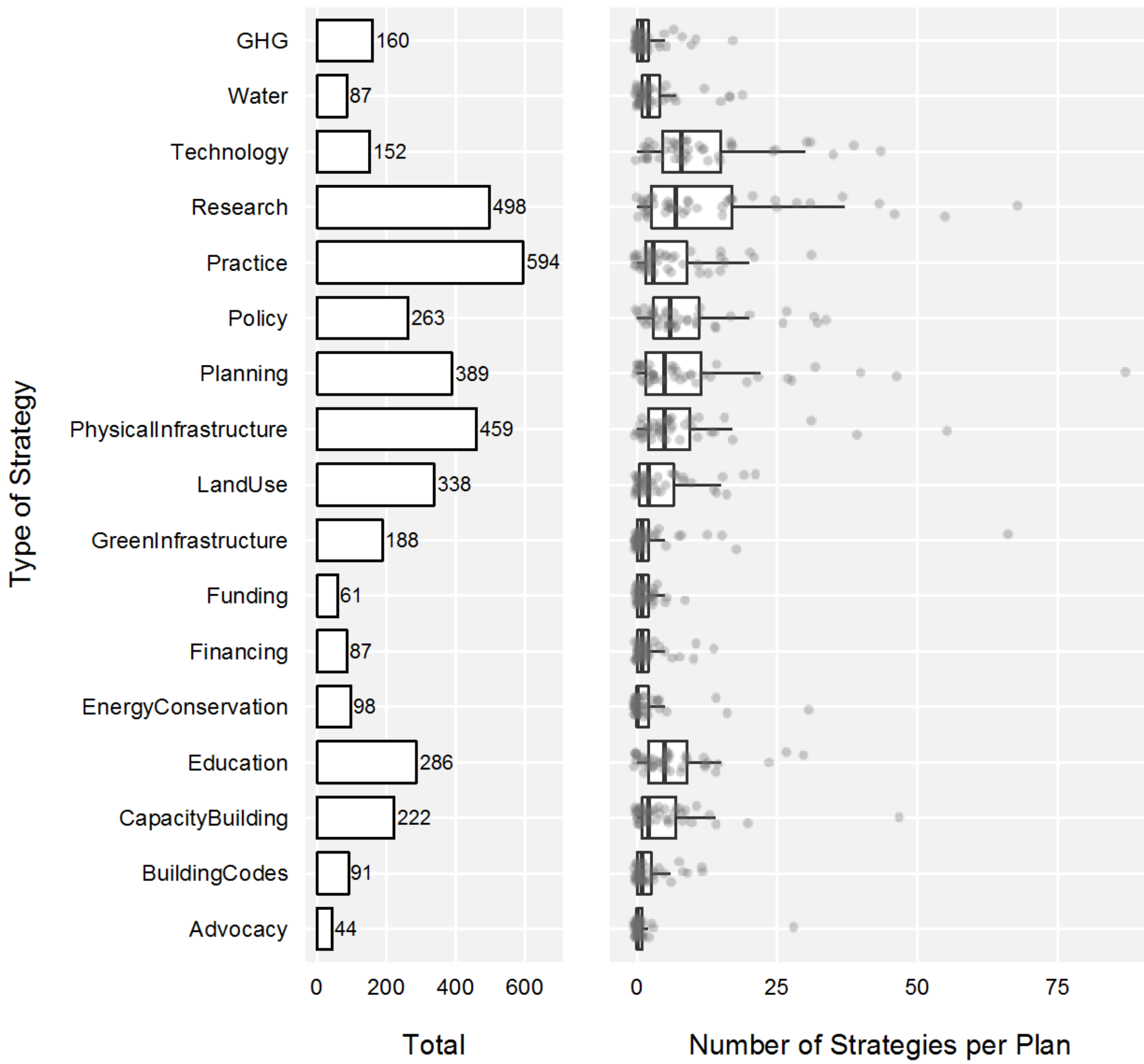
All but one plan (Milwaukee, WI) included *research and monitoring* actions (Figure 9). Most of the actions categorized as *research and monitoring* focused on collecting more information about projected climate impacts on a specific sector or system of concern, researching appropriate adaptation actions, or monitoring the effectiveness of a given adaptation action. For example, Dane County, WI included the following four actions, all of which were tagged as *research and monitoring* actions: 1) identify private wells most at risk of contamination from flooding; 2) model potential flood impacts and impact zones; 3) identify immediately available flood prevention methods; and 4) ensure that land the County owns, or has enforcement authority over, is not contributing to runoff pollution.

Practice and behavior (e.g., changing operations and maintenance schedules, opening cooling centers, implementing best management practices) and *planning* actions (e.g., creating new or updating existing plans) were found in 41 of the 43 plans analyzed. *Land use* actions (e.g., transfer of development rights, no-build policies) were also prevalent, having been identified in 40 of the 43 plans. The least common type of adaptation action was *advocacy*, which was found in only 11 of the 43 plans analyzed. *Energy conservation* (found in 19 of the 43 plans), *water conservation* (22 out of 43), and *greenhouse gas mitigation* actions (22 out of 43) were also found in relatively few plans.

Of the 3,375 actions identified and categorized, the most common type was *practice and behavior* (594 actions; Figure 10), followed by *research and monitoring* (498 actions) and *physical infrastructure* (459 actions). The least common type of adaptation action was *advocacy* (New York City had 28 of the 44 advocacy actions identified). *Funding*, *water conservation*, *financing*, *building codes and engineering design standards,* and *energy conservation* were also infrequent (Figure 10).

Several types of actions were also commonly found together. For example, all plans that include a building code action also had actions related to land use. All plans that include an action related to financing also had planning actions. In addition, all plans that included actions focused on energy conservation also contained technology actions.

Figure 10. Total number of actions categorized by strategy type and the average number of times each strategy occurred per plan. The left panel shows the total number of actions categorized by strategy type across the sample. The right panel depicts the number of times, on average, each strategy type occurred in the plans. Each point represents a plan in the sample (right panel).



4.2 Climate Impacts and Adaptation Actions

Most adaptation plans identified the same climate impacts as discussed in their corresponding regional chapter of the National Climate Assessment. However, 13 coastal communities focused exclusively on impacts related to sea level rise, such as inundation, erosion, and storm surge. For example, Miami-Dade County, FL, Santa Barbara, CA, and Anne Arundel County, MD focused exclusively on sea level rise, omitting rising temperatures, extreme heat, and changing precipitation patterns. While plans that focus on coastal impacts explore the implications for numerous sectors such as public health, water supply, and infrastructure, ignoring other changes may leave communities unaware of and unprepared for other projected climate impacts.

Twenty-eight out of the 43 plans (66%) linked actions to possible future climate impacts or goals. This connection, however, was often broad, which made it impossible to connect individual adaptation actions to climate impacts. Fresno County, CA, for example, organizes adaptation actions into eight sector based categories: 1) agriculture, 2) freshwater aquatic and riparian systems, 3) governance and planning, 4) health and emergency preparedness, 5) infrastructure, 6) valley floor grasslands and semi-desert, 7) water resources and infrastructure, and 8) woodlands and forests. For each sector, the plan identifies climate impacts; agriculture, for example, will be affected by rising temperatures, drought, and an increase in heavy downpours. Because each sector will be affected by multiple climate change impacts, it can be difficult to connect actions back to climate impacts. Many of the plans in the sample follow this approach, identifying high-level climate impacts and then organizing adaptation actions by sector. The sectors also vary considerably between plans. Grand Rapids, MI organizes actions into broad social, environmental, and economic sectors. Baltimore uses infrastructure, natural systems, and public services. Denver uses building and energy, food and agriculture, health and human services, land use and transportation, and urban natural resources.

New York City's plan, *A Stronger, More Resilient New York*, links actions to specific neighborhoods. To do this, the plan begins each chapter by identifying the specific climate impacts likely to affect a given neighborhood and then proposes actions for each area, but it does not specify which adaptation actions are connected to specific impacts. In this case, the action "*Implement planned upgrades to vulnerable City-owned, industrial properties*" falls within the

Brooklyn Queens-Waterfront chapter, where the major regional risks are identified as storm surge, sea level rise, increased precipitation, heavy downpour, and heat wave, many of which may threaten industrial properties. Portsmouth, NH similarly proposes different actions for planning subareas and even details actions for specific streets.

Ultimately, adaptation plans in the sample rarely and unevenly connect adaptation actions to the specific climate related impacts they are intended to address. Exceptions exist in the case of Santa Barbara, CA and Waveland, MS. For example, in its adaptation plan, *City of Santa Barbara Sea Level Rise Vulnerability Study*, Santa Barbara identifies the action, "*Develop retrofit or retreat plans for existing infrastructure subject to future inundation*", which is specifically targeted at inundation caused by sea level rise. Similarly, Waveland, MS's *Local Hazard Mitigation Plan* identifies the action, "*provide an annual pre-hurricane season workshop and exercise for elected officials and emergency operations staff*" to specifically address hurricane-related risks.

Because plans in the sample rarely connected adaptation actions to climate impacts, its unclear whether the actions proposed in the plans corresponds to the theoretical types of actions that the literature recommends communities implement. The analysis was, however, able to determine if the types of actions recommended in the literature (Table 11) were missing from each of the plans. Results showed that, in general, communities are including the types of adaptation actions proposed in the literature to address relevant climate impacts. Exceptions include a lack of building code actions: building code actions do not appear in 35% of plans that identify sea level rise as an issue, 40% that identify extreme precipitation as an issue, 40% that identify wildfires as an issue, 43% that identify storm surge as an issue, 44% that identify hurricanes and coastal storms as an issue, and 38% that identify extreme wind as an issue. Other gaps include a dearth of green infrastructure actions in plans where sea level rise, drought, or heat was identified as an issue of major concern; 27%, 29%, and 35% of the plans identifying these respective impacts omitted green infrastructure actions. Additionally, 33% of plans that identified drought as an issue of concern did not include water conservation actions. Table 13 shows the types of adaptation actions missing from plans, which are grouped based on the National Climate Assessment regions.

Table 13. This table indicates the number of adaptation plans in each of the National Climate Assessment regions missing a given adaptation strategy type. The number in parenthesis below each of the NCA regions listed in the header represents the number of plans in the sample from each region. In each of the remaining boxes, the total number of plans that do not have a given strategy are identified, followed by the percentage of plans within each region that omit that given strategy in parenthesis. Note: Hawaii was not included as a region because no plans in our sample are from Hawaii. In addition, the NCA regions, rural communities and coasts, were not included as separate categories because using this classification would cause duplication with in the data. As such, only seven of the ten 2014 NCA regions were used for categorizing plans within our sample.

		NCA Region						
		Alaska (1)	Great Plains (5)	Midwest (4)	Northeast (17)	Northwest (2)	Southeast (5)	Southwest (9)
Strategy Types	Advocacy	0 (0%)	4 (80%)	3 (75%)	12 (70.5%)	2 (100%)	4 (80%)	7 (78%)
	Building Codes and Engineering Design Standards	0 (0%)	2 (40%)	4 (100%)	4 (24%)	1 (50%)	2 (40%)	4 (44%)
	Capacity Building	0 (0%)	0 (0%)	1 (25%)	5 (30%)	0 (0%)	0 (0%)	2 (22%)
	Education	0 (0%)	1 (20%)	2 (50%)	2 (12%)	0 (0%)	0 (0%)	1 (11%)
	Energy Conservation	0 (0%)	3 (60%)	1 (25%)	11 (64%)	2 (100%)	3 (60%)	4 (44%)
	Financing	0 (0%)	3 (60%)	1 (25%)	9 (53%)	1 (50%)	1 (20%)	2 (22%)
	Funding	0 (0%)	1 (20%)	3 (75%)	7 (41%)	1 (50%)	0 (0%)	4 (44%)
	Green Infrastructure	1 (100%)	1 (20%)	0 (0%)	5 (30%)	1 (50%)	0 (0%)	3 (33%)
	Land Use	0 (0%)	1 (20%)	1 (25%)	0 (0%)	0 (0%)	0 (0%)	1 (11%)
	Physical Infrastructure	0 (0%)	2 (40%)	0 (0%)	1 (6%)	0 (0%)	1 (20%)	1 (11%)
	Planning	0 (0%)	0 (0%)	1 (25%)	1 (6%)	0 (0%)	0 (0%)	0 (0%)
	Policy	0 (0%)	1 (20%)	1 (25%)	3 (18%)	0 (0%)	0 (0%)	1 (11%)
	Practice and Behavior	0 (0%)	0 (0%)	0 (0%)	2 (12%)	0 (0%)	0 (0%)	0 (0%)
	Research and Monitoring	0 (0%)	0 (0%)	1 (25%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
	Technology	0 (0%)	0 (0%)	0 (0%)	7 (41%)	0 (0%)	1 (20%)	1 (11%)
	Water Conservation	1 (100%)	1 (20%)	1 (25%)	14 (82.4%)	0 (0%)	2 (40%)	1
	Other GHG	0 (0%)	1 (20%)	2 (50%)	10 (59%)	2 (100%)	1 (20%)	5 (56%)

4.3 Implementation Guidance

Although adaptation plans in the sample include a large number and multiple types of actions, the limited attention to implementation raises questions about whether the proposed actions will translate into real world projects. Results showed that many of the plans lack details about actions that may be important for implementation; for example, only 51% of the plans in the sample discuss co-benefits. Cost is also rarely discussed; 44% of plans mention that the cost of inaction would be greater than the cost of preparing for climate change, but only 16% of plans provide the cost associated with implementing each identified action (Figure 11).

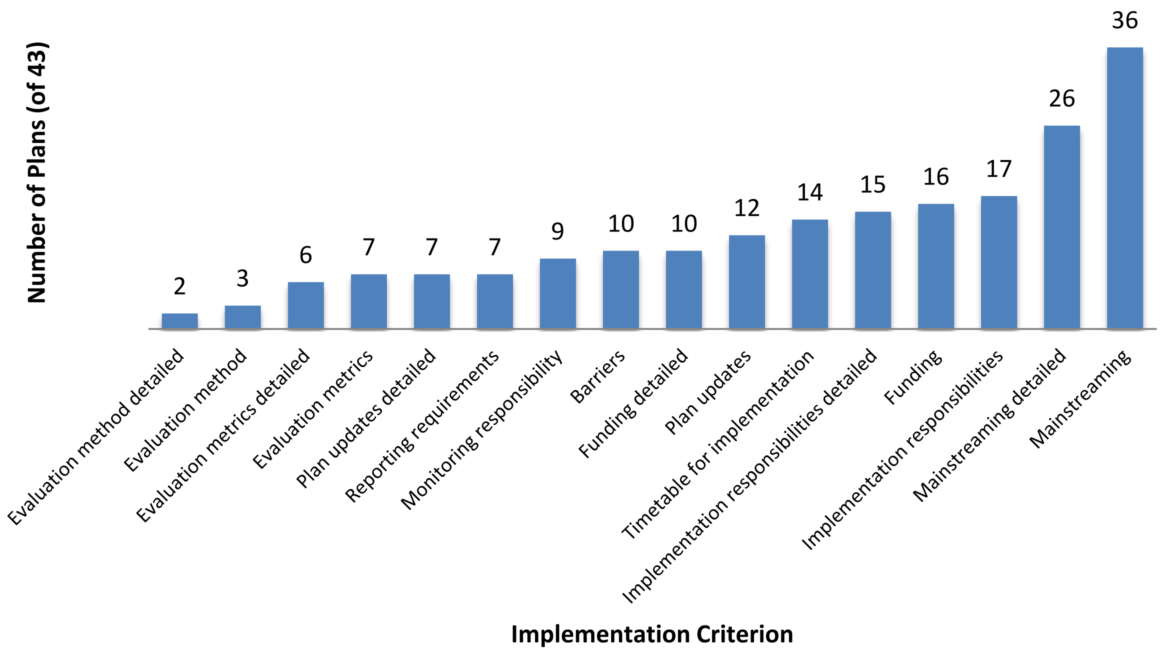


Figure 11. Number of plans containing each of the implementation criterion assessed.

Overall, plans perform poorly on all of the implementation and monitoring metrics. On average, plans within the sample contained only five of the 16 metrics deemed important in the literature to support implementation. Only two plans in the sample, Baltimore, MD and Waveland, MS, contained over 80% of the implementation metrics. Plans for Grand Rapids, MI and Milwaukee, WI had none of the implementation metrics, and seven plans (Oakland, CA; Dane County, WI; Fairbanks, AK; Santa Barbara, CA; Austin, TX; Worcester County, MD; and Salem, MA) contained only one of the 16 implementation metrics.

