Measuring Climate Adaptation:
Assessing the Use of Indicators in U.S. Coastal Cities

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Abstract

In response to the growing threat of climate change, in recent years many U.S. cities have developed climate adaptation plans. However, they have made limited progress implementing these plans and even less progress evaluating the effectiveness of them. Indicators have the potential to help cities track the implementation and effectiveness of their adaptation strategies. They have been used in many fields to simplify complex systems, measure achievement, reflect changes over time, facilitate communication and information exchange, allow for comparison between places and provide relevant information to decision-makers. To date there has been a lack of information on whether U.S. cities are using indicators in their adaptation planning. Based on an analysis of adaptation plans and interviews with staff in nine large coastal cities in the United States, this thesis finds that most cities are not using indicators to measure their adaptation efforts, although several cities are considering developing them. It also finds that cities face a number of barriers to using adaptation indicators, including those related to resources, information, technical challenges, and organizational structure. Adaptation indicator sets and frameworks developed by research organizations and non-profits can help cities overcome some of these barriers and select and use adaptation indicators. This thesis concludes by providing recommendations for cities and nonprofit and research organizations for developing quality indicators, overcoming barriers and advancing the state of knowledge about adaptation indicators.

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Chapter 1: Introduction

With the effects of climate change already being felt and expected to worsen in the future, cities are planning for how to address climate change. In a historic international agreement in Paris in December 2015, nations pledged to limit global warming to under 2° Celsius; however, the country commitments that make up the agreement are unlikely to keep warming below 2.7° C (Schiermeier 2016). This means that even if these commitments are met – which would require rapid and ambitious cuts in greenhouse gas emissions – the world will still experience drastic global warming and its effects, including sea level rise, flooding, extreme heat, drought, heavy precipitation, and more intense storms (Schiermeier 2016; IPCC 2014).

In cities, the effects of climate change will be exacerbated by existing urban stressors, such as aging infrastructure, concentrations of poverty and high population density (Melillo, Richmond, and Yohe 2014). Urban infrastructure is highly vulnerable to the impacts of climate change: flooding could damage roads and airports, severe storms could lead to power outages, and extreme heat could prevent trains from operating safely, to name a few examples. Interdependencies between critical services mean that a problem with one type of infrastructure could lead to cascading failures throughout entire urban systems (The Lifelines Council 2014).

In addition to affecting infrastructure, climate change impacts the people living in cities and metropolitan areas – 80% of the U.S. population (Melillo, Richmond, and Yohe 2014). People are vulnerable to the health effects of increased heat and flooding, including heat-related illnesses and deaths, cardiovascular and respiratory diseases, vector-borne diseases, stress and poor mental health (Crimmins et al. 2016). Social characteristics,

including socioeconomic status, race, gender and age, also affect both who faces the impacts of climate change and how well people are able to cope with these impacts (Melillo, Richmond, and Yohe 2014). For example, urban elderly are particularly vulnerable to heat waves and will be adversely impacted by the increased heat resulting from climate change.

While there has not been sufficient action to address climate change on the international and national scale, in the last 10 years cities have taken a leadership role in reducing greenhouse gas emissions, which is also known as climate mitigation (Rosenzweig et al. 2010). Cities are conducting emissions inventories, setting emissions reductions goals, and developing plans for how they will reach these goals (Rosenzweig et al. 2010; Steinhoff and Wei 2015). Cities are also combining emissions reduction strategies with broader sustainability efforts that improve both the environment and quality of life for residents.

Climate adaptation was once viewed as something that would distract from efforts to reduce emissions, but this changed in the mid-2000s (Pielke et al. 2007). Spurred by the experience of extreme weather events such as Superstorm Sandy on the U.S. East Coast in 2014, as well as the realization that the world will experience impacts of climate change even if emissions are curtailed (Berrang-Ford, Ford, and Paterson 2011; Pielke et al. 2007), cities are beginning to plan for how to adapt to climate change. Today, cities are pursuing climate adaptation as a complementary strategy to mitigation (Carmin, Nadkarni, and Rhie 2012).

Many U.S. cities have developed adaptation plans, but have made limited progress in implementing these plans (Carmin, Nadkarni, and Rhie 2012; Hansen et al. 2013). Even if adaptation plans are implemented, most cities and organizations are not evaluating the

effectiveness of these adaptation strategies (Hansen et al. 2013). Without this kind of evaluation, cities have inadequate information about which adaptation strategies are most effective in limiting the impacts of climate, how well prepared they are to meet the challenges of climate change, and what positive or negative effects adaptation strategies will have on other aspects of the community (for example, whether they will increase or decrease emissions or disproportionately burden the poor).

Indicators – quantitative or qualitative variables that measure particular conditions or attributes (USAID 2009) – can help cities track the implementation and effectiveness of their adaptation efforts. Indicators are used to simplify complex systems, measure achievement, reflect changes over time, facilitate communication, promote information exchange, and provide relevant information to decision-makers (OECD 2002; Smeets and Weterings 1999; Solecki et al. 2015). They can also be used to compare and rank cities, countries or organizations (The Rockefeller Foundation and Arup 2014). Although indicators have been used in many fields, including public health, education, and sustainability, their use in adaptation planning thus far is limited. Academic and gray literature discusses the challenges of using indicators to measure adaptation, and many frameworks and tools have been developed to help cities and organizations use adaptation indicators. However, there has been little research on whether U.S. cities are actually using indicators to measure adaptation.

In this thesis, I attempt to fill this gap by examining to what extent cities are using indicators in their adaptation planning, both to track the implementation of adaptation plans and to measure the effectiveness of adaptation strategies. I also explore the barriers preventing cities that are not currently using adaptation indicators from doing so. Finally, I

evaluate how cities can use existing tools and frameworks to help them develop adaptation indicators.

To answer these questions, I analyzed adaptation plans and conducted interviews with city staff from nine U.S. coastal cities. I also reviewed existing adaptation indicator sets and frameworks for developing indicators and assessed their utility to U.S. cities. I find that although the use of indicators in adaptation planning thus far is limited, several cities are planning to develop indicators to measure the effectiveness of their adaptation strategies. In addition, although cities cite many obstacles preventing them from using adaptation indicators, there are strategies that can help them overcome some of these barriers. Although adaptation indicators face many challenges, they are valuable in helping cities understand what is and is not working and how they can adjust their strategies to be more effective in combating the impacts of climate change.

Roadmap

I begin in Chapter 2 by reviewing the literature on climate adaptation and how U.S. cities are pursuing it. Chapter 3 introduces the concept of indicators, explains their use in other fields, and describes considerations for choosing indicators based on a literature review. In this chapter I also provide examples of how indicators have been used in adaptation planning to date. Chapter 4 describes my methodology, and Chapter 5 provides the results of my analysis of adaptation plans and interviews with city staff. This chapter describes the structure of the adaptation plans, the use of indicators for measuring implementation and effectiveness, and barriers to using indicators that cities face. Chapter 6 reviews four adaptation indicator frameworks that were brought up in the interviews

and assesses their utility to cities undertaking adaptation planning. Finally, Chapter 7 concludes the thesis by providing recommendations to cities and nonprofit and research organizations for developing quality indicators, overcoming some of the barriers to adaptation indicators and advancing the state of knowledge about adaptation indicators.

Chapter 2: Climate Adaptation Background

Defining adaptation and resilience

Since the early 2000s, there has been an increase in the number of cities pledging to address climate change through reducing greenhouse gas emissions, also known as climate mitigation. Many cities have set emissions reduction goals; for example, an 80% reduction in carbon emissions by 2050 is a goal adopted by many governments and supported by the International Panel on Climate Change (IPCC) (Steinhoff and Wei 2015). Cities are pursuing strategies to reach these mitigation goals, but are also incorporating emissions reduction into broader sustainability efforts. Mitigation strategies that cities are pursuing include increasing renewable energy usage, increasing energy efficiency in buildings, adopting strategies to reduce the number of car trips, and promoting food waste reduction, among many others (Steinhoff and Wei 2015).

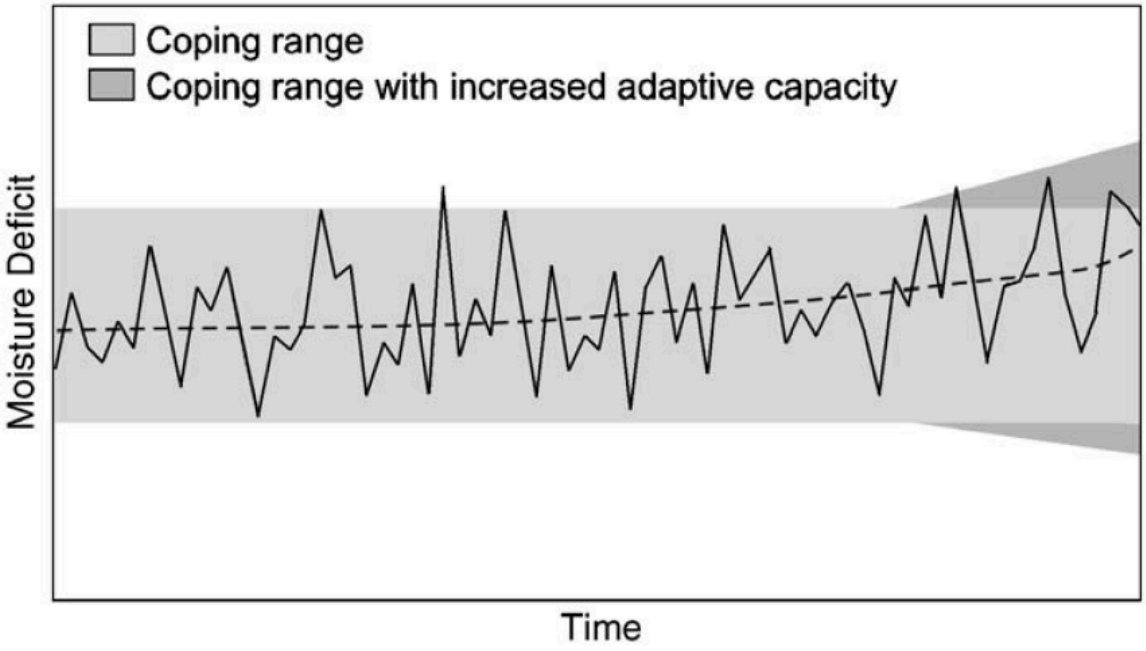
However, the effects of climate change are already being experienced worldwide and are likely to persist even if greenhouse gas emissions are curtailed. Therefore, to address climate change many countries and cities are turning to adaptation as a complementary strategy to mitigation. Climate change adaptation is the process of adjustment to actual or expected climate change and its effects (International Panel on Climate Change 2013). Adaptation can be reactive, in response to a stress that has already occurred, or anticipatory, in an attempt to lessen an anticipated negative impact from future events (Engle 2011). Adaptation is expensive, but less costly than not taking action; in the United States, investing approximately $50 billion in adaptation over the next 20 years could lead to approximately $135 billion in averted losses over the lifetime of the adaptive measures (Melillo, Richmond, and Yohe 2014).