The most common implementation related information captured in plans was *mainstreaming*, the integration of climate adaptation into other sector policies or plans (Friend et al., 2013), which was found in 86% (36 of 43) of plans (Figure 11). These plans commonly provide specific guidance on how to integrate climate related considerations into other plans. No other implementation metrics were present in more than half of the plans. The least common implementation metrics were *evaluation methods* and *metrics*, which are intended to provide guidance on how to measure the implementation progress of the plan. Also infrequent across the plans was any discussion regarding when and how to report on plan implementation and update the plan (Figure 11).

5. Discussion

The variation in the types of actions included in plans indicates that communities have taken different approaches to planning for climate change. While this variation does limit one's ability to analyze and compare plans, it also suggests that adaptation plans are being tailored to the local context. Rather than just identifying regional climate impacts and proposing generic adaptation actions, communities are proposing actions to address their unique vulnerabilities and sectors of concern.

The breadth of action types included in plans may suggest that communities realize that they need a mixture of actions to prepare local services and sectors for climate related impacts. On the other hand, the identification of a variety of actions may be a "hedging" strategy (Woodruff and Stults, 2016) whereby communities are selecting a variety of actions in hopes that at least one of them will help reduce vulnerability. Regardless of the motivation, the variety of activities is promising, as it demonstrates that communities planning for climate change are looking to use their full range of authority to prepare.

Contrary to previous studies of local climate adaptation, results also suggest that communities are pursuing concrete or action-oriented actions as opposed to just capacity building actions. This is even true if research and monitoring, planning, advocacy, and education are grouped with capacity building to mirror the definition of capacity building presented by Tompkins et al. (2010). Doing this, we found that 1,439 of the 3,375 actions (just under 43%) are what Tompkins et al. consider capacity building. Conversely, the remaining 1,935 (57%) are non-capacity building actions, which, if implemented, could result in direct reductions in vulnerability. The prevalence of land use actions (338 total actions; 10%), which the hazard mitigation literature has highlighted as the most effective method for reducing vulnerability (Burby et al., 2000), is also encouraging. This move towards more concrete adaptation actions suggests that there is growing awareness of both the types of actions available to local governments, and the need to prioritize actions that can result in direct reductions in vulnerability.

Some adaptation actions, however, are still not widely used. For example, advocacy actions are included in only 11 of the 43 plans, but advocacy may be an important strategy for local governments to effect change. Local governments frequently cite federal and state laws and lack of authority as barriers to adaptation (Eisenack et al., 2014; Ekstrom and Moser, 2014), such as FEMA's policy of funding recovery to pre-disaster conditions. Since local governments have little direct ability to influence these policies, advocacy can be an important tool to ameliorate or lessen these barriers.

While it appears that communities are including the types of actions that have been recommended in the literature based on their regional climate impacts, *building codes* and *green infrastructure* are not as widely used as expected given the climate threats facing communities in the sample. In many states, local governments do not have the authority to change or adopt different building codes; this may partially explain their limited use. In these cases, local governments may be opting to use different types of actions to enhance the resilience of buildings and infrastructure, such as policies mandating that buildings be elevated to address flood risk or land use actions that limit development in disaster-prone regions. Conversely, the we posit that communities may not be aware of how building codes can help address climate related impacts such as wildfire or extreme heat.

Similarly, *green infrastructure* actions have traditionally been associated with stormwater management. Only recently has the potential of green infrastructure to address heat and air quality been explored (Larsen, 2015). While the green infrastructure actions identified suggest that green infrastructure is being used to address multiple impacts, some communities may still not be aware of the multiple benefits associated with green infrastructure, which could explain why it is not being prioritized. More research is needed, however, to confirm if this is true in practice.

In regards to the lack of implementation criteria, findings from this analysis are in alignment with previous plan evaluation studies (Berke et al., 2015; Lyles et al., 2014). Overall, the adaptation plans in the sample rarely included details that are theorized to be important in motivating implementation of plans, such as implementation responsibilities (40% of plans), timetables for implementation (33% of plans), and funding sources to support action implementation (23% of plans).

In addition to weak implementation details, plans also have weak monitoring components. To address the uncertainty associated with knowing exactly what future climate conditions will be, the adaptation literature emphasizes the need for iterative and flexible planning approaches that incorporate new information and lessons learned into future adaptation efforts (Quay, 2010). The omission of evaluation metrics and timelines for updating the plan raises additional questions about how flexible these plans are to changing climatic conditions.

6. Conclusion

Analyzing the actions in local adaptation plans is critical to improving understanding of what actions local communities are prioritizing to prepare for climate change. In addition, it can help state and federal agencies, foundations, and academics better support local governments in implementing adaptive actions. Using content analysis, this paper identified the actions and implementation details in 43 stand alone, local climate adaptation plans in the U.S. A grounded theory approach was then used to re-categorize actions to better understand what actions local communities are prioritizing to address projected climate impacts. In total, 3,375 discrete actions were identified and analyzed. On average, each of the plans in the sample included 93 actions from 12 of the 17 types profiled (median of 54). This breadth of actions suggests that communities are using their full range of authority to prepare for climate change. The number of action-oriented, concrete actions included in plans (as opposed to those focusing solely on capacity building) also suggests that there is growing awareness of the need to implement a variety of actions to reduce placed based vulnerability. Moreover, adaptation plans generally appear to include the type of actions recommended in the literature to address their projected climate impacts. These results suggest that adaptation planning is being tailored to local conditions and needs.

However, limited details about actions and weak implementation guidance raise concerns about whether plans will translate into on-the-ground action. The lack of monitoring details also indicates that plans may not be launching adaptive, iterative adaptation programs. Greater emphasis should be placed on these components in the next generation of climate adaptation plans.

Going forward, more research needs to be done to evaluate which actions are actually implemented in local communities and whether plan content influences action implementation. This includes determining whether implemented adaptation actions are in fact reducing vulnerability, meeting community goals, and ultimately creating more resilient communities.

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Chapter Five
Integrating Climate Change into Hazard Mitigation Planning: Opportunities, Constraints, and Real-World Examples[21]

1. Abstract

Over the last several decades, natural disasters in the United States have become more numerous and costly. Climate change threatens to further exacerbate this trend by increasing both the severity and duration of many natural disasters, ultimately leading to even greater costs in both human life and monetary resources. To prepare for these changes, a handful of local communities have integrated climate change into their Federal Emergency Management Agency approved hazard mitigation plans. This paper analyzes 30 U.S. local hazard mitigation plans against a conceptual framework for how climate change could be integrated into the requirements specified in the FEMA Plan Review Crosswalk, a checklist used by FEMA to evaluate and approve local hazard mitigation plans. Results show that the majority (23/30) of communities are openly discussing how climate change could affect or already is affecting the occurrence of natural disasters. Additionally, over half also include hazard mitigation actions that are designed to be viable in a climate-altered future. These actions, however, represent only a small portion of the total actions proposed in the plans and are generally focused on researching, planning, and capacity building. In addition, few communities include a formal commitment to adapting to climate change or include clear mechanisms for integrating new climate information as it is developed into plan revisions. In general, results from this analysis show that there is very little consistency in how communities are integrating climate change into hazard planning. These findings point to both the nascence of this practice and the opportunity to develop more formalized guidance that can steer communities towards holistic integration of climate change into hazard mitigation planning.

[21] This chapter is a modified version of an article currently under review for publication in the Journal of the American Planning Association

2. Introduction

The number of natural disasters is on the rise. Over the last sixty-three years for which reliable data exists, 59 disaster declarations, on average, have occurred in the United States annually (Federal Emergency Management Agency [FEMA], 2016a). Between 2006 and 2015, however, an average of 127 disasters were declared annually, with 242 declarations in 2011 alone (FEMA, 2016a). In addition, natural disasters are becoming more costly in terms of both human life and monetary resources. In 2015, there were 10 disasters in the U.S. with losses that exceeded $1 billion each: one drought, two floods, five severe storms, a wildfire, and a winter storm (National Centers for Environmental Information, 2016): these ten disasters were responsible for the deaths of 155 people. Of these disasters, seven ranked as among the costliest disasters worldwide, according to Munich RE (Munich Re, 2016). In contrast, between 1980 and 2015, the annual average number of billion dollar disasters was 5.2 (National Centers for Environmental Information, 2016). Looking forward, Cummins, Suher, and Zanjani (2010) estimate that the cumulative exposure of the U.S. government to disasters will continue to increase, rising to $7 trillion over the next 70 years.

Exacerbating the growing cost and number of natural disasters is the reality that the global climate is changing and, with these changes, the intensity, frequency, and duration of many natural disasters are likely to increase (Babcock, 2013; Mimura et al., 2014). While no single event can be definitively attributed to climate change, scientists agree that the current trend of more intense and frequent natural disasters is precisely what is expected in a climate altered future (Allen, 2006; Solecki, Leichenko, and O'Brien, 2011). In light of these factors, there has been a growing recognition of the need to integrate climate change considerations into natural disaster (i.e., hazard mitigation) planning.

There are a number of ways that local communities can plan for climate change, such as creating stand alone climate adaptation plans, embedding climate change into sustainability or climate plans, or embedding climate considerations into sector specific plans (e.g., water resource planning, wildfire planning) (Woodruff and Stults, 2016). Recently, a number of local governments have explored opportunities for embedding climate change into their multi hazard mitigation plans (Joyner and Orgera, 2014). While not yet required, these activities represent a policy innovation that can provide insight into how communities can meet existing FEMA requirements for pre-disaster mitigation planning while simultaneously ensuring that they are considering how climate change could affect future hazards. To date, no comprehensive assessment of these plans has been undertaken, leaving scholars and practitioners with little understanding of how to integrate climate change into hazard mitigation planning. This paper fills this void by answering two questions: 1) how could the existing Federal Emergency Management Agency hazard mitigation planning guidelines be best altered to integrate climate change, and 2) how are local communities currently integrating climate change into hazard mitigation planning?

To start, this paper briefly explores the history of hazard mitigation planning in the U.S., providing details about why hazard mitigation planning is being undertaken in over 80% of communities. This is followed by a description of the FEMA requirements communities must meet in order to have a federally approved hazard mitigation plan. Next is a brief discussion about what is known from existing studies of hazard mitigation planning, including details about the generalized strengths and weaknesses of local hazard plans. This is followed by a presentation of research methods, including the identification of numerous ways that climate change could be embedded into existing FEMA requirements. Next, results are presented that specifically describe how 30 communities in the U.S. have embedded climate change into their existing hazard mitigation plans and a discussion regarding what this tells us about the state of the practice. The paper concludes with recommendations for scaling up the integration of climate considerations into community hazard mitigation planning, identifying strategic opportunities as well as potential obstacles.

3. A Brief History of U.S. Disaster Legislation

In 1950, the United States Congress passed the first national legislation tied to federal disaster assistance: the Federal Disaster Assistance Program (Baca, 2008). This program authorized the federal government to respond to major disasters by providing financial relief to support disaster *response* by state and local governments. In this legislation, Congress passed the authority to provide federal disaster assistance from itself to the President, giving the President broad authority to decide "whether to provide disaster assistance and which federal agencies would provide the assistance" (Lindsay and McCarthy, 2015, p. 2). Prior to 1950, Congress provided disaster assistance on a case-by-case basis, which meant that for each disaster assistance request, the legislature had to meet, debate, and pass individual legislation authorizing a response (Baca, 2008; Lindsay and McCarthy, 2015).

In 1966 Congress passed another major piece of disaster legislation, the Disaster Relief Act, which expanded earlier legislation to allow federal disaster funds to be used for *recovery* as well as response (Baca, 2008). The Disaster Relief Act was adjusted again in 1970 and 1974, with both adjustments expanding the assistance the federal government could provide to states and local communities. The 1974 Disaster Relief Act also called upon the President to "establish a program of disaster preparedness using the services of all appropriate federal agencies" (United States Congress, 1974). To operationalize this requirement, in 1979 President Jimmy Carter created the Federal Emergency Management Agency (FEMA) and transferred "all the disaster related statutory authority that had been vested in the Presidency, or in other Federal agencies, to FEMA" (Baca, 2008, p. 1).

In 1988, primarily due to inefficiencies associated with the growing number of agencies involved in disaster response, Congress again amended the Disaster Relief Act through the passage of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (the Stafford Act) (Berke, Smith, and Lyles, 2012; Godschalk, 2003). The Stafford Act is the principal authority that currently governs federal assistance for emergencies and major disasters and dictates how FEMA operates (Lindsay and McCarthy, 2015). In addition, the Stafford Act created the foundation for a number of disaster recovery programs, including the Hazard Mitigation Grant Program (HMGP) (Schwab and Topping, 2010), which was created to: 1) prevent loss of life and damage to property due to disasters, 2) implement state or local hazard mitigation plans, 3) implement mitigation measures during immediate recovery from a disaster, and 4) provide funding for previously identified mitigation measures that benefit the disaster area. The major drawback of the HMGP is that it was structured to provide assistance following a major disaster declaration; thus it was a reactive program. According to Schwab and Topping (2010), "if mitigation funding is provided only after disasters, it cannot have the same preventative value as it would before a disaster" (p. 17).

Hazard mitigation is defined as "sustained action to reduce or eliminate long-term risk to human life and property from natural, human-caused, and technological hazards" (FEMA 2003).

In 2000, Congress addressed this concern in addition to the problem of the growing number of disasters and preventable disaster losses, through the passage of the Disaster Mitigation Act (DMA) (Berke and Godschalk, 2009; Burby and Dalton, 1994; Mileti, 1999; Schwab, 2010; Stevens, Berke, and Song, 2010). The DMA amended the Stafford Act in a number of ways, including “repeal[ing] the previous mitigation planning provisions and replac[ing] them with a new set of requirements that emphasize the need for State, local, and Indian Tribal entities to closely coordinate mitigation planning and implementation efforts” (FEMA, 2016b). Through this provision, the DMA provides the legal basis for FEMA’s mitigation planning requirements for state, local and tribal governments as a pre-condition for mitigation grant assistance. In addition, the DMA authorized up to 7% of hazard mitigation grant program funds to support the development of state, local, and tribal hazard mitigation plans. In summary, the DMA advanced hazard mitigation efforts in two important ways: “1) it required states and localities to prepare multi-hazard mitigation plans as a precondition for receipt of HMGP and other federal mitigation grants, and 2) it established a competitive Pre-Disaster Mitigation program providing for mitigation planning and project grants *before* disasters strike” (Schwab and Topping, 2010, p. 17).

The requirement to plan in advance of a hazard or disaster occurrence is one of the most notable advances of the DMA. This proactive approach to disasters is validated through a FEMA finding that for every dollar invested in hazard mitigation, four dollars of disaster losses were avoided (Multihazard Mitigation Council, 2005). As of the end of 2015, 22,706 communities representing 82.8% of the nation’s population had local mitigation plans that were FEMA approved or approvable pending adoption (FEMA, 2016c).

4. Local Hazard Mitigation Plan Requirements

To get a local hazard mitigation plan approved and thereby become eligible for mitigation grant funding, communities must adhere to strict requirements outlined by FEMA (Frazier, Walker, Kumari, and Thompson, 2013). These requirements are detailed in the FEMA Plan Review Crosswalk and the FEMA Local Hazard Mitigation Plan Review Guide (FEMA, 2013). The purpose of these guides, according to FEMA, is to “help Federal and State officials assess Local Mitigation Plans in a fair and consistent manner, and to ensure approved Local Mitigation Plans meet the requirements of the Stafford Act and Title 44 Code of Federal Regulations §201.6” (FEMA, 2013). The six elements required by FEMA in all local hazard mitigation plans are: A) documentation of the hazard mitigation planning process; B) hazard identification and a risk assessment; C) mitigation actions; D) details on plan review, evaluation, and implementation; E) details on plan adoption; and F) any additional requirements per each individual state (FEMA, 2013; Frazier et al., 2013; Godschalk, 2003) (Table 14).

Table 14. Requirements for local hazard mitigation plans per FEMA's Local Mitigation Plan Review Guide.

Elements	Sub-criteria
Element A: Planning Process	1. Does the plan document the planning process, including how it was prepared and who was involved in the process for each jurisdiction? 2. Does the plan document an opportunity for neighboring communities, local and regional agencies involved in hazard mitigation activities, agencies that have the authority to regulate development as well as other interests to be involved in the planning process? 3. Does the plan document how the public was involved in the planning process during the drafting stage? 4. Does the plan describe the review and incorporation of existing plans, studies, reports, and technical information? 5. Is there discussion of how the community(ies) will continue public participation in the plan maintenance process? 6. Is there a description of the method and schedule for keeping the plan current (monitoring, evaluating and updating the mitigation plan within a 5-year cycle)?
Element B: Hazard Identification and Risk Assessment	1. Does the plan include a description of the type, location, and extent of all natural hazards that can affect each jurisdiction? 2. Does the plan include information on previous occurrences of hazard events and on the probability of future hazard events for each jurisdiction? 3. Is there a description of each identified hazard's impact on the community as well as an overall summary of the community's vulnerability for each jurisdiction? 4. Does the plan address National Flood Insurance Program (NFIP) insured structures within the jurisdiction that have been repetitively damaged by floods?
Element C: Mitigation Strategy	1. Does the plan document each jurisdiction's existing authorities, policies, programs and resources and its ability o expand on and improve these existing policies and programs? 2. Does the plan address each jurisdiction's participation in the NFIP and continued compliance with NFIP requirements, as appropriate? 3. Does the plan include goals to reduce/avoid long-term vulnerabilities to the identified hazards? 4. Does the plan identify and analyze a comprehensive range of specific mitigation actions and projects for each jurisdiction being considered to reduce the effects of hazards, with emphasis on new and existing buildings and infrastructure? 5. Does the plan contain an action plan that describes how the actions identified will be prioritized (including cost benefit review), implemented, and administered by each jurisdiction? 6. Does the plan describe a process by which local governments will integrate the requirements of the mitigation plan into other planning mechanisms, such as comprehensive or capital improvement plans, when appropriate?
Element D: Plan Review, Evaluation, and Implementation	1. Was the plan revised to reflect changes in development? 2. Was the plan revised to reflect progress in local mitigation efforts? 3. Was the plan revised to reflect changes in priorities?
Element E: Plan Adoption	1. Does the plan include documentation that the plan has been formally adopted by the governing body of the jurisdiction requesting approval? 2. For multi-jurisdictional plans, has each jurisdiction requesting approval of the plan documented formal plan adoption?
Element F: Additional State Requirements	1. Any additional requirements as mandated by each individual state. This section will only be completed by state reviewers and not by FEMA.

FEMA's requirements for hazard plans are highly structured, but there is some flexibility in how communities achieve each of the required elements. For example, the planning process element (Element A) notes that "the planning process shall include an opportunity for the public to comment on the plan during the draft stage and prior to plan approval" (44CFR 201.6(b)(1)) (FEMA, 2013). These guidelines do not specify how to engage the public, so communities have the flexibility to undertake locally appropriate stakeholder engagement efforts.

Approval of local hazard mitigation plans is required by both the state hazard mitigation office and by FEMA (FEMA, 2013). First, the state hazard mitigation officer must review and approve the local plan. Once the plan is approved, the state forwards it to the appropriate regional FEMA office for additional review and approval (FEMA, 2013). The state is responsible for all coordination with local governments, including sharing the results from FEMA's formal review (FEMA, 2011a). If the state or FEMA determines that the proposed hazard mitigation plan fails to meet certain requirements, a list of required revisions is generated by FEMA and sent back to the local jurisdiction for revision. If these revisions are not made within one year, the plan must undergo a full re-review. However, if the required revisions are made within the year, FEMA will review only the required changes (FEMA, 2013).

In order to maintain eligibility for FEMA hazard mitigation project grant funding, local hazard mitigation plans must be updated at least every five years (FEMA, 2013). As part of these updates, a local jurisdiction must "review and revise its plan to reflect changes in development, progress in local mitigation efforts, and changes in priorities…" (FEMA, 2011b, p. 3). Local governments are allowed to work together on a regional or multi-jurisdictional plan (often done at the county level), as long as each community has its own hazard mitigation actions (Lyles, 2012). In addition, each community that seeks FEMA approval must formally adopt the completed hazard mitigation plan, regardless of whether it is a local or multi-jurisdictional plan (Schwab, 2010).

5. Hazard Mitigation Plan Content

Analyses of hazard mitigation plans find that they regularly include substantive citizen participation, have strong identification and prioritization of hazards, use the best available data on hazards from state and federal sources, conduct methodologically strong vulnerability analyses, and adopt mitigation measures that will respond to the community's hazard profile (Lyles, Berke, and Smith, 2014; Schwab and Topping, 2010; Stevens et al., 2010). However, studies regularly find that hazard mitigation plans consistently fail to identify future land-use and development trends and how they could affect hazards and risk, have little linkage to other local plans that have regulatory teeth, and generally include a list of un-prioritized mitigation actions that are dominated by emergency response and preparedness actions – not mitigation actions (Lyles, Berke, and Smith, 2012; Lyles et al., 2014; Schwab and Topping, 2010).

Regarding the specific types of actions included in hazard plans, studies find that they tend to have a strong emphasis on structural preparedness such as flood defenses, use of culverts, and enhanced building codes (Babcock, 2013; Berke et al., 2012; Burby, Deyle, Godschalk, and Olshansky, 2000; Travis, 2010). Some recent work shows that non-structural actions such as changes in policy and the use of natural systems to lessen the impact of hazards on human systems are beginning to emerge in local hazard plans (Abt 2016; Berke et al., 2015). Overall, however, the actions promoted by the hazards community rarely emphasize issues pertaining to *adaptive capacity enhancement*, the use of *green infrastructure* to manage risk, or *land-use* actions (Committee on Increasing National Resilience to Hazards and Disasters, 2012; Kates, Travis, and Wilbanks, 2012; Lyles et al., 2014; Olshansky and Kartez, 1998).

Additional studies on hazard mitigation plans find a strong emphasis on emergency response as opposed to proactive hazard mitigation (Frazier et al., 2013; Kapucu, 2012; Lyles, 2012). Emergency response actions commonly identified in local hazard mitigation plans include updating emergency operations centers, buying generators, creating disaster warnings, and generally improving emergency response capabilities (Lyles, 2012). This disconnect between what should be included in hazard mitigation plans based on FEMA’s intent when mandating them (FEMA 2011b; FEMA 2013) and what is included raises concerns about how well these plans are preparing communities for future hazards. More specifically, questions have been raised about whether hazard mitigation efforts proactively translates into safer, better prepared, and more resilient communities (Berke et al., 2015; Schwab and Topping, 2010).

6. Climate Change and Natural Hazards

In principle, hazard mitigation plans should create roadmaps for increasing a community’s preparedness and resiliency in the face of hazards (Berke et al., 2012; FEMA, 2013; Highfield and Brody, 2013). More commonly, research shows that communities and states undertaking hazard mitigation planning strive to meet the minimum requirements set by FEMA and often overlook critical issues and actions that could protect against future harm (Frazier et al., 2013; Lyles et al., 2012). As noted by Frazier et al. (2013), "minimum requirements, as stipulated by the Disaster Mitigation Act of 2000, are all that is needed to qualify for federal mitigation grant funding regardless of plan quality or appropriateness of HMPs to local hazards and risks" (p. 52). Issues such as the integration of socio-economic vulnerability factors, the consideration of future changes in climate, and interactive stakeholder engagement approaches are not specifically required by the DMA, and therefore FEMA does not use these criteria to evaluate hazard mitigation plans (Babcock, 2013; Cutter et al., 2008; Solecki et al., 2011). As a result, these topics are frequently omitted from hazard mitigation plans and planning processes (Babcock, 2013).

In light of these limitations and the reality that natural disaster incidences are on the rise due to climate change (Berke, Lyles, and Smith, 2014; IPCC, 2014), FEMA recently passed updated guidance that requires states to consider climate change during their hazard mitigation planning (FEMA, 2015). This requirement is not legally binding for local communities. However, some states are beginning to require or strongly encourage their municipalities to think about climate change during hazard planning. For example, in October of 2015, the State of California passed Senate Bill 379 requiring that all municipalities within the state consider climate change when drafting their hazard mitigation plans. No California municipalities have submitted SB379 compliant plans yet. As they work to update their existing plans, there is a clear need to understand how to effectively consider climate change in hazard mitigation planning. This will ensure that municipalities are creating State and FEMA approvable plans—plans that will ultimately help them prepare for a climate-altered future.

7. Methods

The most recent hazard mitigation plans for every local United States community known to have a stand alone climate adaptation plan (44 plans based on the sample used in Woodruff and Stults, 2016), was compiled. This sample was chosen because communities with a stand alone climate adaptation plan have, presumably, gone through a detailed process to understand how climate change could affect their community. Going through this process sheds insight into how natural disasters are and will continue to change. Because of this, I expect that communities with a stand alone climate adaptation plan will be more likely to embed climate considerations into their hazard mitigation plan because they are aware of the strong likelihood that climate change will increase the frequency, intensity, and duration of natural disasters.

When the community itself did not have a hazard mitigation plan, the hazard mitigation plan for its county was acquired. If no plan could be found for the community or the county, the community was removed from the sample. In total, 35 plans[22] were compiled: 27 plans specifically for the target local community, 6 plans for the county that the target municipality resides in (Cococino County's plan for Flagstaff, AZ; Kent and Ottawa Counties' plan for Grand Rapids, MI; Marquette County's plan for Marquette, MI; Charlotte County's plan for Punta Gorda, FL; San Diego County's plan for Chula Vista, CA; and Santa Barbara County's plan for the City of Santa Barbara, CA), and 2 plans that are annexes of a county or regional plan (Oakland, CA and Groton, CT) (Table 15).

Table 15. Name of community (column one) and title of community hazard mitigation plan included in sample (column two). Column three denotes the date of each plans publication.

Name of Community	Name of Plan	Date of Plan Publication
Anne Arundel County, MD	Anne Arundel County, Maryland -- 2012 Hazard Mitigation Plan Update	2012
Austin, TX	City of Austin Hazard Mitigation Plan Update	2010
Baltimore, MD	City of Baltimore Disaster Preparedness and Planning Project: A combined all hazards mitigation and climate adaptation plan	2013
Boston, MA	City of Boston Natural Hazard Mitigation Plan: A component plan of Boston's Comprehensive Emergency Management Program	2015
Boulder County, CO	Hazard Mitigation Plan	2014
Chula Vista, CA	San Diego County Hazard Mitigation Plan Update	2016
Dane County, WI	Dane County Multi-Hazard Mitigation Plan	2009
Denver County, CO	Denver Regional Natural Hazard Mitigation Plan	2010
Durham, NH	Durham Multi-Hazard Mitigation Plan 2012 Update	2012
Fairbanks, AK	A Multi-Hazard, Multi-Jurisdictional Plan for the Fairbanks North Star Borough and its Communities	2014
Flagstaff, AZ	Coconino County Multi-Jurisdictional Hazard Mitigation Plan	2010
Fresno County, CA	Fresno County Multi-Hazard Mitigation Plan	2009
Grand Rapids, MI	Hazard Mitigation Plan for Kent and Ottawa Counties	2012
Groton, CT	Hazard Mitigation Plan Update: Annex for the Town of Groton	2013
Guilford, CT	Town of Guilford Natural Hazard Mitigation Plan	2012
Keene, NH	City of Keene, NH Hazard Mitigation Plan Update	2012
Lafourche Parish, LA	Lafourche Parish Hazard Mitigation Plan Update	2010
Laguna Woods, CA	City of Laguna Woods Local Hazard Mitigation Plan	2013
Lee County, FL	Joint Unified Local Mitigation Strategy for Lee County, Florida	2010
Lewes, DE	The City of Lewes Hazard Mitigation and Climate Adaptation Action Plan	2011
Los Angeles, CA	City of Los Angeles Hazard Mitigation Plan	2011
Marquette, MI	Hazard Mitigation Plan: County of Marquette	2015
Miami-Dade County, FL	Local Mitigation Strategy: Miami-Dade County	2012
Milwaukee, WI	City of Milwaukee All Hazards Mitigation Plan	2012
Missoula County, MT	Pre-Disaster Mitigation Plan: 2011 Update	2011
New York City, NY	2014 New York City Hazard Mitigation Plan	2014
Oakland, CA	Annex to 2010 Association of Bay Area Governments Local Hazard Mitigation Plan: Taming Natural Disasters	2010
Portsmouth, NH	City of Portsmouth, NH Hazard Mitigation Plan Update 2010	2011
Punta Gorda, FL	Local Mitigation Strategy 2010: Charlotte County and the City of Punta Gorda	2010

[22] Hazard mitigation plans could not be found for Albany, NY; Chester, PA; Confederated Salish and Kootenai Tribe; Dorchester County, MD; Jamestown S'Klallam Tribe; Seabrook, NH; Somerset County, MD; and Swinomish Tribe.

Salem, MA	City of Salem Hazard Mitigation Plan 2011 Update	2011
San Luis Obispo County, CA	San Luis Obispo County Local Hazard Mitigation Plan	2011
Santa Barbara, CA	2011 Santa Barbara County Multi-Jurisdictional Hazard Mitigation Plan	2011
Santa Cruz, CA	City of Santa Cruz Local Hazard Mitigation Plan	2012
Waveland, MS	City of Waveland Local Hazard Mitigation Plan	2013
Worcester County, MD	Worcester County Hazard Mitigation Plan Update	2014

Next, the FEMA Crosswalk was reviewed and potential ways that climate change could be integrated into each step were identified. This was done by reviewing the FEMA planning guidance associated with each step in the Crosswalk as well as FEMA hazard mitigation plan evaluation criteria, and determining different ways that climate change could be integrated into each step. Care was taken to ensure that proposed edits maintained the main goal/objective of each of the various steps within the Crosswalk.

In total, 21 general and specific ways to integrate climate change throughout hazard mitigation planning, based on the requirements outlined in the FEMA Crosswalk, were identified. This list was reviewed by a FEMA liaison from Region IX to ensure that the proposed criteria: 1) covered all obvious ways to integrate climate change into hazard mitigation plans, 2) included nothing that would cause FEMA to reject a hazard plan, and 3) were all feasible. A small number of edits were recommended through this review, which were all integrated into an updated list of proposed ways to integrate climate change into local hazard mitigation plans.

Next, a coding protocol was developed that used the 21 aforementioned ways to integrate climate change into hazard mitigation planning as the coding criteria. All criteria were grouped into the five required elements of hazard mitigation planning: A) Planning Process; B) Hazard Identification and Risk Assessment; C) Mitigation Strategy; D) Plan Review, Evaluation, and Implementation; and D) Plan Adoption (Appendix 9).

The 21 criteria are intended to represent a holistic and comprehensive way in which communities could embed climate change into hazard planning. This means that the criteria are mutually exclusive of one another with two exceptions:

1. A community would not be expected to evaluate climate change as a stand alone hazard ***and*** consider how climate change could affect all other hazards.
2. The "*discussion of how climate change could affect each hazard in the community*" criterion was affiliated with two FEMA Crosswalk requirements: "Does the plan include a description of the type, location, and extent of all natural hazards that can

affect each jurisdiction?" and "Is there a description of each identified hazard's impact on the community as well as an overall summary of the community's vulnerability for each jurisdiction?"

Next, the coding protocol was applied to the 35 plans in the sample. *NVivo version 10* qualitative analysis software package was used to link content from each of the plans to the relevant coding criteria (QSR International Pty Ltd, 2012). In addition, each plan was searched for any of the following key phrases: '*climat*', '*warm*', '*prepar*', '*sea level*', '*flood*', '*heat*', '*adapt*', '*resilien*', '*sustain*', '*inaction*', and '*future*'. If these phrases were found, the surrounding text was read to assess if the content was referring to climate change. If yes, the text was coded into the relevant criteria. Doing both a thorough read-through of each plan and a "spot-check" using the key words identified above ensured that all relevant climate related text was identified.

Once all plans had been analyzed, descriptive statistics were run to determine the criteria most frequently incorporated into plans, the average number of criteria per plan, and the percentage of total plans that contained each criterion.

8. Results

Of the 35 plans in the sample, 30 included at least one of the climate related criteria in the coding protocol. The five plans that did not include any climate related criteria were Coconino County, AZ; Denver County, CO; Grand Rapids, MI; Lafourche Parish, LA; and Missoula County, MT. Of the 30 remaining plans, each averaged just over one quarter of the climate related criteria from the coding protocol (27.6%). Baltimore, MD included the most criteria, 18/21 (86%), omitting only *climate change considered as a stand alone hazard, discussion of progress in implementing previously identified climate related hazards*, and *regional climate related entitles included in planning process*. Boston, MA's plan included 13 of the 21 criteria (62%), and Lewes, DE's and Miami-Dade County, FL's plan included 12 out of the 21 criteria (57%). No other plan included more than 50% of the possible criteria.