Adaptation involves reducing the vulnerability of a system to climate change. Vulnerability is a function of *exposure* to risks and the *sensitivity* of a system, or the degree to which people and places can be harmed by the exposure (Cutter et al. 2008). Climate mitigation strategies attempt to reduce exposure to risks by reducing the greenhouse gas emissions that are causing climate change and sea level rise. Adaptation strategies typically address the sensitivity of a system by minimizing the harms that communities experience when faced with these risks.

Adaptation often involves building adaptive capacity, which is the ability of a community to respond to changes (Adger, Arnell, and Tompkins 2005). Increasing adaptive capacity expands the range of risks that a community can cope with (see Figure 1). It is determined by factors such as access to financial, technical and information resources, leadership, and the institutions present in a community (Smit and Wandel 2006). Actions that governments have taken to increase adaptive capacity include modeling expected sea level rise, developing adaptation plans, and educating the public about evacuation routes.

In addition to increasing a community's adaptive capacity, adaptation involves transforming that capacity into action by implementing adaptation decisions (Adger, Arnell, and Tompkins 2005). Examples of adaptation strategies that cities have pursued include building dykes to prevent ocean flooding, planting trees to minimize the heat island effect, and moving electrical equipment from basements to upper floors so they will not get damaged in floods. Adaptation strategies can also support mitigation, and vice-versa; these types of actions are often referred to as having "co-benefits". For example, planting trees both reduces atmospheric carbon dioxide and leads to a reduction in the heat island effect.

Figure 1: Effect of increased adaptive capacity on coping with drought
(Smit and Wandel 2006)



A related concept to adaptation is resilience. Building off of earlier definitions from the field of ecology (Holling 1973), the International Panel on Climate Change (IPCC) defines resilience as, "the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity of self-organization, and the capacity to adapt to stress and change" (IPCC 2007). Specific to cities, resilience is "the capacity of cities to function, so that the people living and working in cities – particularly the poor and vulnerable – survive and thrive no matter what stresses or shocks they encounter" (The Rockefeller Foundation and Arup 2015b). This perspective on resilience emphasizes enhancing the performance of a system that faces multiple and unpredictable hazards, some but not all of them resulting from climate change.

Resilience and adaptation are closely related. Part of the IPCC's definition of resilience – "the capacity to adapt to stress and change" – mirrors the definition of adaptive

capacity introduced above, a critical part of climate adaptation. However, not all resilience strategies address climate change, and not all adaptation strategies build resilience. Although actions taken to increase a community's resilience often address climate threats, they also deal with broader stresses a community might face, such as economic development or inequality. In addition, adaptation actions can be carried out in a way that does not build resilience. For example, building a sea wall could protect a community from the specific threat of a certain amount of storm surge, but would not build the capacity of the community to withstand or bounce back from other hazards. This reinforcement of physical assets is sometimes referred to as "hardening"; most cities in their adaptation plans are looking beyond the hardening of infrastructure to pursue social and ecological strategies as well.

Some U.S. cities have developed resilience strategies that involve climate change adaptation, while others have developed standalone adaptation plans that do not explicitly address broader elements of resilience. The term adaptation will be used throughout this thesis to refer to both of these types of planning for climate change. Resilience will be used when a plan or source explicitly focuses on this concept.

Climate adaptation planning in U.S. cities

Climate adaptation is dependent on context and linked to location, both in terms of the climate risks faced and the solutions to address them. While mitigation requires action on a global scale, adaptation actions taken at the local level can help to protect that community from the effects of climate change. Therefore, the local government and community scale is an appropriate scale for adaptation action (Mimura et al. 2014).

Adaptation planning has become more common in recent years. Between 2007 and 2013, when the IPCC published its fourth and fifth assessment reports, the world made significant progress on adaptation, particularly at the national level but also at the municipal level (Mimura et al. 2014). Still, cities are spending a small amount of their budgets on adaptation-related activities. Georgeson et al (2016) evaluated the "adaptation economy" in ten megacities worldwide and found that these cities are spending a maximum of 0.33% of their gross domestic product on adaptation. In all of the cities studied, the largest percentage of this spending is in the built environment subsector, while many also spend relatively large percentages on adaptation activities related to water, transportation infrastructure, and professional services. In all but one of the cities, spending on adaptation grew by an average of 2.5-4.5 percent annually between 2008 and 2015 (Georgeson et al. 2016).

The prevalence of urban adaptation planning in the U.S. is lower than in the rest of the world (Hughes 2015), and monitoring and evaluation of these efforts is extremely low (Hansen et al. 2013). A 2012 global survey on climate adaptation in cities found that 68% of the cities that responded were pursuing adaptation planning; however, only 59% of cities in the U.S. were doing so (Carmin, Nadkarni, and Rhie 2012).[1] The same survey also categorized cities by their stage of adaptation planning, ranging from preparatory stages to monitoring and evaluation. 18% of cities globally were engaged in implementation; in the U.S., only 9% of cities were in the implementation phase. None of the U.S. cities surveyed

[1] Since this survey was sent to members of ICLEI: Local Governments for Sustainability, who have joined an international coalition of cities that support sustainability, it likely overestimates the prevalence of adaptation planning worldwide.

were in the monitoring and evaluation phase (Carmin, Nadkarni, and Rhie 2012; Shi, Chu, and Debats 2015).

Implementation of climate adaptation strategies is proceeding slowly at the state level as well. Ray and Grannis (2015) reviewed the implementation of 14 state adaptation plans and found that only 59% of the goals in the plans were either in progress or completed. Only 0.5% of the goals addressed post-implementation monitoring. Similarly, a review of community plans in British Columbia found that they had limited consideration for implementation and monitoring of both climate adaptation and mitigation strategies (Baynham and Stevens 2014).

U.S. cities engaging in adaptation planning often work with international and national networks. Most prominent is the Rockefeller Foundation's 100 Resilient Cities (100RC) program, which provides selected cities worldwide funding to hire a Chief Resilience Officer for two years to lead the city's resiliency efforts. Selected cities also become part of a network of cities undertaking resilience efforts and receive technical support from the Rockefeller Foundation and other partners. To date, the Rockefeller Foundation has selected 67 cities to participate in the program, including 15 from the United States. The rest of the 100 cities will be announced in mid-2016 (Rockefeller Foundation 2016).

Organizations and networks that have traditionally supported cities in their work on sustainability are also moving into the adaptation space. These include the global networks ICLEI: Local Governments for Sustainability and C40 Cities, as well as the Urban Sustainability Directors Network (USDN) in the United States (ICLEI 2016; "C40 Cities" 2016; USDN 2016).

Factors leading to adaptation planning

Researchers have used both interviews and quantitative analyses to evaluate what leads some cities to pursue climate adaptation planning while others do not. Hughes (2015) found that factors leading to adaptation planning fall into the categories of motivations and framing, governance arrangements, and financing. Motivations include a level of awareness about climate change among decision makers (often triggered by a hazard or natural disaster) and the desire of local leaders to show leadership. Adaptation efforts are often framed as a necessary strategy for protecting a city's assets and reducing vulnerability, or as no-regrets actions that will lead to benefits no matter what climate impacts the city experiences. Governance arrangements leading to adaptation planning include a task force or coordinating body within city government, regional coordination between cities, and coordination between cities and other levels of government, NGOs or researchers. Finally, financing is a huge barrier to adaptation. Many cities overcome this barrier by relying on external funding sources like state or federal governments or foundations.

Similarly, Shi, Chu, and Debats (2015) found that factors associated with cities engaging in climate adaptation planning include greater commitment by elected officials, higher municipal spending per capita, and perceptions that the climate is already changing. A study based on interviews with local decision makers found that political will and local political culture are important factors leading to adaptation planning, while scientific uncertainty and politicization of climate change may inhibit climate action (Carlson and McCormick 2015). Other barriers to adaptation include lack of leadership, lack of financial and technical resources, limited communication and information about the problem and

solutions, and differing values and beliefs affecting how people think about and perceive risk (Moser and Ekstrom 2010).

Chapter 3: Indicators in Climate Adaptation Planning

Defining indicators

The term indicator refers to a quantitative or qualitative variable that provides a reliable means to measure a particular phenomenon or attribute (USAID 2009). Indicators are used to simplify complexity; they provide bits of information that reflect the status of large or complex systems (Smeets and Weterings 1999; Tyler Norris Associates et al 1997). Indicators have several purposes: they can measure achievement, reflect changes over time, facilitate communication, promote information exchange, and provide relevant information to decision-makers (OECD 2002; Smeets and Weterings 1999; Solecki et al. 2015). Indicators can also be used to compare and rank cities, countries or organizations (The Rockefeller Foundation and Arup 2014).

Although some might think of indicators as numerical, they can actually be either quantitative or qualitative; a metric is a quantitative indicator. Indicators are often categorized into outcome and process indicators. Outcome indicators demonstrate that a particular objective has been achieved (Bours, McGinn, and Pringle 2014b). For example, a common outcome indicator for climate change mitigation strategies is the carbon emissions reduced as a result of a particular program. In contrast, process indicators measure the progression towards the achievement of an outcome, but do not guarantee or measure the final outcome itself (Bours, McGinn, and Pringle 2014b). For illustration, an example of a process indicator related to climate mitigation is the amount of renewable energy installed. Renewable energy usage typically leads to emissions reductions, but does not measure this outcome directly. In program evaluation, process indicators are often

divided into inputs to a program, such as dollars invested or staff time, and outputs, such as the number of pilot projects launched (Stadelmann et al. 2011).

Since the use of indicators in climate adaptation planning is relatively new, it is useful to look to other fields that have developed indicators in order to understand when it is appropriate to use indicators. Moreover, some of the indicators used in other fields could be repurposed to measure adaptation as well. The following sections discuss examples of indicators from several fields and perspectives: results-based management, sustainability, public health, and city government. These examples are not meant to be a comprehensive accounting of all of the ways that indicators have been used in these fields. Rather, the discussion shows that indicators have been used in a variety of public policy contexts and that attempts to develop indicators for climate adaptation follow this trend.

Indicators in public policy

Indicators have been used to measure organizational and government performance for over half a century. In 1943, Clarence E. Ridley and Herbert A. Simon published "Measuring Municipal Activities", the first attempt to explain how governments should measure what they do in addition to how much it costs them (Walters 1994). Since then, governments and other organizations have used indicators to measure progress in many sectors, including international development, education, public health and sustainability.

Developing indicators to measure performance stems from the tradition of results-based management, which focuses on achieving results and continually improving based on information about performance (Binnendijk 2000). Results-based management, which is also called performance management, allows an organization to objectively measure how

well its stated objectives are being met. It involves articulating and agreeing on objectives, selecting indicators, setting targets, monitoring performance by collecting data on the indicators, and analyzing those results vis-à-vis the targets (Binnendijk 2000). These results are then used for accountability, learning, and decision-making (Bakewell and Garbutt 2005).

The logical framework approach (LFA) is a type of results-based management that is commonly used in international development but has also spread to other fields. In the LFA, a goal is developed, and underlying outcomes, outputs, activities and inputs are identified (Bakewell and Garbutt 2005). Indicators can measure any of the elements of the framework. The logical framework is often displayed in a matrix, which includes a summary of the goal, outcomes, outputs, etc.; indicators to measure each one of these elements; a description of the means of verification for the indicators; and assumptions (see Figure 2) (Bakewell and Garbutt 2005).

The pressure-state-response (PSR) model is a common framework for presenting environmental indicators. The PSR model is based on the concept of a causal chain, and makes a distinction between forces that act on the environment, such as social and economic changes (pressure); changes that happen to the environment as a consequence (state); and the societal response to those changes (response) (Niemeijer and de Groot 2008). Indicators can measure the pressure, state, or response. For example, in the case of climate change, carbon dioxide emissions would be the pressure, which affects the concentration of CO2 in the atmosphere, the state; a response may be the implementation of a carbon tax (Bossel 1999). Variations of this framework have also been developed, such as the driving force-pressure-state-impact-response (DPSIR), which identifies more steps

along the causal chain (see Figure 3) (Niemeijer and de Groot 2008). Although this framework is typically used for presenting indicators, it can also be used as a guide in their selection (Niemeijer and de Groot 2008).

Figure 2: Illustration of the Logical Framework Approach
(Bakewell and Garbutt 2005)

Narrative summary	**Objectively verifiable indicators**	**Means of verification**	**Assumptions**
Goal – the overall aim to which the project is expected to contribute	Measures (direct or indirect) to show the project's contribution to the goal	Sources of information and methods used to show fulfillment of goal	Important events, conditions or decisions beyond the project's control necessary for maintaining the progress towards the goal
Outcomes (or objectives) – the new situation which the projects is aiming to bring about	Measures (direct or indirect) to show what progress is being made towards reaching the objectives	Sources of information and methods used to show progress against objectives	Important events, conditions or decisions beyond the project's control, which are necessary if achieving the objectives is going to contribute towards the overall goal
Outputs – the results which should be within the control of the project management	Measures (direct or indirect) to show if project outputs are being delivered	Sources of information and methods used to show delivery of outputs	Important events, conditions or decisions beyond the project's control, which are necessary if producing the outputs is going to help achieve the objectives
Activities – the things which have to be done by the project to produce the outputs	Measures (direct or indirect) to show if project outputs are being delivered	Sources of information and methods used to show that activities have been completed	Important events, conditions or decisions beyond the project's control, which are necessary if completing activities will produce the required outputs
Inputs	Resources – type and level of resources needed for the project Finance – overall budget Time – Planned start and end date		

Figure 3: Pressure-state-response and related frameworks
(Niemeijer and de Groot 2008)

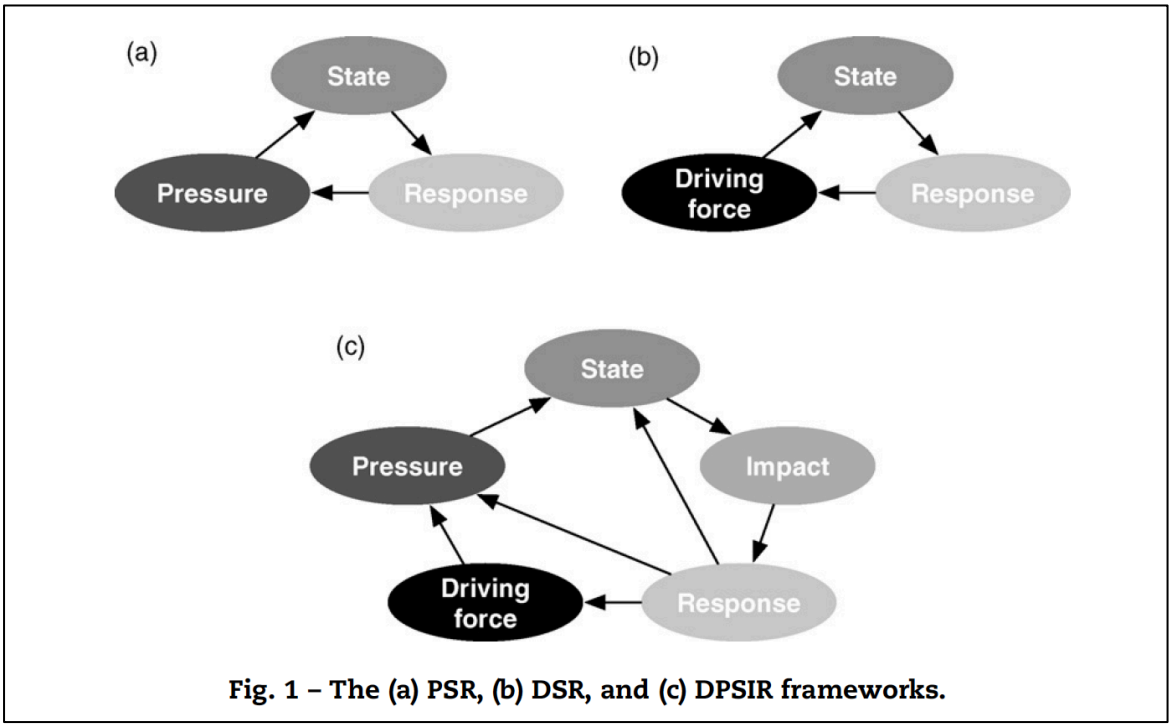


Fig. 1 – The (a) PSR, (b) DSR, and (c) DPSIR frameworks.

Location-based indicators

Many cities have developed indicators to track various aspects of government and performance. For example, the New Orleans Office of Performance and Accountability (OPA) publishes an interactive, online annual report that lists indicators across a variety of topic areas and city departments. The indicators are displayed along with objectives and targets, so that residents and others viewing the site can see where the city is meeting its targets and where it is falling short (City of New Orleans 2016). Similarly, Los Angeles has an online dashboard that tracks progress in meeting the short and long-term goals laid out in its sustainability plan. The website displays indicators associated with each of the goals

and provides information on whether or not the city is on track to meet the goals (City of Los Angeles 2016).

In Boston, the Boston Foundation, a local philanthropic organization, spearheaded an initiative to track indicators at the municipal scale across a variety of sectors. The Boston Indicators Project includes 30-year goals that will end in 2030, along with indicators for each goal (The Boston Foundation 2016). Every three years, the project publishes a report that describes the status of the various indicators with a particular focus (Martin and Vance 2015).[2] Goals and their associated indicators are also displayed online. Also in the Boston area, the Metropolitan Area Planning Council (MAPC) uses indicators to track progress towards achieving the goals laid out in MetroFuture, the region's long-term vision plan. MAPC also periodically publishes reports focusing on a specific aspect of the indicators, such as equity or regional prosperity (Metropolitan Area Planning Council 2016).

Sector-specific indicators

Indicators have also been applied to characterize particular sectors, such as education and health. In field of public health, indicators have been used to measure health outcomes, determinants of health, and the effectiveness of public health interventions. For example, the Center for Disease Control's National Environmental Public Health Tracking Program has a goal of providing communities with information that they can use to improve their health. The CDC and state partners track a number of indicators that link environmental and health trends (Centers for Disease Control and Prevention 2015).

[2] For example, in 2015 the report focused on upward mobility.

Researchers have also developed frameworks around the nexus between health and the environment (Hambling, Weinstein, and Slaney 2011; Briggs 2003).

In the field of education, the use of indicators grew out of the education reform movement and an increased interest in accountability in schools in the mid-1980s (Blank 1993). This trend continued with a move towards "results-based accountability", the idea that educators are accountable for student learning and accountable to the general public (Anderson 2004). The 2001 No Child Left Behind Act, with its focus on high-stakes assessments, exemplifies this trend (Anderson 2004). Indicators have also been used in education to compare and assess performance across countries (OECD 2014) and states (NEA Research 2015), and within individual states (Educate Maine 2015).

Sustainability Indicators

As climate adaptation is closely related to sustainability, efforts to measure adaptation may have the most to learn from sustainability indicators. Beginning in the mid to late 1990s, numerous organizations and researchers attempted to develop indicators of sustainable development (Bossel 1999; Meadows 1998; Barnett, Lambert, and Fry 2008; OECD 2003; Reed, Fraser, and Dougill 2006; Peet and Bossel 2000). These efforts faced the challenge of first defining sustainable development, and then determining what indicators could effectively measure it (Meadows 1998).

One of the first efforts to develop sustainability indicators at the municipal scale occurred in Seattle, where sustainability indicators were developed by a volunteer working group in the early 1990s as a way of introducing the concept of sustainability and establishing a foundation for future advocacy and policy work (AtKisson 1996). In 1996, an

international group of leading measurement and assessment experts created the Bellagio Principles to provide guidance on sustainable development indicators (Pintér et al. 2012). Rather than proposing a particular set of indicators, this framework includes eight principles for measuring and assessing sustainable development, such as agreeing on a guiding vision (a definition of sustainability), incorporating an adequate scope (time and geography), and encouraging transparency, effective communication, and broad participation (Pintér et al. 2012). In 2003, the Compendium of Sustainable Development Indicators listed over 500 sustainability indicator efforts (Parris and Kates 2003). None of these efforts were universally accepted, and the majority were local or metropolitan in scope (Parris and Kates 2003).

Today, while there is still not a universally agreed upon set of sustainability indicators, there are several widespread indicator frameworks that companies and cities use. For example, the Global Reporting Initiative ("GRI" 2015) and Carbon Disclosure Project ("CDP" 2015a) provide a structure for companies and cities to report on a specific set of indicators related to sustainability and carbon emissions. Sustainability rating systems such as LEED and STAR Communities score buildings or communities on their sustainability based on a set of credits that these organizations have developed (U.S. Green Building Council 2016; STAR Communities 2016). The LEED ratings can themselves be considered indicators, with a "LEED Platinum" rating signifying that a building was constructed according to high sustainability standards. In addition, many city sustainability plans contain specific targets that can be tracked with clearly defined indicators (for example, the Sustainable DC Plan (District of Columbia 2013)).

Rationale for adaptation indicators

Climate adaptation is starting to follow the trend seen in other fields of using indicators to measure performance. Scholars have proposed several reasons why the field of climate adaptation can benefit from using indicators. Adaptation indicators allow governments and organizations to assess the effectiveness of their programs and ensure that adaptation is achieving its desired outcomes, such as reducing vulnerability to climate change (Ford et al. 2013; Pringle 2011; DEFRA 2010; Preston et al. 2009). From a financial perspective, evaluating adaptation programs can help justify funding spent on adaptation and achieve maximum value for money (Ford et al. 2013; DEFRA 2010).