Four plans in the sample included only a single criterion: Durham, NH; Fresno County, CA; Lee County, FL; and Los Angeles, CA. Two plans included only two criteria (Anne Arundel County, MD and Portsmouth, NH), and four plans included only three criteria

(Fairbanks, AK; Milwaukee, WI; Punta Gorda, FL; and Salem, MA). There was no consistency across these plans regarding which criteria were included.

The most common criterion was a *general discussion about climate change and natural hazards*, which was found in 23 of the 30 plans that included at least one climate related criterion (76.7%). This most often took the form of a short description of how climate change could affect a single natural hazard of concern. For example, Durham, NH's plan states:

> "With extreme variation in environmental conditions due to global warming possibly on the rise, drought probability may grow in the future. Currently, drought possibility seems moderate. The large amount of water resources and relatively sparse population in New Hampshire have tended to minimize the impacts of drought events in the region, but this regional protection may be endangered in the future with increases in drought frequency or severity" (Strafford Regional Planning Commission, p. 25).

Another approach used by communities that included the criterion a *general discussion about climate change and natural hazards* was a discussion about the relationship between climate change and changes to the overall intensity and frequency of natural hazards within the introduction to the plan. For example, within the introduction to San Luis Obispo County, CA's plan are the remarks: "Data gathered by NASA and NOAA indicate that the Earth's average surface temperature has increased by about 1.2 to 1.4^{o}F in the last 100 years…This warming trend may well have an impact on the naturally occurring hazards in San Luis Obispo County" (p. 23).

The second most common criterion across all plans was the inclusion of *actions that are specifically designed to be viable in a climate altered future* (16/30 plans; 53%). To receive this code, actions had to be specifically labeled as being viable in a climate altered future or include a description that indicates their climate value. For example, Worcester County, MD's plan included a single action in this category: "Engage county and municipal decision makers in identifying hazards and climate change issues and make connections to existing planning and policy efforts" (S and S Planning and Design, p. 101). The City of Austin, TX's plan included five actions that were explicitly identified as providing hazard mitigation and climate adaptation value: 1) Develop a study to determine the relationship between infectious disease and climate change, 2) Develop a geospatially coded tool that will allow users to use climate related environmental public health indicator surveillance to plan and prioritize environmental management decisions and policy changes related to climate change…, 3) Develop a study to determine the relationship between allergies and climate change, 4) Increase tree plantings along public rights of way to reduce the Urban Heat Island effect, and 5) Complete a study for the Capitol Metropolitan region to downscale US climate change models to show climate change impacts expected in our region (H2O Partners, 2010).

Of the 16 plans that included *actions that are specifically designed to be viable in a climate altered future,* 11 included actions focused on research and monitoring as well as actions focused on planning for climate change. For example, San Diego County's hazard mitigation plan includes the following planning action: "incorporate objectives and policies that address sea level rise into updates to the General Plan and related implementation documents" (p. 156). It also includes this research and monitoring action: "Update and adopt Local Coastal Program to include assessment of impacts and vulnerabilities associated with sea level rise…" (p. 133). Ten plans included actions focused on capacity building, including actions such as convening a preparedness task force (Boston, MA and Marquette County, MI) and working with regional colleagues to share climate information and coordinate adaptation action (Miami-Dade County, FL and San Diego County, CA). Only two plans included actions focused on energy conservation (Baltimore, MD and San Luis Obispo County, CA) or water conservation (Baltimore, MD and Santa Cruz, CA) as an adaptation action.

The least common criterion found in plans was *a formal commitment to climate adaptation* as indicated in an opening letter made by an elected official or the inclusion of climate language in the plan approval documentation (found only in Baltimore, MD's plan). Commitment to climate adaptation, however, may actually be more pervasive than indicated in the coding results, as formal adoption of a hazard mitigation plan by a local elected body is a requirement of FEMA plan approval. Thus, the fact that these plans were approved may be a better proxy of political commitment to climate adaptation than the above-mentioned criterion.

Only one plan in the sample included a *plan to integrate new climate information, as it's developed, into plan and accompanying actions* (Baltimore, MD). Also infrequent was any discussion of *regional climate initiatives* or *the evaluation of and identification of mitigation actions for structures in the 1 in 500 year (or greater) floodplain*, which were both found in 3 out of the 30 plans that included climate change criteria (10%). This suggests that communities at the vanguard of integrating climate change into hazards planning still have significant opportunities to ensure that they are preparing for existing as well as future hazards.

9. Discussion

Hazard mitigation strives to reduce future disaster related losses through proactive planning and action. To guide planning, FEMA has outlined specific steps that must be taken (e.g., public participation), as well as specific content that must be included (e.g., risk assessment) in any hazard mitigation plan seeking FEMA approval. Given that FEMA approval is a pre-requisite for pre-disaster mitigation funding, the number of communities seeking to develop approvable hazard mitigation plans continues to grow (Berke et al., 2014).

Part of the impetus for the growth in hazard mitigation planning may also be the fact that in the last several years the number and intensity of natural disasters has risen. Some of this rise is likely due to people living in more dangerous places (e.g., coasts), and some is likely attributable to natural climate variability (e.g., El Nino Southern Oscillation). It is also very likely that climate change is a leading factor in explaining this increase in intensity, duration, and return frequency of natural disasters (Intergovernmental Panel on Climate Change, 2012). If so, hazard mitigation planners should no longer use historical disaster information as a foundation for planning for future disasters, but instead must find ways to integrate projections of future climate change into their hazards planning.

Research discussed in this paper shows that a handful of communities have successfully integrated climate change into their hazards planning. This work is unfolding in a variety of ways, with the most common approach being a *general discussion about how climate change will impact the future occurrence of one or more hazards*. Of the 30 plans that included climate considerations, 23 included at least a general discussion about climate change and future natural hazard occurrences. This suggests that communities in the sample are, in general, aware that climate change will affect how natural disasters occur in the future. Given that the sample includes only communities that, in addition to having a hazard mitigation plan, also have a stand alone climate adaptation plan, this result is not surprising.

It is surprising that some communities with a stand alone climate adaptation plan have not integrated climate change into their hazard mitigation planning. Five communities, Coconino County, AZ; Denver County, CO; Kent and Ottawa Counties, MI; Lafourche Parish, LA; and Missoula-County, MO, made no mention of climate change in their hazards plan. In these cases, climate change may have been omitted because none of the stakeholders involved in preparing the community's hazard mitigation plan were the lead or supporting authors of the climate adaptation plan. Another factor may be that, with the exception of Missoula County, these communities created their adaptation plans after the approval of their most recent hazard mitigation plans. This may mean that the community did not have a thorough understanding of climate related impacts to natural hazards when drafting their most recent hazard plan. If true, one would expect that the next hazard mitigation plan update for each of these communities will include some mention of climate change. In all five communities, an update to the hazard mitigation plan is either late or imminent: updates for Denver County, Coconino County, and Lafourche Parish were due in 2015; updates for Missoula County are due in 2016; and updates for Kent and Ottawa County are due in 2017.

A promising finding is that over half of the communities in the sample appear to be selecting some actions that will be viable in a climate-altered future. While most plans included only a small number of climate specific actions (an average of 6 per plan), the fact that communities are deliberately prioritizing actions that will prepare them for a climate altered future suggests that they may be preparing for more aggressive climate action. It is also surprising that the climate specific actions selected for inclusion in plans in this sample differ from the types of actions traditionally found in hazard mitigation plans (Berke, et al., 2015; Frazier et al., 2013; Fu and Tang, 2013; Stevens et al., 2010). Previous hazard mitigation studies found a preponderance of actions focused on physical infrastructure and emergency response. The climate adaptation actions found through the research presented in this paper focus on researching climate related changes and relevant impacts as well as undertaking more holistic climate planning. Additionally, 10 plans included capacity building actions, which have not been previously found to be a dominant type of strategy within hazard mitigation plans (Berke et al., 2015; Frazier et al., 2013). This finding may suggest that communities realize that capacity building is an important component of preparing for climate change, even if it is not a frequently promoted technique in the disaster literature.

Regarding the inclusion of *actions viable in a climate-altered future*, it is important to acknowledge that the coding protocol may have prevented the identification of other climate-relevant actions. For example, to receive the actions code, communities had to explicitly label mitigation actions as being viable in a climate altered future or include a description that indicates that the action had climate adaptation value. If a community did not explicitly state either of these things, then the action was not captured during coding. This conservative coding approach means that it is very likely that these plans include more actions that will help communities prepare for climate change. Since the intent of this research was not to interpret the meaning or intent behind each action, the coding protocol provided a consistent way of examining each plan. In the future, this analysis could be combined with interviews or stakeholder engagement approaches to more explicitly understand how and why certain actions were included in the final hazard mitigation plan.

Another notable variation between the results of this study and what may really be happening on the ground is the lack of formal commitment to climate adaptation as determined based on coding results. Since all communities in the sample have locally approved hazard mitigation plans, this suggests that local elected bodies either were aware of or indifferent to the municipality's decision to integrate climate change concerns into the local hazard mitigation plan. Therefore, even though only one plan in the sample included explicit language from an elected official about the need to prepare for climate change (Baltimore, MD), it is possible that many—if not all—of the other plans had an implicit commitment to climate adaptation since these elected bodies formally approved each of the plans in the sample. Whether or not this commitment to climate adaptation still exists, however, remains unknown and is therefore an area for future research.

The finding that, on average, each plan contains only a quarter of the possible ways to integrate climate change into hazard mitigation planning suggests that this practice is in its infancy. This finding is further validated by the fact that only four plans (Baltimore, MD (18/21 approaches); Boston, MA (13/21 approaches); Lewes, DE (12/21 approaches); and Miami-Dade County, FL (12/21 approaches)) used more than half of the approaches for integrating climate change into their hazard plans. Moreover, all four communities explicitly set out to integrate climate change into their hazards planning, which means that they were openly working with stakeholders and elected officials to ensure that they were simultaneously planning for climate change and natural disaster occurrences.

The fact that these vanguard communities were unable to fully integrate climate change into hazards planning suggests that there is room for more guidance, engagement, and assistance in fully embedding climate considerations into hazards planning. One important possibility is the creation of formal guidance from FEMA outlining the various mechanisms that local communities can use to integrate climate change into their planning. This would also necessitate the training of regional FEMA staff responsible for reviewing and approving local hazard mitigation plans. The adjusted FEMA Crosswalk presented in this paper (Appendix 9) could become the foundation for this guidance.

Finally, this research suggests that communities still have significant work to do to prepare for climate impacts that cut across geopolitical boundaries. For example, only 3 of the 30 plans had any discussion of the need for or existence of *regional climate initiatives*. Since climate change will create impacts that cut across political boundaries (Adger et al., 2011; Dessai and Hulme, 2007; Preston, Westaway, and Yuen, 2010), it is imperative that communities plan for and collaborate with their neighboring jurisdictions to ensure that the community and the larger region are cooperating in building resilience to climate change and natural disasters.

In recent years, FEMA has openly discussed the importance of integrating climate change into hazards planning. In January 2012, the agency released a climate adaptation policy statement, which created an "Agency-wide directive to integrate climate change adaptation planning and actions into Agency programs, policies, and operations" (FEMA, 2011a, p. 1). More recently, the agency passed guidance that requires states to consider climate change in their hazard mitigation planning (FEMA, 2015). While this requirement is not relevant to local municipalities, it is likely that FEMA or the states will begin strongly encouraging local communities to consider climate change when developing or updating their hazard mitigation plans. For those plans to succeed, however, FEMA and state agencies will need to ensure that communities have the information, guidance, and tools needed to support their efforts to prepare for future disasters.

10. Conclusion

In creating the Disaster Mitigation Act of 2000 (DMA), the federal government took a more proactive approach to disasters by encouraging pre-disaster planning and making available pre-disaster preparedness grants for states, tribes, and local communities (Schwab, 2010). Following the passage of the DMA, the number of local communities planning in advance of a disaster increased rapidly, with more than 82% of the U.S. population currently residing in a community with a hazard mitigation plan (FEMA, 2016c). Despite this laudable progress, the DMA still encourages reactivity due to its requirement that communities use previous occurrences of hazards as a foundation for estimating the probability of future hazard events. In practice, this means that communities are using past events to predict the future. Because climate change is altering the frequency, intensity, and duration of nearly all natural hazards, this approach may leave many communities ill prepared for future disasters.

To remedy this, local communities need to integrate information about projected changes in climate into their hazard mitigation planning. Communities must therefore understand how climate change could affect the future occurrence of natural hazards by strengthening existing natural hazards and potentially introducing new hazards. Hazard mitigation planning must also engage nontraditional stakeholders such as experts in climate science, local organizations working on climate mitigation and adaptation, regional organizations, and the most vulnerable residents.

Fortunately, a number of communities are beginning to integrate climate change into their hazard mitigation planning. These vanguard communities provide important insight into what can be done within the current planning domain, as well as insight into opportunities for rapidly scaling up how communities think about and prepare for disasters in a climate altered future. The lessons learned from this research suggest that communities are just beginning to integrate climate change into hazards planning. This means that a significant opportunity exists to provide structured guidance and flexible tools to allow each community to find the right mix of approaches for embedding climate change into their hazards planning. FEMA has a significant role to play in guiding this work, as do scholars and applied researchers. The adjusted FEMA Crosswalk presented in this paper (Appendix 9) provides a starting point for identifying opportunities for integrating climate change into hazards planning. Hopefully this becomes a tool taken up by FEMA, State Hazard Mitigation Officers, and local planners as they seek to create more disaster and climate resilient communities.

If FEMA cannot use the adjusted Crosswalk presented in this paper, then the organization should identify alternative mechanisms for rewarding or incentivizing communities to voluntarily integrate climate considerations into their planning. One idea is to provide a category for "bonus points" within the Crosswalk. Communities that consider climate change during their hazard planning could receive credit within this bonus category, which would help them to achieve FEMA plan approval.

Another option is the creation of tiers for evaluating hazard mitigation plans. For example, plans that meet the bare minimum would receive a bronze rating. Those that go above and beyond would receive a silver, gold, or platinum rating, depending on how much additional work and information are included in the analysis. Communities scoring in these higher categories could be eligible for additional pre-disaster grants. While a tiered evaluation structure would require more initial work from FEMA, it has the potential to stimulate local communities to create strong and comprehensive hazard mitigation plans that may have a greater likelihood of being implemented. In the end, an approach such as this, especially if paired with information provided in the adjusted FEMA Crosswalk (Appendix 9), could significantly aid in scaling up the number of communities planning for natural disasters in a climate altered world.

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Chapter Six
Conclusions

1. Review of Goals

Climate change is upon us, and nowhere are the impacts being felt more dramatically than at the local level. In the face of this reality, a handful of U.S. local governments have initiated climate adaptation planning processes that detail how they could be vulnerable to projected changes in climate and what actions they propose undertaking in order to prepare. This effort, however, is still nascent, with just over 40 communities having stand alone climate adaptation plans. This dissertation looks at the details associated with these adaptation plans, exploring areas of strength and areas where improvements are needed. Guiding this work are four interrelated questions:

1. How do existing climate adaptation plans align with emerging principles of plan quality? What community attributes are associated with high quality plans?
2. How are U.S. local communities framing uncertainty in their climate adaptation planning? What approaches are local communities using to address uncertainty in their climate adaptation planning?
3. What are U.S. local governments planning to do to prepare for climate change? How do these actions align with the risks or vulnerabilities faced by these local governments? Do local governments provide detail to support the implementation of the actions they identify?
4. How could the existing Federal Emergency Management Agency local hazard mitigation planning guidelines be altered to integrate climate change? How are local communities currently integrating climate change into hazard planning?

In the next section, the major findings and contributions from this work are reviewed. This is followed by several recommendations for both scholars and practitioners working to create more climate adapted local communities.

2. Major Findings and Contributions

As has been argued throughout this dissertation, the global climate is changing and these changes are leading to an array of impacts across scales and sectors of the United States. In light of this, a growing number of scholars and practitioners are calling for more stakeholders, including local communities, to create plans that outline how they are vulnerable to climate change and what actions they propose taking to build their resilience or, at a minimum, reduce their vulnerability. In 2007 this call was answered by the City of Keene, NH, which created the first ever stand alone local climate adaptation plan. Since that time, more than 40 other local communities have created stand alone climate adaptation plans and potentially hundreds more have embedded climate concerns or adaptation actions into other planning processes (e.g., master plans, comprehensive plans, climate mitigation plans, or sustainability plans). These efforts may represent a significant step forward in preparing locally for climate impacts. However, the full effect of these plans cannot be determined without a critical analysis of their content, quality, and the processes used to create them.

The intent of this dissertation was to provide this critical analysis by looking holistically and comprehensively at the content and quality of all publicly available local, stand alone climate adaptation plans in the United States. To do this, Chapter 2 begins by discussing the findings from a plan quality analysis of 44 local, stand alone climate adaptation plans from U.S. communities. This work builds upon more than 20 years of plan quality research undertaken primarily by planning scholars looking at the quality of hazard mitigation plans (e.g., Lyles et al., 2012; Berke et al., 2014; Stevens et al., 2010). This scholarship was added to through the creation of new metrics related to the concept of uncertainty and by adding a variety of metrics built upon concepts promoted within the climate change literature (e.g., transformative versus incremental adaptation). Integrating these new concepts with standard criteria used in plan quality evaluation studies allowed for the identification of 124 criteria that can be used, perhaps with minor adjustments, to evaluate the quality of comprehensive adaptation plans in any country and at any scale. To put it slightly differently, this protocol was designed to serve as an ideal standard that reflects current thinking about adaptation planning.

Using this revised plan quality evaluation protocol, this research found that local adaptation plans perform highest in the fact base principle, with plans often drawing from multiple unique data sources to discuss climate impacts to built, natural, economic, and social systems. Rarely, however, do these plans provide specific spatial details regarding where climate impacts will be felt most acutely. Plans in the sample also perform well in the adaptation action principle, with nearly all plans including a wide variety of adaptation actions. Plans scored moderately well on the public participation principle, with most engaging a wide variety of individuals from public and private sectors in the adaptation planning process. There was, however, notable room for improvement, particularly when it came to engaging non-traditional stakeholders and devising techniques for maintaining public engagement post-plan creation. In general, these findings support the hypothesis that stand alone climate adaptation plans have moderately high alignment with principles of plan quality, especially principles focused on *fact base*, *use of future projections*, *action identification*, and *public participation*.

Plans scored the lowest on the *uncertainty principle* and the *implementation and monitoring principle*. The low scores on the uncertainty principle led to the research described in Chapter 3 (discussed below). The fact that the implementation and monitoring components of these plans received such low scores raises serious concerns about whether the adaptation actions identified in plans will be translated into on-the-ground projects that actually help a community prepare for climate related impacts.

Finally, Chapter 2 also explores why some plans perform better than others, finding that formal adoption of the adaptation plan by an elected body and whether the plan was written by the planning department are variables correlated with higher quality plans. In contrast, state funding to support the creation of an adaptation plan was correlated with lower quality plans. These three variables, in addition to the year the plan was published, explained 50% of the variation in plan quality. While not revolutionary, theses findings do strengthen the argument that planners have an important role to play in creating strong plans (Lyles et al., 2014) that are based on solid public participation processes, and that engaging elected officials in plan creation and adoption helps ensure the creation of higher quality plans (Measham et al., 2011; Bedsworth and Hanak, 2013; Brody, 2003; Eisenack et al., 2014; Tang et al., 2010). The finding that state funding is correlated with lower quality plans may indicate that funding alone is not enough to help communities plan for climate change. Instead, funding paired with capacity may be needed to help ensure that communities not only create strong plans but also have the conditions in place to implement those plans. These results contrast with the hypothesis that communities that are engaged in peer networks, have recently experienced a disaster, and have higher per-capita incomes will create stronger stand alone adaptation plans than their peers. In fact, research showed that none of these variables were significantly correlated to plan quality. The cumulative findings from Chapter 2 show that adaptation plans have significant room for improvement, with the average plan scoring only 40.6% of all possible points. This average score, however, is fairly common within existing plan quality studies (e.g., Preston et al., 2010; Tompkins et al., 2010), suggesting that adaptation plans appear to be of similar quality to hazard mitigation, climate action, and comprehensive plans.

Chapter 3 dives more deeply into how uncertainty is treated within the 44 adaptation plans in the sample. This chapter starts with the presentation of a conceptual framework that organizes the various types of uncertainty relative to the role of the planner, classifying uncertainty as either 1) *within the planners' influence*, 2) *beyond the planners' influence*, or 3) both within and beyond the planner's influence (the latter is referred to as '*bridging uncertainty'*). Next, the various techniques promoted in both the planning and climate literatures for addressing uncertainty are explored and classified as belonging to either a more traditional '*predict and plan*' model of planning or a more flexible '*adapt and monitor*' approach to planning. Finally, the content of the 44 local climate adaptation plans are reviewed to determine the types of uncertainty identified in each plan, as well as the uncertainty reducing techniques used by each community during its planning process.

Results show that communities are most concerned about uncertainty *outside of planners' influence* (54% of uncertainty references), especially uncertainty related to future climate conditions. *Bridging uncertainty* was also common, with 31% of all uncertainty references pertaining to uncertainty related to what local climate impacts will be. In contrast, very few communities express uncertainty associated with things deemed *within the planner's influence*. On the surface, this suggests that planners may have all of the information they need to effectively address issues that are within their influence. This finding, however, may actually denote that planners are fixating on uncertainty that lies outside of their influence because the literature and media focus on these sources of uncertainty (e.g., uncertainty about what future climate conditions or local impacts will be). This focus on external uncertainty is likely obscuring uncertainty that exists in areas that are within the planners' influence. Thus, Chapter 3 argues that sources of uncertainty that lie outside of the planner's influence need to be acknowledged but should not stymie local climate adaptation efforts.

Chapter 3 also profile 198 uncertainty reducing approaches found across the 44 plans in the sample, 103 of which are from the traditional '*predict and plan*' approach to planning, and 95 of which are from the '*adapt and monitor*' approach. The two most common uncertainty reducing techniques are multiple climate scenarios (present in 74% of plans) and vulnerability assessments (present in 73% of plans), both of which are from the '*predict and plan*' approach. The two most popular techniques from the '*adapt and monitor*' approach are monitoring changing climate conditions (present in 55% of plans) and discussing the need for adaptive management (present in 50% of plans). Despite the slight dominance of techniques from the '*predict and plan*' approach, it is promising that 35 out of the 44 plans include at least one uncertainty reducing technique from the '*adapt and monitor*' approach. Much more work is needed, however, to ensure that comprehensive approaches from the '*adapt and monitor*' approach become the foundation for local adaptation planning. As it stands, the most commonly used techniques from the '*adapt and monitor*' approach are general approaches, which often entail descriptions of why things such as adaptive management are needed, without giving specific details about how a local community is creating an adaptive management approach. The holistic integration of flexible uncertainty reducing approaches from the '*adapt and monitor*' approach to planning is a significant opportunity for improving local adaptation plans.

Results from Chapter 3 also show a notable disconnect between theory and practice, i.e., between the types of uncertainty reducing techniques being promoted and those actually being used. This disconnect is most notable in the absence of scenario planning, robust actions, and flexible actions from the plans in the sample. The dearth of these approaches may be associated with the cost, time, and staffing commitment necessary to adequately apply these approaches (Chakraborty, 2011; Zapata and Kaza, 2015; Quay, 2010). This disconnect warrants much further study.

In Chapter 4, the types of adaptation actions prioritized and implementation guidance provided in 43 U.S. local adaptation plans are analyzed (Satellite Beach, FL's plan is omitted because it does not include actions). In addition, the actions proposed in each plan are compared to actions believed to be important for addressing climate impacts likely to be faced in the region in which each community resides.

Results show that local communities include numerous and varied actions in their adaptation plans, with the most common types of actions being those related to *research and* *monitoring* and changing *practice and behavior*. These results contrast with previous plan evaluation studies (as well as one of the initial hypotheses), which found that capacity building actions dominated planning (Preston et al., 2010; Tompkins et al., 2010). The breadth of action types included in plans may suggest that communities realize the need for a mixture of actions to prepare local services and sectors for climate related impacts. On the other hand, the identification of a variety of actions may be a "hedging" strategy (Woodruff and Stults, 2016) whereby communities are selecting a variety of actions in hopes that at least one of them will help reduce vulnerability. Regardless of the motivation, the variety of activities is promising, as it demonstrates that communities planning for climate change are looking to use their full range of authority.

Findings in Chapter 4 also show that plans rarely contain significant details about how actions will be implemented. In particular, plans rarely included details about implementation responsibilities (40% of plans), timetables for implementation (33% of plans), and funding sources to support action implementation (23% of plans). While these findings are consistent with those of previous plan evaluation studies (Berke et al., 2015; Lyles et al., 2014), and partly in alignment with one of the initial hypotheses (*stand alone adaptation plans have weak implementation guidance but a strong emphasis on iterative and flexible planning approaches that align with principles of adaptive management*), they raise concerns about whether plans will translate into real-world projects that help a community prepare for climate related impacts.

On the positive, actions included in plans appear to align with the theoretical types of actions one would expect to find in plans based on regional projections of future climate. The exception is the general lack of green infrastructure and building code actions, which are valuable actions for addressing things such as changing precipitation regimes and sea level rise. In total, however, the fact that plans nearly always include the actions believed to be important based on projected changes in future climate suggests that, rather than just identifying regional climate impacts and proposing generic adaptation actions, communities are proposing actions to address their own unique vulnerabilities and sectors of concern.

Chapter 5 explores the relationship between climate change and natural hazards, presenting a conceptual framework composed of 21 ideas for how climate change could be embedded into local hazard mitigation plans. The content of 35 U.S. local hazard mitigation plans, for 35 communities that also have a stand alone climate adaptation plan and for which a hazard mitigation plan could be found, was compared to this conceptual framework.

Results in Chapter 5 show that most (30/35) of the plans analyzed include at least some discussion of climate change. This is most commonly a *general discussion regarding how climate change could affect or already is affecting the occurrence of natural disasters*. Half of the plans that discussed climate change also included hazard mitigation *actions that are designed to be viable in a climate-altered future*. Unfortunately, these actions are few in number, especially when compared to the total number of actions proposed in each plan. The adaptation actions proposed in these plans also focus on either *planning*, *research and monitoring* or *capacity building*, with few actions focused on *green infrastructure*, *physical infrastructure*, *land use*, or changing operational *practice and behavior*.

The least common approaches to embedding climate change into hazard mitigation plans were a *plan to integrate new climate information, as it's developed, into plan and accompanying actions* (found in 1 plan) as well as any discussion of *regional climate initiatives* or *the evaluation of and identification of mitigation actions for structures in the 1 in 500 year (or greater) floodplain* (which were both found in 3 plans). These omissions suggest that hazard mitigation planning is seen as more rigid than climate planning, a view that fails to acknowledge the need for iterative and adaptive planning approaches. This rigidity might be attributable to the fact that hazard mitigation plans need to be updated every five years, which lessens the need for explicit discussion of adaptive and flexible approaches within the plans themselves. The lack of discussion about regional initiatives and impacts is worrying, as climate change is creating and will continue to create impacts that cut across political boundaries (Adger et al., 2011; Dessai and Hulme, 2007; Preston, Westaway, and Yuen, 2010). Thus, communities must collaborate with their neighboring jurisdictions to ensure that the larger region is building resilience to climate change and natural disasters.

On average, each plan analyzed in Chapter 5 contains only one-quarter of the possible ways to integrate climate change into hazard mitigation planning, which suggests that this practice is still in its infancy. This finding is further validated by the fact that only four plans (Baltimore, MD (18/21 approaches); Boston, MA (13/21 approaches); Lewes, DE (12/21 approaches); and Miami-Dade County, FL (12/21 approaches)) used more than half of the approaches for integrating climate change into their hazard plans, even though all four communities explicitly set out to integrate climate change into their hazard planning. The fact that even these vanguard communities were unable to fully integrate climate change into hazards planning suggests that localities need more guidance, engagement, and assistance in fully embedding climate considerations into hazards planning.

In general, results detailed in Chapter 5 show that a handful of communities have successfully integrated climate change into their hazards planning. It is surprising, however, that there is very little consistency in how communities are integrating climate change into hazard planning. This is evident from the wide ranging techniques and the combination of techniques found in Chapter 5. These findings point to both the nascence of this practice and the opportunity to develop more formalized guidance that can steer communities towards holistic integration of climate change into hazard mitigation planning. The adjusted FEMA Crosswalk presented in Appendix 9 provides a starting point for identifying opportunities for integrating climate change into hazards planning.

Table 16 provides a summary of the strengths and opportunities for improving both local stand alone climate adaptation plans and hazard mitigation plans, based on research presented in this dissertation.

Table 16. Summary of the strengths and areas of improvement for both local stand alone climate adaptation plans and local hazard mitigation plans based on results from the research conducted in this dissertation and supplemented with findings from previous studies, specifically on hazard mitigation plan quality.

	Strengths	Opportunities for Improvement
Local Stand Alone Climate Adaptation Plans	• Strong fact base with pervasive use of multiple climate scenarios • Strong vulnerability assessments, with analysis of climate impacts to built, economic, natural, and social systems • Lots of actions, with a dominance of research and monitoring, planning, and practice and behavior actions • Moderately strong public participation in plan creation • High linkage to other community plans, including hazard mitigation plans • Identification of a variety of sources of uncertainty • Using uncertainty reducing techniques from both the 'predict and plan' and 'adapt and monitor' approaches	• Limited details about ***where*** impacts will occur • Limited engagement of non-traditional stakeholders in planning process • Limited discussion about maintaining public participation post plan creation • Limited use of advanced uncertainty mitigating techniques from "*adapt and monitor*" approach • Extremely limited implementation details • Limited prioritization of actions
Local Hazard Mitigation Plans	• Moderately high public participation • Strong identification of local hazards • Strong face base • Emphasis on structural preparedness actions	• Few adaptation actions (those that do exist are planning or research and monitoring actions) • Little discussion or processes for adaptive management • Little regional collaboration around climate • Extremely limited discussion of land use and green infrastructure strategies • Extremely limited implementation details • Limited prioritization of actions • Over-emphasis on emergency response actions

3. Recommendations for Practice

Similar to results from Bierbaum et al. (2013), aggregate results from this dissertation indicate that significantly more climate adaptation planning is taking place than originally thought, but much more is critically needed in order to truly prepare U.S. communities for climate related impacts. Results also suggest that there is no single 'right' way to plan for climate change. Instead, multiple approaches are available, and local communities need to decide which are the most viable given local priorities, available resources, and community goals. Drawing on the aggregate findings from this dissertation research as well as my professional experiencing working for more than a decade with local governments on climate and sustainability initiatives, three pathways for improving the state of local adaptation planning are offered.

Jointly create an adaptation framework and embed climate change into other planning domains

Local communities are strongly encouraged to create a stand alone climate adaptation framework (not a full plan) while simultaneously embedding climate change into other, more entrenched planning processes. Doing so sends the message that preparing for climate change is a priority for the local community, while also respecting existing planning initiatives and processes. This approach also has the advantage of providing a holistic strategic roadmap for local adaptation initiatives in the form of a stand alone adaptation framework that can then be used as a foundation for embedding climate considerations into specific department or sector plans. If climate is being integrated into department or sector plans during regular plan update periods, then this approach should be extremely cost effective, leading to minimal additional expense to the local government. Moreover, if done thoughtfully, this approach can also help to prevent maladaptive actions, or actions in one department that have negative consequences for another.

To be effective, however, this approach needs to be spearheaded by a staff person who has authority to hold other departments and staff accountable for adhering to the priorities outlined in the stand alone adaptation framework. Ideally, this person would be situated in a mayor's or a city/county administrator's office and would have direct access to and authority stemming from local management. This person would be tasked with monitoring the work of the individual departments, providing strategic adaptation related guidance, and helping to comprehensively organize, coordinate, and integrate all city climate adaptation activities. This staff person would also serve as a resource for peers who would retain responsibility for embedding climate change into their individual departments or sector based plans. Seattle Public Utilities (Abt, 2016) provides an example of this approach that others could look to for more guidance.

Communities pursuing this approach should take caution to ensure that the responsibility for coordinating this work is institutionalized so that changes in administration or political priorities do not lead to termination of the work.