Adaptation indicators can also support learning by allowing governments to discover which strategies are working well and which are struggling, and to adjust their approach accordingly (Preston et al. 2009; Pringle 2011). One way of doing this is through adaptive management, an iterative learning process that aims to produce improved understanding and management over time (William, Szaro, and Shapiro 2009). While adaptive management is typically used in the field of natural resource management, it has also been attempted in other arenas (William, Szaro, and Shapiro 2009). Adaptive management can increase resilience to climate change through increasing ecological stability and developing more flexible institutions (Tompkins and Adger 2004). It involves integrating the decision-making, monitoring, and assessment processes and designing a monitoring plan from the outset, of which indicators can be an important part (William, Szaro, and Shapiro 2009).

In addition to facilitating learning, monitoring can support accountability by demonstrating if governments have met their stated commitments to climate adaptation

(OECD 2015; Preston et al. 2009). Adaptation indicators can also help cities communicate to the public about climate change impacts and what is being done to address them (Ford et al. 2013). Using a similar set of indicators across cities can facilitate comparison and allow planners to adopt adaptation strategies from successful cities (Pringle 2011). Finally, having indicators tied to an adaptation strategy can let cities take credit for adaptation initiatives that they are already undertaking, such as initiatives that are part of a sustainability plan but also contribute to adaptation.

Challenges for adaptation indicators

Despite these benefits, researchers have identified a number of challenges in using indicators to measure climate adaptation efforts. Although some of these are broader monitoring and evaluation (M&E) challenges, many of them relate to complex systems or elements of climate change specifically. Some of the foremost challenges discussed in the literature are presented below, along with strategies that researchers have suggested to address these challenges.

Long time horizon

Climate adaptation initiatives often have a long time horizon, and the effects of an intervention may not be seen for decades. However, most programs and evaluation of them focus on the short term (Ford et al. 2013; Bours, McGinn, and Pringle 2014a; DEFRA 2010; Climate-Eval 2015). Since some adaptation interventions will have a shorter-term impact, researchers have suggested that indicators should reflect both short and long timescales (Spearman and McGray 2011).

Attribution

Attributing a particular adaptation intervention to a reduction in vulnerability to climate change is challenging, as many factors influence climate impacts and risk. There is no clear counterfactual that will show what would have happened without an adaptation intervention (OECD 2015; Pringle 2011; Climate-Eval 2015; Spearman and McGray 2011). To address this, evaluations of adaptation can focus on measuring the improvement of adaptive capacity in the absence of stresses and shocks, with the assumption that this will make a community better able to deal with these shocks when they do occur (Climate-Eval 2015). Another approach is to compare the performance of two communities with similar climates and characteristics, but only one of which has undertaken an adaptation strategy (Institute for Sustainable Communities et al 2016).

An additional attribution challenge involves isolating the effects of particular initiatives (Pringle 2011; Climate-Eval 2015). Many factors could lead to a reduction in climate change impacts. How would one determine if fewer heat-related illnesses were caused, for example, by fewer hot days, by an increase in air conditioning use caused by rising incomes, or by an adaptation-specific initiative to open more cooling centers throughout the city? It may be more feasible to focus on the *contribution* that a particular project makes to adaptation, rather than trying to attribute changes to only one intervention (Climate-Eval 2015). Similarly, it may make more sense to try to attribute changes to collective actions, rather than to a single organization or government entity (Ebrahim 2015).

A related challenge is that adaptation is cross-sectoral and involves actors at different levels and departments of government. An effective M&E protocol should consider the entire system and linkages between different elements (Spearman and McGray 2011). However, if one department is leading the effort to develop indicators, this may be difficult in practice.

Uncertainty

Uncertainty around climate impacts makes it difficult to anticipate the effectiveness of adaptation actions (DEFRA 2010; Pringle 2011; Spearman and McGray 2011). An intervention may be successful when judged against one climate scenario, but unsuccessful when played out against the climate impacts that happen in reality. This uncertainty makes it difficult to establish a baseline against which adaptation initiatives are measured (OECD 2015; Climate-Eval 2015). Setting the baseline at present day will lead to very different evaluation results compared to setting the baseline at some point in the future. To address this uncertainty, some advocate for flexibility and ability to change as an important attribute of successful climate adaptation interventions (Bours, McGinn, and Pringle 2014a). However, it can be difficult to measure this kind of flexibility empirically.

Defining success

There is no single, agreed-upon indictor that can show the success of adaptation the way that a reduction in carbon dioxide emissions does with climate mitigation (Ford et al. 2013). Moreover, there is a lack of consensus around what constitutes successful adaptation and how to measure it (Pringle 2011; Spearman and McGray 2011; UNEP 2014).

Perhaps due to this disagreement around what constitutes successful adaptation, many cities and organizations have not set clear and actionable adaptation targets (UNEP 2014; Moser and Ekstrom 2010). Without a clear target, it is impossible to know whether an adaptation action has reached its desired outcomes (OECD 2015) and it is difficult to select indicators to measure it.

Maladaptation

Adaptation interventions have the potential to lead to unintended negative outcomes; this concept is known as maladaptation (Climate-Eval 2015). Maladaptive strategies could increase greenhouse gas emissions, disproportionately burden vulnerable populations, have high costs compared to alternative options, reduce incentives to adapt, or limit the choices available to future generations (Barnett and O'Neill 2010). Incorporating maladaptation into an evaluation is challenging because maladaptive effects are almost always unanticipated. Therefore, it is difficult to include them in predetermined indicators (Climate-Eval 2015). One way to attempt this is to include both big picture analysis and qualitative data in addition to quantitative indicators. Qualitative data may be more likely to show unanticipated negative consequences of adaptation (Climate-Eval 2015).

Data availability and funding

The process of developing a system for adaptation M&E and tracking indicators is resource intensive and works best when there is data collected for other purposes available (OECD 2015). The ability to store, organize, and retrieve data is a barrier to

adaptation M&E (Moser and Ekstrom 2010). If an indicator list is too long, communities may lose the ability to track indicators effectively (Institute for Sustainable Communities et al 2016). However, if a community believes that an indicator is important but does not have the data for it, it can select that indicator as an advocacy tactic to spur agencies to start collecting the data (AtKisson 1996).

Types of adaptation indicators

There are several ways that governments and other organizations are evaluating climate risks and adaptation actions. Each mode of evaluation has a corresponding type of indicator that should be used. First, many governments conduct vulnerability or climate risk assessments to determine baseline risks or evaluate changing risks over time (Ford et al. 2013; OECD 2015). To measure risk and vulnerability, organizations use climate indicators, which measure physical climate trends, and impact indicators, which track the potential impact of a hazard on a community (Jacob et al. 2010). An example of a climate indicator is the number of days above 90 degrees, while a corresponding impact indicator would be the number of heat-related deaths.

Evaluations of "adaptation readiness" are also common. Adaptation readiness refers to the presence of key governance factors that are essential for effective adaptation. Increasing adaptation readiness is an example of increasing the adaptive capacity of a community, and it can be used as a proxy for tracking adaptation (Ford et al. 2013). Readiness indicators could include political leadership, such as the number of speeches given about climate change, or education, such as the number of residents provided with information about climate risks.

Evaluations can also monitor progress on adaptation priorities (OECD 2015). Process indicators measure progression towards the achievement of an outcome, but do not guarantee or measure the final outcome itself (Bours, McGinn, and Pringle 2014b). Examples of process indicators related to adaptation include the number of people trained in disaster response and the number of flood barriers installed. Process indicators are based on assumptions about the effects that certain actions will have – for example, that training people in disaster response will improve a community's ability to reduce the negative impacts of a disaster.

Cities may also be interested in evaluating the effectiveness of an adaptation program or its ability to meet certain goals; this is often done using outcome indicators. As mentioned above, outcome indicators demonstrate that a particular objective has been achieved. Specific to climate adaptation, outcome indicators measure reduced negative climate change *impacts*, as opposed to actions or processes that are expected to reduce risk but do not necessarily do so. Examples of adaptation outcome indicators include the prevalence heat-related illnesses and monetary losses from natural disasters (Ford et al. 2013).[3]

Categorizing indicators into whether they address climate, impact, readiness, process, or outcome can help governments and organizations figure out what kinds of indicators they should use based on their stage of adaptation planning or the type of evaluation they are interested in doing. The next step is to select the indicators themselves. There has been considerable research conducted, largely from outside the field of climate adaptation, on what characteristics indicators should have.

[3] Many climate impact indicators could also be considered outcome indicators, and vice-versa.

Choosing quality indicators

Indicator characteristics

There have been numerous attempts to describe the characteristics of high quality indicators. Most ubiquitous are the SMART principles, which state that goals and their corresponding indicators should be Specific, Measurable, Attainable, Relevant, and Trackable (Binnendijk 2000). Specific denotes that an indicator has a clear and precise meaning and that it only measures one phenomenon (Harley et al. 2008; Morse 2004; Spearman and McGray 2011). Measurable indicators are objective and replicable; anyone using the same data should be able to get the same results (National Academies 2012; Harley et al. 2008; Morse 2004). Attainable refers to the goals or targets set rather than the indicators themselves. It should be possible to achieve goals in an appropriate timeframe and with the resources available. Relevant indicators provide useful information for decision-makers to act upon, and are also something that a wider audience is interested in and cares about (Solecki et al. 2015; Tam and Seville 2014; Spearman and McGray 2011; Morse 2004). Finally, trackable indicators have data sources available that can be collected regularly and assessed to report on progress.

Many scholars have suggested additional characteristics for choosing indicators. For example, indicators should be transparent, so that all stakeholders can understand why an indicator was selected and how it is measured (National Academies 2012; ND-GAIN 2016; Harley et al. 2008). If they are used as part of a performance management system, indicators should be tied to a goal or target that an organization is working towards (Pintér et al. 2012; Tam and Seville 2014; Crowley 2015). Indicators should also be based on

evidence and current best practices and updated when the state of knowledge about the topic changes (ND-GAIN 2016; Crowley 2015).

From a practical perspective, indicators should use data that is reliable, recent, and available (ND-GAIN 2016; Morse 2004; Spearman and McGray 2011; Pintér et al. 2012). They should also be affordable and cost-effective; if it is too costly to collect data on a certain indicator, the indicator will go unused (Spearman and McGray 2011; Morse 2004). For indicators to get used they should also have clear ownership, in terms of who is responsible for collecting the data and evaluating progress towards a target (Spearman and McGray 2011; Tam and Seville 2014).

Several authors have proposed criteria for adaptation indicators specifically. Tam and Seville (2014) argue that adaptation indicators should focus on the positive side of resilience rather than on vulnerability because the idea of moving towards a more resilient community is more appealing to a broad audience than a discussion about reducing risk or managing harm, which may scare people off. An adaptation indicator should be sensitive to change such that adaptation actions lead to a change in the indicator (Spearman and McGray 2011; Morse 2004). Finally, adaptation indicators may benefit from a systems perspective. Since climate change and adaptation is complex and multi-dimensional, organizations can benefit from choosing bundles of indicators across different scales rather than searching for a single indicator to measure adaptation (Crowley 2015).

Most of this literature focuses on selecting individual indicators, but Parris and Kates (2003) propose criteria for developing sets of indicators. Indicator sets should have salience, credibility, and legitimacy. Salience refers to the relevance of the indicator set to decision-makers. Credibility means that the measurement system is scientifically and

technically accurate. Finally, legitimacy refers to the perception that the indicator set is respectful of divergent views and is unbiased.

Criteria for successful adaptation

In order to select adaptation indicators, cities need to know not only what makes a good indicator, but also what these indicators should be measuring. That is, what does successful adaptation look like? This is often determined by goals that a city itself sets in its adaptation plan. However, there are also several common frameworks that describe successful adaptation or resiliency. These frameworks can help cities in setting goals and selecting indicators.

Adger, Arnell, and Tompkins (2005) propose four criteria for successful adaptation: effectiveness, efficiency, equity, and legitimacy. Effectiveness refers to whether adaptation achieves its expressed objectives. Efficiency refers to the costs and benefits of adaptation and how these are distributed. Equity can be evaluated based on the outcome (who wins and who loses) as well as the process (who decides). Finally, legitimacy is the extent to which decisions about adaptation are acceptable to the stakeholders affected by the decisions. These criteria often involve competing values; which ones are prioritized will depend on the values and world view of those engaging in the adaptation planning process (Adger, Arnell, and Tompkins 2005).

In addition to effectiveness, efficiency and equity, Hedger et al (2009) propose flexibility and sustainability as criteria for successful adaptation. Adaptation should be flexible to address the range of possible climate scenarios. Flexible adaptation involves avoiding large up-front sunk costs, building capacity to improve resilience and make better

decisions in the future, and implementing "no regrets" actions that will be desirable regardless of what climate scenario plays out. Sustainability refers to the long-term impact and viability of an adaptation action, as well as the broader environmental, social, and economic impacts. Based on repeated consultations with experts, Doria et al define successful adaptation as, "any adjustment that reduces the risks associated with climate change, or vulnerability to climate change impacts, to a predetermined level, without compromising economic, social, and environmental sustainability'' (Doria et al. 2009, 815).

The International Federation of the Red Cross (IFRC) and Arup describe "safe and resilient" communities as those that are knowledgeable and healthy, organized, connected, have infrastructure and services, have economic opportunities, and can manage their natural assets (Arup International Development and International Federation of Red Cross and Red Crescent Societies 2011). Tyler and Moench (2012) identify three elements of a city – systems, agents, and institutions – and describe characteristics that would make each element resilient. Systems refer to physical infrastructure and ecosystems that allow for the provision of services and networks of exchange. Resilient systems have flexibility and diversity, redundancy, and the ability to fail safely. Resilient social agents should exhibit responsiveness, resourcefulness, and a capacity to learn. Institutions that are resilient have clear rights and entitlements to use key resources or access urban systems, have a transparent and accountable decision-making process, and provide credible and meaningful information about risk and vulnerability to the community. They should also facilitate the generation and application of new knowledge to enhance resilience.

In their "City Resilience Framework", the Rockefeller Foundation and Arup propose seven characteristics of a resilient city. Resilient cities are reflective, meaning that they accept uncertainty, have the ability to continually evolve and learn from past experiences. They are robust, with well-managed physical assets and the ability to fail safely, as well as redundant, with spare capacity purposely created within the system. Resilient cities are also flexible, resourceful, and inclusive. Finally, they are integrated, with alignment between different city systems (The Rockefeller Foundation and Arup 2015b).

Examples of adaptation indicators

As discussed above, policymakers and planners have become interested in adaptation indicators for their ability to assess the effectiveness of adaptation actions, justify funding, support learning and adaptive management, and demonstrate accountability to the public. However, adaptation indicators face methodological challenges related to the uncertainty and long time horizon of climate change, the difficulty of attributing changes in vulnerability to particular actions, and the lack of a clear definition of what successful adaptation is. Despite these challenges, and the fact that adaptation planning – and the use of indicators to measure it – is relatively new, there are numerous examples of indicators sets that have been created to measure adaptation and frameworks created to guide the development of indicators. These examples fall into three main categories: top-down indicator sets, bottom-up indicator sets, and guiding frameworks. Chapter 6 discusses the utility of several of these frameworks to U.S. cities.

With bottom-up indicator sets, a community measures its own progress with a specific set of indicators.[4] The community may use a standardized set of indicators that are developed by an outside group or use indicators that they chose themselves; either way, it uses the indicators to measure its *own* progress or effectiveness. In contrast, with top-down indicator sets this evaluation is done by an outside organization. Finally, guiding frameworks have the objective of helping communities with the process of selecting and using indicators, but do not prescribe which indicators should be used.

Top-down indicator sets

With a top-down indicator set, an outside organization such as a higher level of government, a foundation or non-profit organization, or a researcher collects the data and evaluates the indicators. Approaches within this category include quantitative analyses and indexes.

Quantitative approaches

Researchers use quantitative approaches to identify outcome indicators by finding correlations between particular indicators and observable impacts of climate change. Using the indicators of deaths from natural disasters and the correlation between skin cancer death rates and living in a warm state, Kahn tests the "adaptation progress hypothesis" that society is adapting to climate change over time (Kahn 2003). Brooks et al (2005) examine the statistical relationships between factors that represent sensitivity and exposure to climate hazards and mortality from climate-related disasters; through this process they

[4] Here a community can refer to a country, state, city, neighborhood or some other relevant scale.

identify 11 indicators of vulnerability. Stadelmann et al (2011) evaluate two potential indicators for measuring adaptation effectiveness: wealth saved from destruction through climate change impacts, and disability-adjusted life years saved.

Yohe and Tol (2002) propose a quantitative method of evaluating adaptive capacity by assessing the potential contributions of various adaptation options to improving a system's coping capacity. This methodology is designed to produce unitless indicators to facilitate comparison of relative vulnerability and adaptive capacity. Finally, Wheeler (2011) developed country-level indicators for three dimensions of climate change: more extreme weather, sea level rise, and loss of agricultural productivity. He incorporates the indicators into a methodology for cost-effective allocation of adaptation assistance.

Indexes

Indicators can facilitate comparison between cities, states, or countries about both vulnerability and the effectiveness of adaptation initiatives. To allow for comparison on the same scale, indicators are often combined into indexes, which aggregate multiple indicators into a single measure (Morse 2004). A number of indexes have been developed to compare vulnerability and resiliency between cities or countries. With these top-down indexes, an outside organization typically does the evaluation, using the same dataset or comparable data to score and rank cities or countries. Many of these indexes track vulnerability to climate change rather than the effects of particular adaptation actions.

The University of Notre Dame has developed a Global Adaptation Index (ND-GAIN), which compares countries on vulnerability to climate change and readiness to adapt ("Notre Dame Global Adaptation Index" 2015). Building off of this global index, ND-GAIN

and the Kresge Foundation are developing an urban-scale assessment framework for climate vulnerability and testing it in five U.S. cities ("The Urban Adaptation Assessment Framework" 2015). The index will include indicators in three categories: vulnerability of lives and livelihoods to climate change, readiness to adapt, and adaptation plans. Indicators are being developed in consultation with an advisory group of 35 adaptation practitioners and researchers from throughout the United States. The project is focused on developing empirically based indicators by correlating potential indicators with outcome data such as the economic or health effects of climate change (Meghan Doherty, personal communication, February 11, 2016).

The Social Vulnerability Index (SoVI) uses socioeconomic and demographic data to create an index of vulnerability to environmental hazards, and applies it on a county level in the United States (Cutter, Boruff, and Shirley 2003). Cutter, Burton, and Emrich (2010) developed disaster resilience indicators that can be used to track changes in resilience in communities over time or to compare communities. This index is made up of indicators that measure social, economic, institutional, and infrastructure resilience as well as community capital.

Several other indexes focus on particular geographic areas or sectors. At the state level, the States at Risk report uses a grading system to show to what extent U.S. states are prepared for current and future climate risks. The letter grades are based on both the magnitude of current and future threats and the actions states have taken to prepare for them, relative to other states (Climate Central and ICF International 2016). The Resilience Capacity Index, developed by the Buffalo Regional Institute, takes an economic approach to evaluating the resilience of 361 metropolitan areas in the U.S. The index includes 12

indicators in three categories: regional economic capacity, socio-demographic capacity, and community connectivity capacity (Rockefeller Foundation and Arup 2014). CityNet developed an index comprised of 125 variables to assess the disaster resilience of Asian cities. The scoring is based on questionnaires that the cities themselves fill out. This index focuses on measuring response to extreme events rather than broader measures of resilience (Rockefeller Foundation and Arup 2014).

Wheeler developed a vulnerability index that ranks 233 countries and regions across 11 indicators. This index is designed to provide information to donor institutions that seek to offer financial assistance for adaptation to climate change on a national level (Wheeler 2011). Finally, the Resilience Scorecard evaluates local plans by assessing the degree to which local land use plans target areas most prone to hazards (Berke et al. 2015).

Bottom-up indicator sets

If a community were to use a bottom-up indicator set, it would measure its own adaptation progress or effectiveness with a specific set of indicators. The community may use a standardized set of indicators that are developed by an outside group, or use indicators that they choose themselves. Approaches fitting into this category include community assessment tools as well as individualized sets of indicators developed by a country or a city.

Community assessment

In contrast to top-down indexes in which an outside party measures the vulnerability or resilience of a community, several organizations have developed

community assessment tools that guide communities through measuring their own adaptation or resilience using a set of predetermined indicators. The Coastal Resilience Index is a self-assessment tool that allows a community to predict whether it will reach and maintain an acceptable level of functioning after a disaster and figure out where it needs to prioritize resilience actions. The tool asks cities to develop scenarios based on a bad storm in the past (selected by the community) and a future storm (50% worse than the bad storm). The tool guides the community through a set of yes/no questions about how it would respond to these disasters. By counting up the responses in different categories, the tool ranks the community's resilience in those areas as low, medium, or high (Sempier et al. 2010).

Similarly, the Disaster Resilience Scorecard for Cities, developed by the UN International Strategy for Disaster Risk Reduction (UNISDR), is a set of assessments that allow cities to understand how resilient they are to natural disasters. Within the categories of governance and financial issues, planning and disaster preparation, and disaster response and post-event recovery, the scorecard lists items for the community to rank themselves on using a 1-5 scale; descriptions are provided for each rank (UNISDR 2015).