Create a stand alone climate adaptation plan

In some communities a clear need for a stand alone climate adaptation plan may exist. This is likely true in communities where strong commitment exists to climate adaptation action, where resources for climate adaptation planning are readily available, and where partnerships and capacity are available to undertake a climate adaptation planning process. For communities choosing this path, the following advice is offered:

1. Make sure that local planners are engaged in, if not leading, the local adaptation planning effort.
2. Engage non-traditional stakeholders, including the most vulnerable members of the community, throughout each step of your climate adaptation planning.
3. Work with regional counterparts, private sector representatives, local universities, and non-profit organizations to ensure that a wide range of perspectives and expertise are represented during the adaptation planning process.
4. Acknowledge different sources of uncertainty, but don’t let uncertainty limit local climate planning. Instead, use adaptive management approaches and approaches such as scenario planning to ensure that the community is planning for a wide range of possible futures. Lean on the expertise in the community, including any academic expertise, as well as the support of federal and state agencies to help fully apply appropriate uncertainty reducing approaches.
5. Identify a range of potential adaptation actions and provide details that will help support implementation of actions. This includes information such as who is responsible for implementing an action, how it will be paid for, and how it will be measured and monitored over time.
6. Create a clear process and timetable for updating the plan. Adaptation planning should not be a one-time effort, so it is critical to create a process to continually update and revise the

plan as new information becomes available. A key piece of this process is creating a clear vision with supporting goals and objectives that the community is trying to achieve through adaptation planning. Use these as indicators to measure progress in creating the vision of a more prepared/adapted/resilient community and revise future planning as needed to ensure continued progress towards the vision.

Embed climate change into other planning domains

Many communities may not have the option of creating a stand alone climate adaptation plan. In communities where financial resources are limited, political or public support is minimal, and staff capacity is already strained, creating a stand alone climate adaptation plan or framework may not be possible. In these communities, the integration of climate change into existing community planning processes may be the most viable approach. One of the easiest ways to start this process is by embedding climate change into local hazard mitigation planning. For communities interested in following this approach, the revised FEMA Crosswalk, presented in Appendix 9, can serve as a tool for understanding how climate change could be integrated into hazard planning while still ensuring the creation of a FEMA approvable plan.

For communities looking for more aggressive ways to embed climate change into local planning and decision-making, local comprehensive or master plans may present a viable option. Little work has been done to evaluate the effectiveness of this approach; theoretically, however, embedding climate change into comprehensive planning presents a significant opportunity to transform the way scholars and practitioners think about and design cities. For example, factoring sea level rise into land use decisions may translate into a local community prioritizing open space and park development along the coastline in order to manage more frequent inundation, as opposed to the more traditional focus on residential and commercial development. Alternatively, a community facing drought may prioritize the replacement of city owned water lines over other infrastructure projects, especially if significant quantities of water are being lost during transport. Moreover, since comprehensive or master plans generally have more regulatory teeth due to their connection to the Capital Improvements Plan, which sets out the priority areas for local government investment, they present a unique way for climate change to become a more mainstream component of city thinking and operation.

General Recommendations

Regardless of the approach taken, significantly more communities need to formally think about and plan for climate change. As more is done to scale up the practice of planning for climate change, scholars and practitioners should keep in mind five points derived from research detailed in this dissertation:

1. *Planners matter.* Empower them to lead or be active members in adaptation planning.
2. *Elected leader support improves plans.* Engage elected leaders in the planning process and work to get their approval of any final plans. This can significantly improve the quality and implementability of plans.
3. *Don't let uncertainty derail your process.* An array of approaches exists for reducing uncertainty. Find the ones that are most appropriate for the community and work with colleagues to fully implement them. To the fullest extent possible, try to use techniques from the '*adapt and monitor*' approach to create flexible plans that can adjust as new information becomes available.
4. *Prioritize a variety of types of adaptation actions,* paying particular attention to actions that have the potential to significantly reduce vulnerability. Capacity building actions can be powerful, especially when paired with practice and behavior actions, green infrastructure actions, land use actions, or technology actions. Regardless of the actions prioritized, identify details associated with implementing each action, including who is responsible for implementing it; this will help ensure that the actions translate into real-world projects.
5. *Continue to embed climate change into other planning processes and operational decision making frameworks*. This will help ensure that climate change is considered at all levels of decision making and in all sectors and local departments. Be sure that some framework, person, or structure exists to coordinate all of these disparate actions. Without this coordination, adaptation actions in one sector could be maladaptive to those in another.

4. Recommendations for Scholarship

For scholars looking to build upon this work, two areas clearly exist where more research is needed. The first relates to how climate change is being integrated (or not) into other, more traditional local plans. For example, a detailed analysis of comprehensive plans or master plans is needed to see whether and how climate change is being considered. Insight from such an analysis will allow us to compare the strengths and weaknesses of this approach to those such as embedding climate change into hazard mitigation planning. This analysis will also help provide more detail about the benefits and drawbacks of creating stand alone climate adaptation plans versus integrating climate change into existing planning processes.

Secondly, additional work is needed to understand whether and how plans translate into on-the-ground adaptation projects. As part of this work, research is needed to understand the degree to which implemented projects actually help communities meet their climate adaptation goals. Recent work looks at adaptation actions in a single place or in a small sample of communities. This work, however, has not compared what is being done on the ground to what was planned for in local adaptation plans. This leaves scholars with an extremely limited understanding of whether and how adaptation plans translate into adaptation projects. Without this understanding, one is unable to fully understand the practical impacts and drawbacks associated with local adaptation planning. Research on what adaptation activities get implemented and why will not only help to advance scholarship, but will also directly improve the practice of adaptation action: a win-win outcome that is desperately needed in the field.

5. Concluding Thoughts

The scientific consensus is clear: the climate is changing (Mimura et al., 2014; Walsh et al., 2014). The current and future changes have real and long-lasting impacts on nearly every dimension of life in local communities, necessitating that local communities holistically plan for a climate altered future. The findings from this dissertation shed light on the promising practices and areas in need of improvement in the first generation of climate adaptation plans. It has been nearly a decade since the first climate adaptation plan was written in Keene, NH. Since that time, the impetus for planning for a climate altered future has grown significantly. As scholars, we have a unique opportunity to critically evaluate the state of adaptation planning in the U.S. so as to determine how best to guide more communities in creating plans that prepare them for a world plagued by climate change.

Creating a strong adaptation plan or embedding climate considerations into existing plans does not guarantee that a community is prepared for climate change, but it is an important step in ensuring that local communities are thinking critically about how climate change could impact their operations and the lives of their citizens. Results from this research suggest that there is no one '*right'* way to plan for climate change. For some communities, creating a stand alone climate adaptation plan will be the most appropriate course of action. Other communities will focus on embedding climate considerations into existing planning domains such as comprehensive planning, hazard mitigation planning, or water resource planning. And for still other communities, a combination of both approaches will be the best course of action.

Regardless of the approach taken, a clear need exists for more communities to begin planning for a climate altered future. Hopefully the analysis presented in this dissertation will be valuable to scholars and practitioners who seek to support communities in planning holistically and comprehensively for climate change. Much more work is needed, but, as this dissertation shows, a majority of the tools and expertise required already exist. We just need to get to work.

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Appendix 1 – Criteria included in the plan quality evaluation conducted in Chapter 2

Table 17. Criteria included in the seven plan quality principles, descriptions of the criteria, the percentage of plans that included each criterion, and the inter-coder reliability scores and Krippendorff's alpha (in parentheses) for each criterion.

	Criterion	Description	% Plans	Reliability % agreement (Krippendorf alpha)
A	**ARTICULATION OF PURPOSE, GOALS, AND OBJECTIVES**			
A1	Plan purpose	States the purpose of the plan.	80%	70% (0.313)
A2	Vision statement	Includes a vision statement, which establishes an overall image of a desired future.	23%	84% (0.567)
A3	Define resilience, adaptation, or preparedness	Defines resilience, adaptation or preparedness.	68%	86% (0.709)
A4	Goals	Includes goals, which are outcomes that the community aspires towards. Goals are usually expressed in adjectives and nouns (not verbs) and are not quantified. Goals reflect public values and express future desired conditions.	50%	79% (0.595)
A5	Objectives	Includes objectives, which are tangible, measurable outcomes leading to the achievement of a goal	16%	72% (0.171)
A6	Objectives detailed	Includes quantifiable objectives for each goal (e.g., reduce heat-related mortality by 1,000 by 2020; must have objectives for each goal).	0%	97% (0)
B	**PUBLIC PARTICIPATION**			
B1	Planning process	Describes the process undertaken to create the plan.	61%	84% (0.681)
B2	Plan preparation involvement	Describes the stakeholders involved in plan preparation.	66%	79% (0.569)
B3	Plan preparation involvement detailed	Includes detailed description of organizations and individuals involved in plan preparation. Description must include number of stakeholders and the general categories of stakeholders (e.g. residents, companies, non-profits, governmental agencies).	43%	65% (.261)
B4	Representative stakeholders	Mentions how stakeholders who were involved represent all the groups affected by proposed policies or how the planning process sought to engage disadvantaged populations. Disadvantaged populations are those that may not traditionally be included in the planning process and may be adversely affected by climate change, such as the poor, elderly, or those for whom English is a second language.	11%	93% (0.629)
B5	Participation techniques	Mentions participation techniques used to create the plan, such as meetings, surveys, charettes, public comments on drafts, etc.	61%	79% (0.594)
B6	Participation techniques detailed	Describes participation techniques with details about each method including number of participants, main topics covered, and activities used to elicit input.	27%	70% (0.196)
B7	Public meetings	States that meetings were used to engage stakeholders and that these meetings were open to the public.	50%	86% (0.725)
B8	Planning or steering committee	States that a steering committee or advisory committee was used to guide plan creation.	59%	72% (0.461)
B9	Public participation maintenance	Discusses how public engagement will continue in plan maintenance/evaluation.	16%	81% (0.448)
C	**COORDINATION**			

C1	Local university	States that local universities were engaged in the planning process.	57%	82% (0.64)
C2	Federal agencies	States that federal agencies were engaged in the planning process.	41%	84% (0.655)
C3	State agencies	States that state agencies were engaged in the planning process.	34%	84% (0.63)
C4	Nonprofits	States that nonprofits were engaged in the planning process.	39%	84% (0.63)
C5	Businesses	States that businesses were engaged in the planning process.	30%	91% (0.76)
C6	Neighboring jurisdictions	States that neighboring jurisdictions were given the opportunity to participate in the planning process. Neighboring jurisdictions include regional planning organizations and counties as well as other cities, towns, or villages.	30%	82% (0.521)
C7	Internal support	Describes agency support and involvement from within the local government.	68%	75% (0.484)
C8	Detailed internal support	Includes detailed description of agency support and involvement. Must describe responsibilities or demonstrate agency support for the planning process.	18%	79% (0.285)
C9	Elected official engagement	Mentions involvement of elected official(s) in the planning process.	16%	84% (0.444)
D	**FACT BASE**			
D1	Data collection	Provides information about the type of data collected and analyzed in order to make the plan.	66%	79% (0.59)
D2	National studies	States that national studies were used to inform the plan. Studies may include climate, demographics, economic projections, etc.	66%	73% (0.451)
D3	Regional studies	States that regional studies were used to inform the plan. Studies may include climate, demographics, economic projections, etc.	89%	77% (0.31)
D4	International studies	States that international studies were used to inform the plan. Studies may include climate, demographics, economic projections, etc.	70%	82% (0.568)
D5	Local knowledge	States that local, indigenous, or traditional knowledge was used to inform the plan.	86%	63.6 (0.136)
D6	Existing impacts	Identifies ways that climate change or changing weather conditions are already affecting the community.	61%	66% (0.261)
D7	Existing conditions	Discusses existing social, economic, environmental, or built infrastructure conditions that could lead to enhanced vulnerability in the future.	86%	75% (0.27)
D8	Existing actions	Identifies actions and plans that are in progress or planned that have adaptation value. Actions do not need to be specifically designed to address climate change.	80%	79% (0.443)
D9	Historic changes weather/climate	Discusses how climate or weather trends in the area have changed to date.	82%	77% (0.401)
D10	Primary economic base(s)	Identifies the community’s major economic sectors.	45%	79% (0.569)
D11	Primary cultural base(s)	Identifies the community’s major cultural assets (e.g., museums, art work, recreation centers).	30%	84% (0.535)
D12	Primary natural system(s)	Identifies the major natural systems that are part of the community.	32%	75% (0.419)
D13	Presidentially declared disaster	Indicates that the community has experienced a presidentially declared disaster.	7%	98% (0.97)
D14	Previous hazardous events	Includes information on previous occurrences of hazardous events.	66%	91% (0.806)
D15	Repetitive loss properties	Discusses areas or specific properties that have been repetitively damaged by hazardous events.	14%	91% (0.618)
D16	Projected changes	Identifies climate change exposure, which is the climate change effects a community expects to feel, e.g., warmer temperature, increased precipitation, rising sea level.	100%	91% (-0.036)
D17	Prioritized exposure	Prioritizes climate change effects or hazards.	36%	75% (0.458)
D18	Non-climatic drivers	Mentions other factors that may impact future vulnerability or resilience. Non-climatic factors include a shifting economy, growing or depleting population, or changing land use patterns.	50%	70% (0.413)
D19	Non-climatic drivers detailed	Explicitly discusses projections for non-climatic factors over time and how this could affect vulnerability or resilience. Non-climatic factors include a shifting economy, growing or depleting population, or changing land use patterns.	11%	77% (0.046)
D20	Vulnerability assessment	Clearly indicates that a vulnerability assessment was undertaken as part of the planning process. A	73%	75% (0.458)

		vulnerability assessment includes an analysis of exposure, sensitivity, and adaptive capacity.		
D21	Adaptive capacity	Clearly indicates that an assessment of adaptive capacity was undertaken. Adaptive capacity is the community's current and future ability to address projected impacts.	34%	79% (0.503)
D22	Adaptive capacity detailed	Provides a detailed description of adaptive capacity, including a clear description of what factors were considered in assessing adaptive capacity.	14%	86% (0.184)
D23	Risk assessment	Clearly indicates that a risk assessment was undertaken as part of the planning process. A risk assessment includes an assessment of the likelihood and consequence of an event.	30%	93% (0.842)
D24	Water supply	Discusses impacts of changing climate conditions on the community's water supply.	82%	73% (0.232)
D25	Water supply detailed	Provides a detailed description of the vulnerability of water supplies to changing climate conditions. Must include a map of areas at risk or a detailed text description of vulnerable areas that identifies specific locations.	14%	89% (0.468)
D26	Water quality	Discusses impacts of changing climate conditions on the community's water quality.	73%	86% (0.676)
D27	Water quality detailed	Provides a detailed description of the vulnerability of water quality to changing climate conditions. Must include a map of areas at risk of low water quality or a detailed text description of at-risk areas that includes the location of specific vulnerable areas.	5%	98% (0.79)
D28	Natural systems	Discusses impacts of changing climate conditions on natural systems.	95%	93% (0.54)
D29	Natural systems detailed	Provides a detailed description of the vulnerability of natural systems to changing climate conditions. Vulnerable natural systems must be mapped, or a detailed text description including the specific location of vulnerable natural systems must be provided.	36%	68% (0.3)
D30	Vulnerable populations	Identifies populations that will be disproportionately impacted by changing climate conditions. Must identify specific populations, not just mention that some groups will be adversely affected.	68%	82% (0.612)
D31	Vulnerable populations detailed	Provides a detailed description of populations vulnerable to changing climate condition. Vulnerable populations must be mapped, or a detailed description of vulnerable populations and their specific location must be provided.	14%	95% (0.832)
D32	Human/public health	Identifies public health issues that will be impacted by changing climate conditions.	86%	91% (0.698)
D33	Human/public health detailed	Provides a detailed description of public health vulnerabilities to changing climate conditions. Public health issues must be mapped, or a detailed description of where public health impacts are expected to be severe must be provided.	2%	93% (-0.024)
D34	Cultural assets	Identifies cultural assets that will be impacted by changing climate conditions. Includes things such as archeologically significant sites, recreational opportunities, events such as sports tournaments, museums, public art, and other culturally relevant places.	73%	79% (0.525)
D35	Cultural assets detailed	Provides a detailed description of cultural assets that are vulnerable to changing climate conditions. The location of vulnerable cultural assets must be mapped, or a detailed description of the cultural assets and their location must be provided.	30%	86% (0.64)
D36	Built environments / infrastructure	Identifies infrastructure that will be impacted by changing climate conditions.	100%	91% (-0.036)
D37	Built environments / infrastructure detailed	Provides a detailed description of infrastructure vulnerable to changing climate conditions. Vulnerable locations are mapped, or a detailed description of the vulnerable built environments and their location is provided.	61%	86% (0.728)
D38	Public services	Identifies sensitive public services, including emergency services, that will be impacted by climate change.	77%	89% (0.691)
D39	Public services detailed	Provides a detailed description of public services vulnerable to changing climate conditions. Vulnerable public services must be mapped, or a detailed description, including a list of vulnerable services, must be included.	30%	91% (-0.036)