The Rockefeller Foundation and Arup are developing a City Resilience Index that describes what makes a city resilient and provides cities a way to assess their own resilience and make decisions based on it (The Rockefeller Foundation and Arup 2015b). To date, the initiative has identified 12 goals that describe the outcomes of a resilient city, as well as high-level indicators. Moving forward, it will identify more specific measures that cities will be able to use and track. To help cities use the index to assess their resilience, this framework will lead cities through a series of online prompt questions. These will

include both quantitative indicators and qualitative assessments that use a sliding scale (The Rockefeller Foundation and Arup 2015a).

C40's Climate Risk and Adaptation Framework and Taxonomy (CRAFT) is a standardized reporting framework for cities to disclose information about local climate hazards and impacts, risk and vulnerability assessments, and adaptation planning and implementation. Cities will be able to access the framework through tools that have traditionally been used for sustainability reporting – CDP Cities and the Carbonn Climate Registry (C40 Cities, n.d.; CDP 2015b; carbonn Climate Registry 2014). Reporting through this framework will allow cities to benchmark their performance against global averages and leaders as well as identify other cities that are facing similar climate risks in order to share adaptation strategies and best practices (CDP 2016).

Developed by a country

Many countries are addressing adaptation at the national level, and have been developing methods for evaluating progress at this scale. In a recent report, the OECD describes national monitoring and evaluation frameworks for adaptation in 11 countries in Europe, Asia, and Africa (OECD 2015). For example, the United Kingdom conducts repeated vulnerability and risk assessments and evaluates changes, and Kenya uses outcome and process indicators that focus on institutional adaptive capacity (OECD 2015). Over the past few years, Germany developed 102 climate adaptation indicators aligned with the 15 action fields in its strategy for Adaptation to Climate Change (DAS). Beginning this year, the indicators have been used to track progress towards the goals laid out in the DAS (GIZ GmbH 2013).

Developed by a city

Adaptation indicators are being developed at the municipal scale as well. The New York City Panel of Climate Change (NPCC) recommends that the city develop a Climate Resiliency Indicators and Monitoring System and proposes potential indicators in the categories of climate indicators, impact indicators, social vulnerability indicators, and resiliency indicators (Solecki et al. 2015). Eco Adapt and the Boston Harbor Association developed a set of sample adaptation indicators for Boston, although tracking these has not been integrated into city practice. Vancouver Canada's climate adaptation plan includes adaptation indicators in its appendix (United Nations Development Programme 2007).

Guiding frameworks

Numerous frameworks have been created to guide cities or organizations through the process of developing adaptation indicators, without necessarily prescribing what indicators they choose. Writing about sustainability assessment frameworks, Magee et al note that, "Frameworks may not be sufficient but they remain necessary to the development of robust and relevant sustainability assessments. They are important to guiding associated planning, decision-making, monitoring, and implementation activities" (Magee et al. 2013, 26). None of the frameworks that have been developed for adaptation indicators has been universally agreed upon, and there have been numerous efforts to identify gaps or drawbacks to existing frameworks and propose new ones (The Rockefeller Foundation and Arup 2014; Institute for Sustainable Communities et al 2016).

Many of these frameworks focus on the project or program scale in an international development context. A series of "guidance notes" from Sea Change and UKCIP discusses how practitioners might identify adaptation indicators and develop a "theory of change" model for mapping out desired outcomes and pathways to achieve them (Bours, McGinn, and Pringle 2014a-c). The International Federation of the Red Cross and Arup held workshops in 30 communities in Asia to identify the characteristics of resilient communities. The six characteristics identified will be used in designing Red Cross programs as well as in measurement and evaluation (Arup International Development and International Federation of Red Cross and Red Crescent Societies 2011).

The United Nations Development Programme's (UNDP) Monitoring and Evaluation Framework for Adaptation to Climate Change was created to fulfill the mandates of two adaptation-focused funding programs mandated by the United Nations Framework Convention on Climate Change (UNFCCC). The framework is intended to guide UNDP staff in the design of monitoring and evaluation methods for adaptation initiatives, including developing indicators (United Nations Development Programme 2007). Similarly, the Adaptation Fund Results Framework was designed to help agencies implementing UNFCCC Adaptation Fund projects design program baselines and results frameworks using a logical framework approach (Adaptation Fund 2011).

Brooks et al propose an approach to evaluating adaptation that involves assessing both how well climate risks to development are managed by institutions (upstream indicators) and how successful adaptation interventions are in reducing vulnerability and keeping development on track (downstream indicators) (Brooks et al. 2011). Similar frameworks for developing indicators include the TANGO Resilience Assessment

Framework and the Community-Based Resilience Assessment (CoBRA) (Climate-Eval 2015).

Several recent initiatives provide guidelines for developing indicators at the city level. In the United States, the Urban Sustainability Director's Network (USDN) has published a white paper that reviews existing adaptation indicator frameworks and assesses their utility to cities (Institute for Sustainable Communities et al 2016). Although the project set out to recommend a particular framework or set of indicators, the authors realized that because the context for adaptation varies across cities, it would be more useful to develop a set of guidelines geared towards city adaptation professionals (Mike Crowley, personal communication, February 1, 2016). The final product provides guidelines for how urban adaptation practitioners can develop indicators customized for their communities.

An ongoing UN-HABITAT project has the goal of providing local governments with tools for measuring and increasing resilience to multiple hazards, including those associated with climate change. Based on partnerships with 10 cities around the world, the project intends to produce a set of indicators, a set of global standards, and a monitoring framework. The project will also involve publishing city resilience profiles of the selected cities (The Rockefeller Foundation and Arup 2014).

The ADAPTMe Toolkit guides organizations of any scale through developing an adaptation evaluation process, including determining the purpose of the evaluation, determining the logic that underpins assumptions, overcoming challenges and developing indicators. The toolkit is practice-oriented; questions for practitioners to consider as they are developing the evaluation are listed throughout the report (Pringle 2011). Spearman

and McGray (2011) propose a 6-step framework for developing M&E systems for climate adaptation. The framework emphasizes matching an intended program to socioeconomic, environmental, climatic, institutional, and other key contexts. The report also provides guidance for choosing indicators and example indicators.

Indicator limitations

Despite the proliferation of indicators in public policy, sustainability and other fields, and their growth in climate adaptation, indicators are not without limitations. Although they are often presented as objective measures of reality, there is in fact a great deal of subjectivity involved in selecting and using indicators, including in choosing the areas that they focus on, what they measure, and how they are measured. Those who select indicators have power to set an agenda, direct policy priorities and funding, and shape how a phenomenon is perceived (Morse 2004). Indicators tend to be perceived as having authority (i.e., "if the indicator says it, it must be true!"). However, this often distracts from direct experience, which can sometimes differ from what indicators show (Meadows 1998). The fact that indicators simplify complexity is necessary for them to facilitate decision-making and knowledge exchange. However, too much simplification can also lead to indicators that do not correctly convey information about the system they represent (Meadows 1998).

Poorly chosen indicators can also lead to problems. An invalid measure does not accurately reflect the concept that it purports to convey; therefore, it does not create meaningful information about a system and how to affect change in it (Moser 2015). For example, a community might select "number of houses with flood insurance" as an

indicator to measure preparation for flooding. However, an increase in this indicator might signify that more people are buying houses in the floodplain, rather than an increase in the percentage of vulnerable homes that are insured.

Indicators are often chosen based on data availability rather than what is actually a priority for the community (Meadows 1998; OECD 2015). In addition, indicators are often chosen in an ad hoc way, based on the interests or expertise of the authors. This leads to sets of indicators that have a great deal of detail in certain areas, while leaving out other important elements (Bossel 1999). Although the pressure-state-response (PSR) framework attempts to develop indicators in a more systematic way, its focus on unidirectional causal chains fails to encompass the complexity of entire systems, which are often dynamic and have many feedback loops (Bossel 1999). Once indicators are chosen, they may not be used in a meaningful way if the data or resources is not available to track them, or if decision-makers are not interested in using the indicators to create change, learn, or revisit prior decisions (Moser 2015; Moser and Ekstrom 2010).

On top of these general concerns about indicators, indexes come with an additional set of drawbacks. Aggregation reduces the ability to see and understand the different elements that make up the index (The Rockefeller Foundation and Arup 2014). Aggregating multiple indicators into a single index can mask deficiencies in one area, which can threaten the overall health of the system (Bossel 1999); a community can score fairly high on a particular index even if it is struggling on one aspect of the index. Similarly, characteristics such as vulnerability are not typically distributed evenly throughout a population. Aggregating these concepts into an index hides spatial variation (Barnett, Lambert, and Fry 2008). For example, a community could be wealthy overall but have

pockets of poverty. An index measuring income and wealth across communities is likely to fail to acknowledge this variation within a single community.

Developing an index involves weighing the different indicators that comprise the index, and this is often done in a subjective way (Barnett, Lambert, and Fry 2008; The Rockefeller Foundation and Arup 2014). Since indexes are often used to compare countries or communities and prioritize funding, how an index is developed and weighted has meaningful implications. For example, indexes of sustainable development often rank wealthy countries higher than poor ones if they do not control for GDP (Morse 2004).

Despite these limitations, experts have noted the value of using indicators. Writing about sustainable development indicators, Donella Meadows explains:

> "Indicators are hard to define. They are based on uncertain models. Their selection and use are full of pitfalls. They carry different messages to different minds. These difficulties don't mean, however, that we shouldn't use indicators. We have *no choice.* Without them we fly blind. The world is all too complex to deal with *all* available information. We have to choose a set of indicators small and meaningful enough to comprehend." (Meadows 1998, 27).

In other words, the alternative to using indicators is to try and understand all of the information available. It will be difficult to use this overload of information to try and guide decision-making.

Although indicators overall and adaptation indicators in particular face some pitfalls, there have been numerous attempts to develop sets of indicators and frameworks that can help governments and organizations with the process of developing adaptation indicators. Some of these frameworks also attempt to overcome some of the challenges with adaptation indicators discussed above. However, there has not been an assessment of whether U.S. cities are actually using adaptation indicators or drawing upon these many

frameworks. In the next three chapters, I will discuss how nine U.S. cities are using or thinking of developing adaptation indicators, based on a review of adaptation plans and interviews with city staff. I will also consider how cities can use existing indicator frameworks to help them develop adaptation indicators.

Chapter 4: Methods

City selection and characteristics

Cities were selected based on three criteria: size, coastal location, and the presence of a climate adaptation plan. I focused on large cities because I hypothesized that large cities have more capacity to both plan for climate change and collect the data required for adaptation indicators. I selected cities with an adaptation plan in place because the presence of an adaptation plan makes it possible to evaluate whether the plan itself includes indicators and also whether the city is using indicators to measure the implementation and effectiveness of the plan.