D40	Economic systems	Identifies economic impacts of changing climate conditions. This may be a general discussion of impacts to entire economic sectors such as agriculture, forestry, tourism, OR a more specific discussion of impacts such as reduced patronage during extreme heat, or business closure and damage during extreme events.	91%	93% (0.54)
D41	Economic systems detailed	Provides a detailed description of the economies vulnerable to changing climate conditions. Vulnerable economies must be mapped, or a detailed description, including a list of the vulnerable economic sectors, must be provided.	25%	89% (0.691)
D42	Prioritization of vulnerabilities or risks	Includes the results of a prioritization of identified vulnerabilities.	36%	73% (0.442)
D43	Prioritization of vulnerabilities or risks detailed	Prioritizes risks and clearly describes how risks were ranked.	25%	77% (0.46)
D44	Underlying Causes / Transformation	Mentions the need to address fundamental drivers of human vulnerability or "transformational" adaptation/change. "Fundamental drivers of vulnerability" refers to underlying causes of social vulnerability reinforced by existing institutions and social systems; "transformational" adaptation or change reassesses the way a system operates and may take the form of new rights claims and changes in political systems. Transformational change affects how individuals and society make decisions and allocate resources to cope with climate change; it may alternatively include changes in institutional arrangements, priorities, and norms.	9%	77% (0.046)
E	**UNCERTAINTY**			
E1	Acknowledgement of uncertainties	The plan acknowledges uncertainties involved in projection of climate change or estimation of vulnerabilities.	75%	77% (0.46)
E2	Acknowledgement of uncertainty detailed	Describes sources of uncertainty.	32%	77% (0.46)
E3	Multiple scenarios	Mentions that different climate scenarios were considered.	70%	84% (0.63)
E4	Multiple scenarios detailed	Provides a detailed description of scenarios. Description must include how scenarios were developed and how scenarios differ in terms of assumptions and impacts.	43%	82% (0.621)
E5	Adaptive management	Mentions adaptive management. Adaptive management is the process of incorporating new information from monitoring and science into decision-making with an emphasis on learning.	43%	66% (0.308)
E6	Adaptive management detailed	Emphasizes adaptive management and learning throughout the plan and establishes a process for incorporating new information from monitoring and science into decision-making.	18%	84% (0.375)
E7	Multiple time frames	Includes both short-term (next 5 years) and long-term (5+ years) actions.	23%	84% (0.535)
E8	Flexible actions	Explicitly recognizes the need for flexible adaptation actions.	23%	86% (0.64)
E9	Flexible actions detailed	Includes flexible actions and explicitly identifies actions as being flexible.	5%	93% (-0.024)
E10	Robust actions	Discusses robust actions as an option to address uncertainty. Robust actions are those that produce positive outcomes across a range of different scenarios or future conditions.	30%	93% (0.54)
E11	Robust actions detailed	Includes robust actions. Robust actions produce positive outcomes across a range of different scenarios or future conditions. Must identify the actions as robust.	20%	100% (1.00)
E12	No- or low-regrets actions	Discusses no- or low-regrets actions as an option to address uncertainty. No-regrets actions are those that can be justified under current climate conditions but also make even more sense with climate change; these may also be called win-win actions. Low-regret actions are low-cost actions with relatively large benefits, although those benefits are realized mainly under projected future climate change. Must explicitly discuss no- or low- regrets actions.	30%	95% (0.887)

E13	No- or low-regrets actions detailed	Includes no- or low- regret actions. No-regrets actions are those that can be justified under current climate conditions but also make even more sense with climate change; these may also be called win-win actions. Low-regret actions are low-cost actions with relatively large benefits, although those benefits are realized mainly under projected future climate change. Must explicitly identify actions as no- or low- regrets.	2%	97% (0)
F	**ACTION IDENTIFICATION**			
F1	Prioritized actions	Prioritizes adaptation actions.	34%	75%(0.392)
F2	Prioritized actions detailed	Prioritizes adaptation actions and describes how actions were ranked.	20%	89% (0.603)
F3	Specific adaptation actions	Includes actions that are linked to specific impacts.	55%	68% (0.337)
F4	Capacity building	Includes capacity-building actions. Capacity building is developing human resources, institutions, and communities, equipping them with the capability to adapt.	84%	95% (0.809)
F5	Advocacy	Includes advocacy actions. Advocacy includes encouraging regional and state agencies to have adaptation-appropriate actions.	25%	82% (0.568)
F6	General actions	Includes generic adaptation actions, which are actions not specific enough to be classified in another category.	91%	77% (0.16)
F7	Information and awareness	Includes information and awareness actions, which focus on increasing public knowledge.	84%	93% (0.732)
F8	Research and monitoring	Includes research or monitoring actions, which focus on gathering information and creating reports, maps, or models. Monitoring includes observation or repeated measurements over time.	95%	91% (0.293)
F9	Planning	Includes planning-related actions, including actions that incorporate understanding of climate science, impacts, vulnerability and risk into government and institutional planning processes, efforts, or existing initiatives.	91%	91% (0.554)
F10	Practice and behavior	Includes actions to change practice and behavior. Practice and behavior actions revise or expand practices and on-the-ground behavior that affect resilience.	95%	89% (0.603)
F11	Policy and legislation	Includes policy and legislative actions aimed at preparing for climate change.	80%	77% (0.31)
F12	Physical infrastructure	Includes physical infrastructure actions to prepare for climate change.	82%	86% (0.736)
F13	Building codes and engineering design standards	Includes actions to improve physical infrastructure's response to changing climate through improved standards or engineering.	70%	68% (0.275)
F14	Green infrastructure	Includes green infrastructure actions aimed at providing protection from climate hazards.	64%	73% (0.417)
F15	Land use	Includes land use actions focused on preparing for climate change.	82%	89% (0.64)
F16	Conservation	Includes conservation actions to preserve biodiversity and protect open space under a changing climate.	66%	82% (0.628)
F17	Financing	Includes financing or insurance actions to prepare for future climate changes.	55%	79% (0.594)
F18	Technology	Includes technology actions.	66%	75% (0.499)
F19	Cost	Estimates the cost of implementing specific adaptation actions.	30%	89% (0.736)
F20	Cost detailed	Identifies the cost of implementing each adaptation action.	16%	91% (0.698)
F21	Cost of inaction	States that taking action to adapt to climate change costs less than not acting.	43%	82% (0.634)
F22	Cost of inaction detailed	Provides specific dollar figures on the cost of inaction versus adaptation-related action.	30%	77% (0.46)
F23	Co-benefits	Identifies co-benefits associated with taking adaptation action.	50%	66% (0.296)
G	**IMPLEMENTATION AND MONITORING**			
G1	Timetable for implementation	Provides a timetable for when each action will be implemented.	32%	93% (0.834)
G2	Implementation responsibilities	Assigns responsibility for policies broadly to organizations or agencies.	39%	91% (0.800)
G3	Implementation responsibilities detailed	Assigns responsibility for the implementation of each action.	34%	89% (0.724)
G4	Funding (need for)	Describes the *need* for funding sources to implement the plan.	36%	75% (0.441)
G5	Potential funding sources	Clearly describes potential funding sources and associates them with particular actions.	23%	86% (0.568)

	detailed			
G6	Reporting requirements	Includes requirements for the regular reporting of implementation progress.	16%	89% (0.486)
G7	Monitoring responsibility	Mentions assignment of responsibility for monitoring.	20%	82% (0.448)
G8	Evaluation method	Establishes a process to evaluate the plan.	7%	95% (0.646)
G9	Evaluation method detailed	Describes when analyses of progress toward objectives will take place and how results will be used.	5%	93% (-0.024)
G10	Evaluation metrics	Mentions how to measure progress towards implementing actions.	16%	98% (0.921)
G11	Evaluation metrics detailed	Mentions how to measure progress towards implementing each action identified in the plan.	14%	98% (0.897)
G12	Mainstreaming	Discusses mainstreaming climate change adaptation. Mainstreaming refers to the integration of climate adaptation into other sector policies or plans.	84%	73% (0.232)
G13	Mainstreaming detailed	Identifies specific plans and programs as opportunities for mainstreaming. Mainstreaming refers to the integration of climate adaptation into other sector policies or plans.	61%	61% (0.232)
G14	Plan updates	Mentions need for updates.	27%	81% (0.568)
G15	Plan updates detailed	Includes timetable for updating plan.	16%	93% (0.784)
G16	Barriers	Mentions barriers to climate adaptation.	23%	84% (0.593)

Appendix 2 – Variables included in multivariate analysis of plan quality conducted in Chapter 2

Table 18. Variables included in multivariate analysis of plan quality assessment described in chapter 2.

VARIABLE	VARIABLE OPERATION	SOURCE
CAPACITY MODEL		
Funding	Did the community receive outside funding to create the plan? 0 for no; 1 for yes	Each adaptation plan
Budget	Log base 10 of community operating budget for fiscal year 2014	Each local government's website
Household income	2009-2013 median household income	American Community Survey
Hazard mitigation mandate	Is the community located in a state with a hazard mitigation planning mandate? 0 for no; 1 for yes	American Planning Association (http://www.slideshare.net/ibhs/summary-of-state-land-use-planning-laws)
Comprehensive plan mandate	Is the community located in a state with a comprehensive planning mandate? 0 for no; 1 for yes	American Planning Association (http://www.slideshare.net/ibhs/summary-of-state-land-use-planning-laws)
COMMITMENT MODEL		
Adoption	Was the adaptation plan formally adopted by an elected body? 0 for no; 1 for yes	Each adaptation plan and local government's website
Public perception	Percent of county population that is worried about climate change	Yale Project on Climate Change Communication and the George Mason Center for Climate Change Communication http://environment.yale.edu/poe/v2014/ (for details, see Howe et al. 2015)
Disaster experience	Number of presidentially declared disasters in county from 2004-2014	FEMA Disaster Declaration website
ICLEI	Is the community a member of ICLEI-Local Governments for Sustainability, USA? 0 for no; 1 for yes	ICLEI USA's membership department
Climate Protection Agreement	Is the community a signatory of the U.S. Mayors Climate Protection Agreement? 0 for no; 1 for yes	U.S. Mayors Climate Protection Agreement signatory list (website)
Resilient Communities	Is the community a signatory of the Resilient Communities for America pledge? 0 for no; 1 for yes	Resilient Communities for America signatory list (website)
CRS	Does the community participate in FEMA's Community Rating System? 0 for no; 1 for yes	FEMA's Community Rating System (CRS) Communities and Their Classes list
POLICY DIFFUSION MODEL		
Year	Year that the plan was published	Each adaptation plan
State adaptation plan	Is the community located in a state with an adaptation plan? 0 for no; 1 for yes	Georgetown Climate Center's State and Local Adaptation Plan Map
ICLEI	Is the community a member of ICLEI-Local Governments for Sustainability, USA? 0 for no; 1 for yes	ICLEI USA's membership department
USDN	Is the community a member of the Urban Sustainability Directors Network (USDN)? 0 for no; 1 for yes	USDN Website
INTERNAL PROCESS MODEL		
Plan author	Organization responsible for writing the plan. Dummy variable for external, internal taskforce, environmental department, and planning department	Each adaptation plan; emails to local government if author was uncertain
Source of funding	Source of outside funding to create the plan. Dummy variable for federal,	Each adaptation plan

	state, or non-governmental organization funding

* Less confidence is placed in data collected directly from plans, since information may be omitted from the plan. When researchers were uncertain about data collected from plans, they reached out to the community for clarification. There is also less confidence in demographic data for tribal communities, since this information is estimated through different procedures. Finally, it is important to note that demographic and financial data is provided for the most recent year available and does not necessarily correspond to when the plan was written.

Appendix 3 - Codes used by researchers to identify types of uncertainty and uncertainty reducing approaches (Chapter 3)

<u>Codes Related to Identification of Uncertainty</u>

1. If the plan ***acknowledges uncertainty***; and
2. If the plan provides details about the ***types or sources of uncertainty*** that exist.

<u>Codes Related to Approaches to Overcome Uncertainty</u>

3. If the plan mentions the value of ***no regrets actions***;
4. If specific actions are labeled as no regrets actions (***no regrets detailed***);
5. If the plan mentions the value of ***low regrets actions***;
6. If specific actions are labeled as low regrets actions (***low regrets actions detailed***);
7. If the plan mentions the value of ***incremental actions***;
8. If specific actions are labeled as incremental actions (***incremental actions detailed***);
9. If the plan mentions the value of ***flexible actions***;
10. If specific actions are labeled as flexible actions (***flexible actions detailed***);
11. If the plan mentions the value of ***robust actions***;
12. If specific actions are labeled as robust actions (***robust actions detailed***);
13. If the community undertook a ***vulnerability assessment***;
14. If actions are selected that span ***multiple time frames***;
15. If the planning process involved ***scenario planning***;
16. If ***multiple climate scenarios*** were used*;*
17. If the community used ***climate downscaling*** or downscaled data in their analysis;
18. If ***monitoring changing climate conditions*** is included as a action in the plan;
19. If the plan identifies ***thresholds or tipping points***;
20. If the plan mentions ***adaptive management***; and
21. If the plan builds in an adaptive management approach (***detailed adaptive management***).

Appendix 4 – Types of uncertainty identified by each plan in the sample analyzed in Chapter 3

Table 19. Type of uncertainty identified by plan. Each community included in the sample and the type of uncertainties identified in their adaptation plan.

Community	Coastal	L (over 250,000); M (50,001-249,999); S (<50,000)	Future Conditions	Soc-Eco Factors	Local Impacts	Effective Actions	Current Coping Capacity
Albany, NY	N	M	1	0	1	0	0
Austin, TX	N	L	1	1	0	0	1
Boulder County, CO	N	L	1	1	1	1	0
Chester, PA	N	S	1	0	0	0	0
City and County of Denver, CO	N	L	1	0	0	0	0
Confederated Salish and Kootenai Tribes, MT	N	L	0	0	1	0	0
Dane County, WI	N	L	0	0	0	0	0
Fairbanks North Star Borough, AK	N	M	0	0	0	0	0
Flagstaff, AZ	N	M	1	0	1	0	0
Fresno County, CA	N	L	1	0	0	0	0
Grand Rapids, MI	N	M	1	0	1	0	0
Keene, NH	N	S	0	0	0	0	0
Laguna Woods, CA	N	S	1	0	1	0	0
Marquette, MI	N	S	0	0	0	0	0
Milwaukee, WI	N	L	1	0	1	0	0
Missoula County, MT	N	M	1	0	0	0	0
Anne Arundel County, MD	Y	L	1	0	0	0	1
Baltimore, MD	Y	L	1	0	1	0	1
Boston, MA	Y	L	0	0	0	0	0
Chula Vista, CA	Y	L	0	0	0	0	0
Dorchester County, MD	Y	S	0	0	0	0	0
Durham, NH	Y	S	1	0	0	0	0
Groton, CT	Y	S	0	0	0	0	0
Guilford, CT	Y	S	0	0	0	0	0
Jamestown S'Klallam Tribe, WA	Y	S	1	0	0	0	0
Lafourche Parish, LA	Y	M	0	0	0	0	0
Lee County, FL	Y	L	0	0	1	0	0
Lewes, DE	Y	S	1	0	0	0	0
Los Angeles, CA	Y	L	1	1	1	1	0
Miami-Dade County, FL	Y	L	1	0	1	0	0
New York City, NY	Y	L	1	0	0	1	0
Oakland, CA	Y	L	1	0	1	0	0
Portsmouth, NH	Y	S	0	0	0	0	0
Punta Gorda, FL	Y	S	1	0	1	1	0
Salem, MA	Y	S	0	0	1	0	0
San Luis Obispo, CA	Y	L	1	0	0	0	0
Santa Barbara, CA	Y	M	1	0	1	0	1
Santa Cruz, CA	Y	M	1	0	1	0	0
Satellite Beach, FL	Y	S	1	0	0	0	0
Seabrook, NH	Y	S	0	0	0	0	0
Somerset County, MD	Y	S	1	0	0	0	0
Swinomish Tribe, WA	Y	S	1	0	0	0	1
Waveland, MS	Y	S	1	0	1	0	0
Worcester County, MD	Y	M	1	0	1	0	0
Total			**29**	**3**	**18**	**4**	**5**

Appendix 5 – Number and type of uncertainty reducing technique used by plan in sample in Chapter 3

Table 20. Number and type of uncertainty reducing technique by plan in sample. Each community included in sample and the uncertainty reducing approaches used in each community's stand alone climate adaptation plan.

				Predict and Plan Techniques								Adapt and Monitor Techniques										
Community	State	Coastal	L = over 250,000; M = 50,001-249,999; S = < or = 50,000	Vulnerability Assessments	Multiple Scenarios	Downscaling	No Regrets Strategies	No Regrets Detailed	Low Regrets Strategies	Low Regrets Detailed	Multiple time frames	Adaptive Management	Adaptive Management Detailed	Scenario Planning	Robust Strategies	Robust Strategied Detailed	Incremental	Incremental Strategies Detailed	Flexible Strategies	Flexible Strategies Detailed	Thresholds	Monitoring Changing Climate Conditions
Austin	TX	N	L		1	1						1									1	
Boulder County	CO	N	L	1	1	1	1					1	1		1				1		1	1
Denver	CO	N	L	1			1		1		1	1					1		1		1	1
Confederated Salish and Kootenai Tribes	MT	N	L	1	1						1	1	1									1
Dane County	WI	N	L	1																		
Fresno County	CA	N	L	1	1		1					1			1				1			1
Milwaukee	WI	N	L		1	1	1															1
Anne Arundel County	MD	Y	L	1	1						1	1	1									1
Baltimore	MD	Y	L	1	1		1				1	1										1
Boston	MA	Y	L	1	1																	
Chula Vista	CA	Y	L				1				1								1			1
Lee County	FL	Y	L	1	1							1	1						1		1	1
Los Angeles	CA	Y	L	1	1							1	1				1		1			1
Miami-Dade County	FL	Y	L									1							1			1
New York City	NY	Y	L		1												1		1	1		1
Oakland	CA	Y	L	1	1	1															1	
San Luis Obispo (county)	CA	Y	L	1	1		1					1							1			1
Albany, NY	NY	N	M	1	1																	
Fairbanks North Star Borough	AK	N	M	1		1					1	1									1	1
Flagstaff	AZ	N	M	1	1	1											1					
Grand Rapids	MI	N	M		1		1												1			
Missoula County	MT	N	M				1					1										
Lafourche Parish	LA	Y	M		1						1								1			1
Santa Barbara	CA	Y	M	1	1																1	1
Santa Cruz (city)	CA	Y	M	1	1	1						1	1									1
Worcester County	MD	Y	M	1	1		1					1										
Chester	PA	N	S	1																		
Keene	NH	N	S	1	1						1	1							1			
Laguna Woods	CA	N	S	1	1	1	1															1
Marquette	MI	N	S	1																		
Dorchester County	MD	Y	S		1														1			
Durham	NH	Y	S		1																	
Groton	CT	Y	S		1										1							
Guilford	CT	Y	S	1	1						1	1	1						1			1
Jamestown S'Klallam Tribe	WA	Y	S	1	1						1	1									1	1
Lewes	DE	Y	S	1	1	1																
Portsmouth	NH	Y	S	1	1												1					1
Punta Gorda	FL	Y	S	1	1		1		1			1			1				1	1	1	1
Salem	MA	Y	S	1								1			1							1
Satellite Beach	FL	Y	S	1	1		1		1			1	1								1	
Seabrook	NH	Y	S																			
Somerset County	MD	Y	S	1	1																	
Swinomish Tribe	WA	Y	S	1	1						1	1					1		1		1	1
Waveland	MS	Y	S	1	1	1															1	

Appendix 6 – Initial metrics included by the authors in the first phase of coding within the 'actions' principle detailed in Chapter 4

Table 21. Initial metrics included by the authors in the first phase of coding within the 'actions' principle. This table summarizes all of the criteria included by the authors within the actions principle. Column one lists the names of the individual criteria. All criteria are grouped into two categories: those that are specific types of adaptation actions and those that help justify the need for adaptation action implementation. Column two briefly describes each criterion, and column three presents the percentage of plans within the sample that included the criterion.

Criterion	Description	Percent Plans
Type of Adaptation Action Proposed		
Capacity building	The plan includes capacity building actions. Capacity building is developing human resources, institutions and communities, equipping them with the capability to adapt.	84%
Advocacy	The plan includes advocacy actions. Advocacy includes encouraging regional and state agencies to have adaptation-appropriate actions.	25%
General actions	The plan includes generic adaptation actions, which are actions not specific enough to be classified in another category.	91%
Information and awareness	The plan includes information and awareness actions, which are actions focused on increasing public knowledge.	84%
Research and monitoring	The plan includes research or monitoring actions, which are those that focus on gathering information and creating reports, maps, or models; monitoring includes observation or repeated measurements over time.	95%
Planning	The plan includes planning-related actions, which include actions that incorporate understanding of climate science, impacts, vulnerability and risk into government and institutional planning process, efforts, or existing initiatives.	91%
Practice and behavior	The plan includes actions to change practice and behavior. Practice and behavior actions revise or expand practices and on-the-ground behavior that affect resilience.	95%
Policy and legislation	The plan includes policy and legislation actions aimed at preparing for climate change.	80%
Physical infrastructure	The plan includes physical infrastructure actions to prepare for climate change.	82%
Building codes and engineering design standards	The plan includes actions to improve physical infrastructure's response to changing climate through improved standards or engineering.	70%
Green infrastructure	The plan includes green infrastructure actions aimed at providing protection from climate hazards.	64%
Land use	The plan includes land use actions focused on preparing for climate change.	82%
Conservation	The plan includes conservation actions to preserve biodiversity and protect open space under a changing climate.	66%
Financing	The plan includes financing or insurance actions to prepare for future climate changes.	55%
Technology	The plan includes technology actions.	66%
Justification for the Adaptation Actions		
Prioritized actions	The plan prioritizes adaptation actions.	34%
Prioritized actions detailed	The plan prioritizes adaptation actions and describes how actions were ranked.	20%
Specific adaptation actions	The plan includes actions that are linked to specific impacts.	55%
Cost	The plan estimates the cost of implementing specific adaptation actions.	30%
Cost detailed	The plan identifies the cost of implementing each adaptation action.	16%
Cost of inaction	The plan states that taking action to adapt to climate change costs less than not acting.	43%
Cost of inaction detailed	The plan provides specific dollar figures on the cost of inaction versus adaptation.	30%
Co-benefits	The plan identifies co-benefits associated with taking adaptation action.	50%

Appendix 7 – Initial metrics included by the authors in the first phase of coding within the 'implementation and monitoring' principle detailed in Chapter 4

Table 22. Initial metrics included by the authors in the first phase of coding within the 'implementation and monitoring' principle. This table summarizes all of the criteria included by the authors within the implementation and monitoring principle. Criteria are grouped into two categories: those that support implementation and those that support monitoring. Column one lists the names of the individual criteria. Column two briefly describes each criterion, and column three presents the percentage of plans within the sample that included the criterion.

Criterion	Description	% Plans
Implementation Metrics		
Timetable for implementation	Provides a timetable for when each action will be implemented.	32%
Implementation responsibilities	Assigns responsibility for policies broadly to organizations or agencies.	39%
Implementation responsibilities detailed	Assigns responsibility for the implementation of each action.	34%
Funding (need for)	Describes the *need* for funding sources to implement the plan.	36%
Potential funding sources detailed	Clearly describes potential funding sources and associates them with particular actions.	23%
Mainstreaming	Discusses mainstreaming climate change adaptation. Mainstreaming refers to the integration of climate adaptation into other sector policies or plans.	84%
Mainstreaming detailed	Identifies specific plans and programs as opportunities for mainstreaming. Mainstreaming refers to the integration of climate adaptation into other sector policies or plans.	61%
Barriers	Mentions barriers to climate adaptation.	23%
Monitoring Metrics		
Reporting requirements	Includes requirements for the regular reporting of implementation progress.	16%
Monitoring responsibility	Mentions assignment of responsibility for monitoring.	20%
Evaluation method	Establishes a process to evaluate the plan.	7%
Evaluation method detailed	Describes when analyses of progress toward objectives will take place and how results will be used.	5%
Evaluation metrics	Mentions how to measure progress towards implementing actions.	16%
Evaluation metrics detailed	Mentions how to measure progress towards implementing each action identified in the plan.	14%
Plan updates	Mentions need for updates.	27%
Plan updates detailed	Includes timetable for updating plan.	16%

Appendix 8 – Plans included in analysis conducted in Chapter 4

Table 23: List of communities with an adaptation plan (left column) and name of the plan (included in the analysis).

Community	Plan Title
Albany, NY	Albany Climate Change: Vulnerability Assessment and Adaptation Plan
Anne Arundel County MD	Sea Level Rise Strategic Plan: Anne Arundel County
Austin, TX	Toward a Climate-Resilient Austin
Baltimore, MD	Disaster Preparedness and Planning Project: Combined All Hazards Mitigation and Climate Adaptation Plan
Boston, MA	Climate Ready Boston: Municipal Vulnerability to Climate Change
Boulder County, CO	Boulder County Climate Change Preparedness Plan
Chester, PA	The City of Chester Vision 2020: Climate Adaptation Planning Elements
Chula Vista, CA	Climate Adaptation Strategies: Implementation Plans
City and County of Denver, CO	City and County of Denver Climate Adaptation Plan
Confederated Salish and Kootenai Tribes, MT	Climate Change Strategic Plan
Dane County, WI	Climate Change and Emergency Preparedness
Dorchester County, MD	Sea Level Rise: Technical Guidance for Dorchester County
Durham, NH	Climate Adaptation Chapter: Developing Strategies to Protect Areas at Risk from Flooding due to Climate Change and Sea Level Rise
Fairbanks North Star Borough, AK	Interior Issues Council Climate Change Task Force: Preliminary Vulnerability Assessment Report
Flagstaff, AZ	City of Flagstaff Resiliency and Preparedness Study
Fresno County, CA	Integrated Strategies for a Vibrant and Sustainable Fresno County
Grand Rapids, MI	Grand Rapids Climate Resiliency Report
Groton, CT	Preparing for Climate Change in Groton, Connecticut: A Model Process for Communities in the Northeast
Guilford, CT	Town of Guilford Community Coastal Resilience Plan
Jamestown S'Klallam Tribe, WA	Climate Vulnerability Assessment and Adaptation Plan
Keene, NH	Adapting to Climate Change: Planning a Climate Resilient Community
Lafourche Parish, LA	The Lafourche Parish Comprehensive Resiliency Plan
Laguna Woods, CA	Climate Adaptation Plan
Lee County, FL	Lee County Climate Change Resiliency Strategy
Lewes, DE	The City of Lewes Hazard Mitigation and Climate Adaptation Action Plan
Los Angeles, CA	Sea Level Rise Vulnerability Study for the City of Los Angeles
Marquette, MI	Adapting to Climate Change and Variability
Miami-Dade County, FL	Second Report and Initial Recommendations: Presented to The Miami-Dade Board of County Commissioners
Milwaukee, WI	Wisconsin Initiative on Climate Change Impacts: Milwaukee Working Group Report
Missoula County, MT	Missoula County Climate Action: Creating a Resilient and Sustainable Community
New York City, NY	A Stronger, More Resilient New York
Oakland, CA	Community Based Climate Adaptation Planning: Case Study of Oakland, California
Portsmouth, NH	City of Portsmouth, New Hampshire’s Coastal Resilience Initiative Climate Change Vulnerability Assessment and Adaptation Plan
Punta Gorda, FL	City of Punta Gorda Adaptation Plan
Salem, MA	Ready for Tomorrow: The City of Salem Climate Change Vulnerability Assessment and Adaptation Plan
San Luis Obispo (county), CA	Integrated Climate Change Adaptation Planning in San Luis Obispo County
Santa Barbara, CA	City of Santa Barbara Sea Level Rise Vulnerability Study

Santa Cruz (city), CA	City of Santa Cruz Climate Adaptation Plan: An Update to the 2007 Local Hazard Mitigation Plan 2012-2017
Seabrook, NH	Adaptation Strategies to Protect Areas of Increased Risk From Coastal Flooding Due to Climate Change
Somerset County, MD	Somerset County, Maryland: Rising Sea Level Guidance
Swinomish Tribe, WA	Swinomish Climate Change Initiative Climate Adaptation Action Plan
Waveland, MS	City of Waveland Local Hazard Mitigation Plan
Worcester County, MD	Sea Level Rise Response Strategy: Worcester County, Maryland

Appendix 9 - Opportunities for embedding climate change into hazard mitigation planning per discussion in Chapter 5

Table 24. Opportunities for embedding climate change into hazard mitigation planning. Column 1 presents the content of the original FEMA Crosswalk, broken into the six main elements required for all local hazard mitigation plans. Column 2 denotes potential ways that climate change could be integrated into each required element of the Crosswalk.

Existing Requirement per the FEMA Crosswalk	Code Used to Assess Whether Climate Change Was Integrated into Each Element of the Crosswalk
Element A: Planning Process	
A1: Does the plan document the planning process, including how it was prepared and who was involved in the process for each jurisdiction?	Climate related stakeholders included in the planning process
	Climate change discussed during public discussions
A2: Does the plan document an opportunity for neighboring communities, local and regional agencies involved in hazard mitigation activities, agencies that have the authority to regulate development as well as others interests to be involved in the planning process?	Regional climate related entities included in planning process
A3: Does the plan document how the public was involved in the planning process during the drafting stage?	
A4: Does the plan describe the review and incorporation of existing plans, studies, reports, and technical information?	Integrated information from existing climate plans or reports into analysis
A5: Is there discussion of how the community(ies) will continue public participation in the plan maintenance process?	
A6: Is there a description of the method and schedule for keeping the plan current (monitoring, evaluating and updating the mitigation plan within a 5-year cycle?)	Plan exists to integrate new climate information, as it is developed, into plan and actions
Element B: Hazard Identification and Risk Assessment	
B1: Does the plan include a description of the type, location, and extent of all natural hazards that can affect each jurisdiction?	Discussion of how climate change could affect each hazard in the community
	General discussion about climate change and natural hazards
	Climate change considered as a stand alone hazard
B2: Does the plan include information on previous occurrences of hazard events and on the probability of future hazard events for each jurisdiction?	Climate change is factored into probability calculations for future hazards
B3: Is there a description of each identified hazard's impact on the community as well as an overall summary of the community's vulnerability for each jurisdiction?	Discussion of how climate change could affect each hazard in the community
B4: Does the plan address NFIP-insured structures within the jurisdiction that have been repetitively damaged by floods?	Considers structures to be flooded given changes to the floodplain
Element C: Mitigation Strategy	
C1: Does the plan document each jurisdiction's existing authorities, policies, programs, and resources and its ability to expand on and improve these existing policies and programs?	Programs related to climate change included in capability statement
C2: Does the plan address each jurisdiction's participation in the NFIP and continued compliance with NFIP requirements, as appropriate?	Evaluation and mitigation actions included for structures in the 1 in 500 year (or greater) floodplain
C3: Does the plan include goals to reduce/avoid long-term vulnerabilities to the identified hazards?	Design goals with climate change in mind
C4: Does the plan identify and analyze a comprehensive range of specific mitigation actions and projects for each jurisdiction being considered to reduce the effects of hazards, with emphasis on new and existing buildings and infrastructure?	Includes actions that are specifically designed to be viable in a climate-altered future
C5: Does the plan contain an action plan that describes how the actions identified will be prioritized (including cost benefit review), implemented, and administered by each jurisdiction?	Include climate change-related criteria in the evaluation of potential actions

C6: Does the plan describe a process by which local governments will integrate the requirements of the mitigation plan into other planning mechanisms, such as comprehensive or capital improvement plans, when appropriate?	Explicit mention of or action for integrating climate related priorities into other plans
Element D: Plan Review, Evaluation, and Implementation (applicable to plan updates only)	
D1: Was the plan revised to reflect changes in development?	Discussion of historical changes in climate
D2: Was the plan revised to reflect progress in local mitigation efforts?	Discussion of progress in implementing previously identified climate related actions
D3: Was the plan revised to reflect changes in priorities?	Climate change integrated as a priority into plan update
Element E: Plan Adoption	
E1: Does the plan include documentation that the plan has been formally adopted by the governing body of the jurisdiction requesting approval?	Formal adoption and commitment to climate adaptation
E2: For multi-jurisdictional plans, has each jurisdiction requesting approval of the plan documented formal plan adoption?	Regional climate initiative discussed or started