I selected coastal cities because the climate risks and associated adaptation actions in coastal and non-coastal cities differ. In particular, coastal cities are vulnerable to the impacts of sea level rise, storm surge and costal storms, in addition to the extreme heat and precipitation events that many non-coastal cities also face. U.S. coastal communities represent concentrations of both population and economic activity. 50% of Americans – 164 million people – live in coastal counties (Melillo, Richmond, and Yohe 2014). In addition, up to $1 trillion in property and structures are at risk of flooding from two feet of sea level rise, which could be reached by 2050-2070 (Melillo, Richmond, and Yohe 2014). Finally, sea level rise and coastal flooding is a very visible impact of climate change and has spurred coastal cities to begin planning for adaptation (particularly following Superstorm Sandy in 2012) (Hughes 2015). Therefore, coastal cities may be further along in their adaptation planning efforts than non-coastal cities.

To select the cities meeting these three criteria, I began with a list of the 100 largest U.S. cities by population, obtained from the U.S. Census Bureau and based on 2014 data

(U.S. Census Bureau, Population Division 2015). 31 of these cities are coastal cities. To determine if the coastal cities had a climate adaptation plan in place, I reviewed the Georgetown Climate Center's Adaptation Clearinghouse (Georgetown Climate Center 2016), which contains an online database of state and local adaptation plans, and the Rockefeller Foundation's 100 Resilient Cities website (Rockefeller Foundation 2016). Since these sources may not be up to date or comprehensive, I supplemented this with Google searches to ensure that I was capturing adaptation plans if the city had them.

Some cities developed their adaptation plan as part of a broader climate action plan or sustainability strategy; I included those cities if the plan contained specific goals related to adaptation. However, just the mention of the need to adapt to climate change or discussion of the climate impacts the city faces did not warrant inclusion. I also included cities that developed their adaptation plans as part of a broader resilience strategy, as long as climate change was one of the risks considered in that plan.

Nine of the 31 coastal cities had an adaptation plan in place that met these criteria. For one of these nine cities – Miami – adaptation planning is occurring at the county level. To account for the range in adaptation governance structures, I included this county plan. Table 1 lists the cities and county selected and provides information about their adaptation plans.

Table 1: Cities included in the study and their climate adaptation plans

Municipality	2014 population[5]	Department responsible for adaptation	Adaptation plan reviewed	Year adaptation plan adopted
New York, New York	8,491,079	Office of Recovery and Resiliency	OneNYC	2015
Miami-Dade County, Florida	2,662,874	Office of Resiliency	Greenprint Sustainability Plan	2010
Boston, Massachusetts	655,884	Energy, Environment, and Open Space Cabinet	Greenovate Climate Action Plan Update	2011
Baltimore, Maryland	622,793	Office of Sustainability	Disaster Preparedness and Planning Project	2013
Virginia Beach, Virginia	450,980	Environment and Sustainability Office	Environmental Stewardship Chapter in Comprehensive Plan	2009
Oakland, California	413,775	Sustainable Oakland (part of Public Works Department)	Energy and Climate Action Plan	2012
New Orleans, Louisiana	384,320	Resilience Office	Resilient New Orleans	2015
Chula Vista, California	260,988	Conservation Section of Public Works Department	Climate Adaptation Strategies Implementation Plan	2011
Norfolk, Virginia	245,428	Resilience Office	Norfolk Resilience Strategy	2015

Adaptation plan review

I analyzed the adaptation plan (or the section dealing with adaptation of a larger plan) of each selected city to determine how the plan is organized, if it includes indicators, and what climate risks it addresses. I categorized the elements of the plans as followed:

- Goal: a general objective to which a project, policy, or program is intended to contribute (USAID 2009).
  Example: Reduce flooding from heavy precipitation events.

- Target: a specified result, often expressed by the value of an indicator, with a defined endpoint and timetable (USAID 2009; Parris and Kates 2003). One can objectively evaluate whether or not a target has been met.

[5] U.S. Census Bureau, Population Division 2015

Example: Increase acres of green infrastructure citywide 30% by 2020.

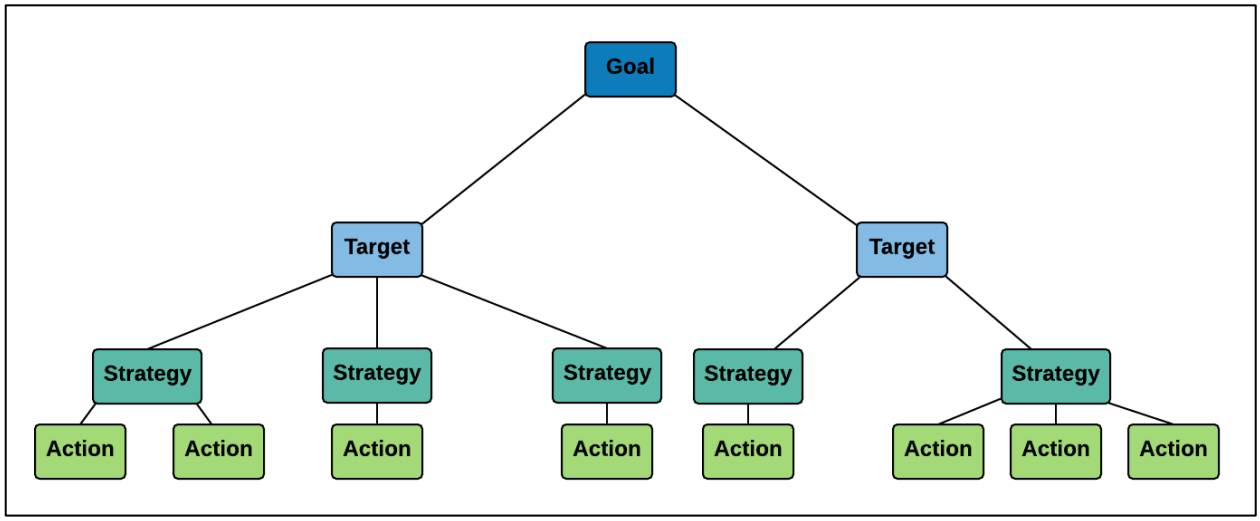
- Strategy: general approaches taken to meet the goals or targets laid out in the plan.
  Example: Encourage businesses to install rain gardens to manage stormwater.

- Action: a specific step, policy, project or program listed in the plan that can be objectively evaluated based on whether it has or has not been completed. Multiple actions can make up a single strategy.
  Example: Initiate a grant program that provides funding for businesses to install rain gardens.

- Indicator: a quantitative or qualitative variable that provides a simple and reliable means to measure achievement, reflect the changes connected to an intervention or to help assess performance (OECD 2002). An indicator can measure any of the other plan elements (goal, target, strategy, or action).
  Example: Acres of green infrastructure installed.

Not all of the plans contained each of these elements (see Figure 4). I categorized the elements by the definitions above, rather than by what they were called in the plan. For example, some plans included elements that were called actions but that fit the definition of strategy above; I have categorized these as strategies.

Figure 4: Hierarchy of adaptation plan elements



Not all adaptation plans will contain each element. An indicator can measure any of the elements.

For the indicators that were included in the plans, I categorized whether they were outcome or process indicators. Process indicators measure progression towards the achievement of an outcome, but do not guarantee or measure the final outcome itself. Process indicators were further divided into input indicators, which measure things that are put into a program, such as dollars invested or staff time, and output indicators, which measure the results of a program, but not its effect. Outcome indicators, on the other hand, demonstrate the effects of a program or whether or not a particular objective has been achieved.

Interviews with city staff and experts

In addition to analyzing the adaptation plans, I interviewed at least one city staff person working on climate change adaptation from each selected city. These interviews were conducted over the phone between December 2015 and March 2016. The interviews were recorded with permission, and interviewees were given the option to have their interviews kept confidential or to have their name and quotes from the interview included in this thesis. The MIT Committee on the Use of Humans as Experimental Subjects (COUHES) reviewed the study and determined it to have exempt status.

The purpose of the interviews was to discuss the adaptation planning process, determine if cities are using climate adaptation indicators or are planning to do so, and identify barriers to using indicators. Questions covered the following topics:

- Adaptation efforts that the city is undertaking, including structure of adaptation planning within city government, climate risks addressed, developing and implementing adaptation plans, and implementing adaptation programs.
- Whether and how the city is tracking the *implementation* of its climate adaptation plan, including whether it is using indicators to do this.

- Whether and how the city is tracking the *effectiveness* of its climate adaptation plan, including whether it is using indicators to do this.

- Whether and how the city is working with outside groups, including regional groups and non-profits, on adaptation planning and indicator development.

As these were semi-structured interviews, if interviewees brought up topics not included in the interview guide, I pursued these topics and asked further questions if I thought they were relevant (see Appendix A for the interview guide).

I interviewed a total of 11 city staff from the nine cities in the study. I interviewed two people from New York and Virginia Beach in order to get the full scope of my questions answered for each city. One person was interviewed from each of the other cities (see Appendix B for the list of people interviewed). The results from the plan analysis and interviews are described in Chapter 5.

I also spoke with several experts who work on climate adaption measurement and evaluation (see Appendix B). These interviews helped me to determine what literature to include in my review, identify challenges to using indicators for adaptation, and become aware of innovate examples around this topic.

Analysis of frameworks

I also reviewed several of the adaptation indicator sets and frameworks introduced in Chapter 3 in more detail in order to assess their utility to cities. I reviewed four frameworks that were developed by organizations mentioned by city staff in the interviews:

- C40 Climate Risk and Adaptation Framework and Taxonomy (CRAFT)
- ND-GAIN Urban Adaptation Assessment
- Rockefeller City Resilience Index

- Urban Sustainability Director's Network (USDN) adaptation indicators project

Based on a careful reading of published materials as well as, in some cases, interviews with experts familiar with these projects, I assessed these plans based on their ability to address several barriers to using indicators raised in the interviews and challenges to adaptation indicators described in the literature. In particular, I assessed the ability of these frameworks and indicators sets to address staff time and resources; data availability; defining successful adaptation and balancing comparability between cities with the ability to tailor indicators to the local context. I also assessed cities' familiarity with the frameworks and the extent to which they addressed the long time horizon and uncertainty associated with climate change. Chapter 6 describes the results of this analysis.

Chapter 5: Adaptation Plan Analysis and Interview Results

The interviews and analysis of adaptation plans demonstrate that cities are structuring both their adaptation planning efforts and the plans themselves in different ways, including as part of broader sustainability or resilience efforts and as standalone adaptation plans. Although all of the cities studied are coastal cities, the adaptation plans address many potential climate change impacts in addition to sea level rise and coastal flooding. In addition, many elements in the plans do not relate to a single climate hazard, but rather address broader concepts of preparedness or resilience.

Cities are further along in devising methods to measure the implementation of their adaptation actions as opposed to the effectiveness of them. Moreover, most cities are not using indicators to measure their adaptation efforts; only two of the adaptation plans reviewed include indicators, and only one city's plan includes clear targets for some of its goals. However, the interviews did reveal that several cities are actively developing adaptation indicators or are planning to do so.

Interviewees identified a variety of barriers preventing them from using adaptation indicators, including barriers relating to resources, information, technical challenges, and organizational structure. Finally, almost all of the cities in the study work with local, regional, national, or international groups to increase their capacity for adaptation planning, including the development of indicators. In the following sections, I discuss each of these findings in more depth and describe evidence from the adaptation plans and interviews that support these findings.

Structure of adaptation planning

Approximately half of the cities in the study (Baltimore, Boston, Chula Vista, Oakland and Virginia Beach) conduct climate adaptation planning as part of a sustainability or environment department. In two of these cities – Chula Vista and Oakland – the sustainability or environment division is a unit within a public works department. Baltimore, Boston, and Virginia Beach have standalone sustainability or environment departments or offices.

In the other cities, adaptation planning sits within a resilience department. The New York City Mayor's Office of Recovery and Resilience primarily addresses climate adaptation. Miami-Dade County recently changed the name of its Office of Sustainability to the Office of Resilience. This department now deals with climate adaptation efforts as well as the implementation of the county's sustainability plan. New Orleans and Norfolk have resilience offices that are charged with developing broad resilience strategies that address climate risks but also social and economic issues.

Several cities with resilience offices are part of the Rockefeller Foundation's 100 Resilient Cities (100RC) program. New Orleans, New York and Norfolk were selected to participate in this program and developed their resilience plans as part of it. Miami-Dade County, along with the cities of Miami and Miami Beach, has applied to be one of the third round 100RC cities. Boston and Oakland are also part of the 100RC program, but the adaptation plans I reviewed were developed prior to and/or separately from their involvement. In Boston, resilience planning is proceeding separately from adaptation planning, with more of a focus on equity and social resilience than climate risks specifically.

In Oakland, the resilience efforts are just getting started and have not been combined with existing adaptation planning efforts.

There is also a great deal of variation in the structure of the adaptation plans themselves. Several cities have standalone climate adaptation plans, but most incorporate these plans into a broader effort. Chula Vista's Climate Adaptation Strategies plan exclusively addresses adaptation. Boston is undergoing a new adaptation planning process, Climate Ready Boston, which will focus solely on adaptation.[6] Baltimore developed its adaptation plan as part of the local hazard mitigation plan required by the Federal Emergency Management Agency (FEMA).

New Orleans and Norfolk include climate adaptation as part of broader resilience strategies that address a variety of challenges. Both resilience plans have a chapter that focuses specifically on climate change and/or sea level rise. Boston, Miami-Dade County, and Oakland have climate action plans that include both mitigation and adaptation. Finally, New York and Virginia Beach incorporate adaptation strategies into a citywide comprehensive or strategic plan (OneNYC and the Virginia Beach Comprehensive Plan, respectively).

Most plans have some sort of hierarchical organization, with actions or strategies listed within goals or targets (see Table 2). The plan that adheres most closely to the comprehensive hierarchy shown in Figure 5 is New York's OneNYC plan. In this plan, many of the goals are quantified by targets, which are measured by indicators. Each target also has strategies or actions listed within it. Baltimore's plan does not have targets, but within each of its six goals lists strategies. For each strategy, several specific actions are listed

[6] Since Climate Ready Boston is ongoing and had not released a plan at the time of my research, I analyzed the existing Climate Action Plan. The interview addresses both planning efforts.

(approximately 300 in total) (see Figure 6). Since this is a much greater level of specificity than the other plans reviewed, these actions are not included in the count of plan elements described in this chapter or in Table 2.

Most of the plans reviewed (those of Boston, Chula Vista, Miami-Dade, New Orleans, and Norfolk) only adhere somewhat to this complete hierarchy. Instead, they list goals and underlying strategies or actions, with no targets. In addition, these strategies and actions are essentially at the same level, underlying the goals (see Figure 7); actions are not assigned to each strategy as they are in the Baltimore plan. Finally, Oakland and Virginia Beach do not have overarching goals in their plans; the plans are essentially a list of various strategies and actions (see Figure 8).

Table 2: Number and type of plan element by city

	Plan element					
City	**Goal**	**Target**	**Indicator**	**Strategy**	**Action**	**Total**
Baltimore[7]	6	-	-	49	-	**55**
Chula Vista	9	-	27	7	23	**66**
Miami	4	1	-	5	7	**17**
New Orleans	16	-	-	5	18	**39**
New York	17	3	10	12	1	**43**
Norfolk	12	-	-	27	15	**54**
Oakland	-	-	-	11	4	**15**
Virginia Beach	-	-	-	25	4	**29**
Boston	9	-	-	25	3	**37**
Total	**73**	**4**	**37**	**166**	**75**	**355**

[7] Baltimore's plan lists 300+ specific actions, but they are at a much more granular scale than the other plans; multiple actions are listed for each strategy. Therefore, to ensure comparability, these actions are not included in the above table or the analysis relating to it.

Figure 5: Comprehensive hierarchy of adaptation plan elements

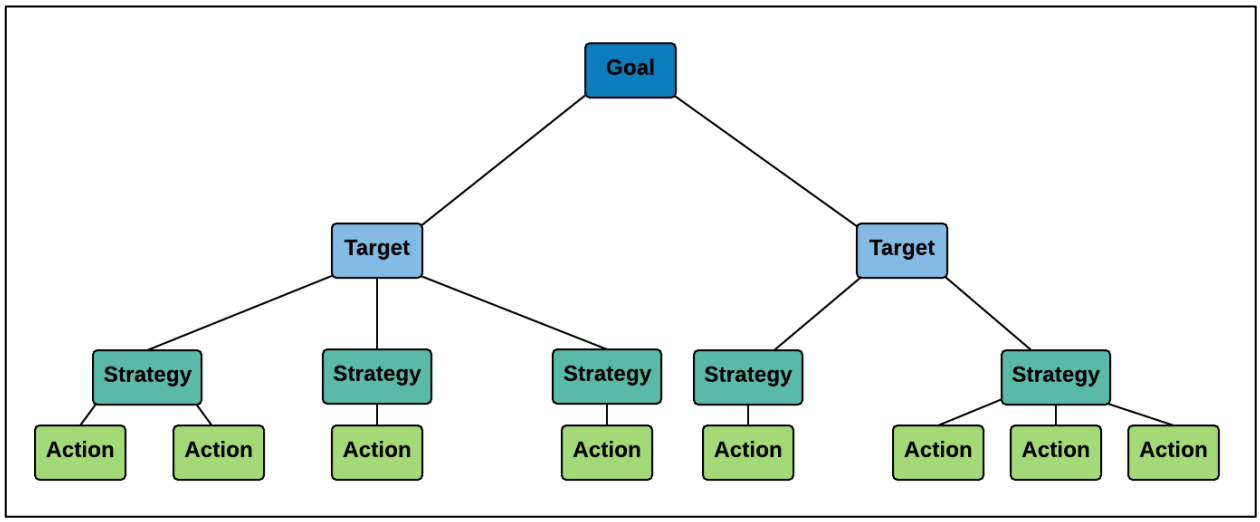


Figure 6: Hierarchy of plan elements with no targets

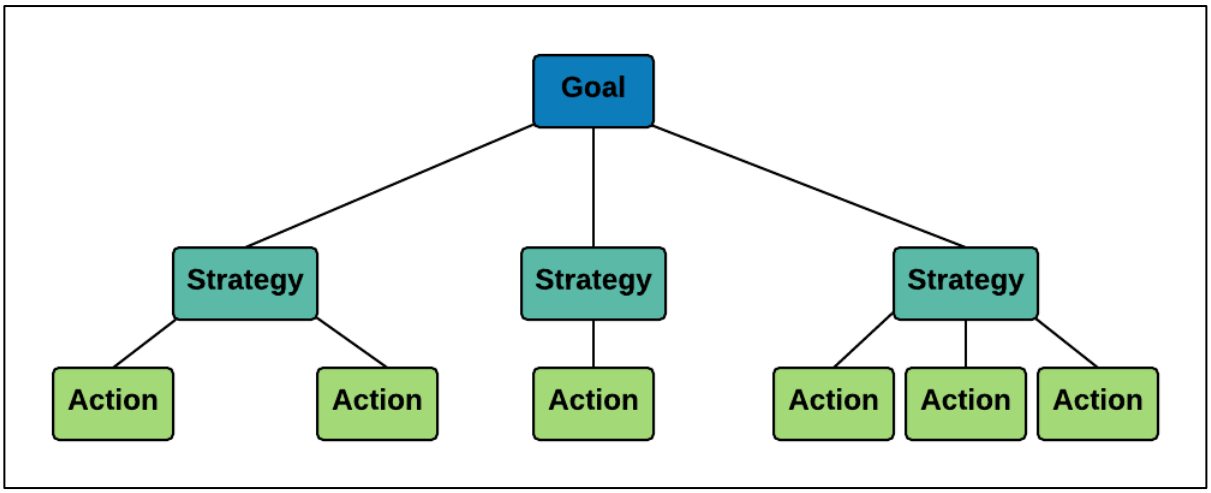


Figure 7: Hierarchy of plan elements with strategies and actions on the same level

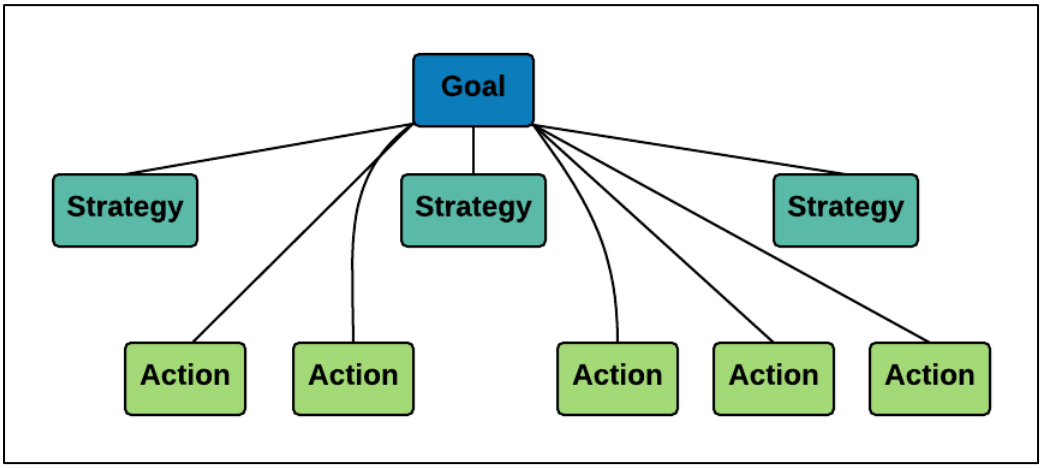
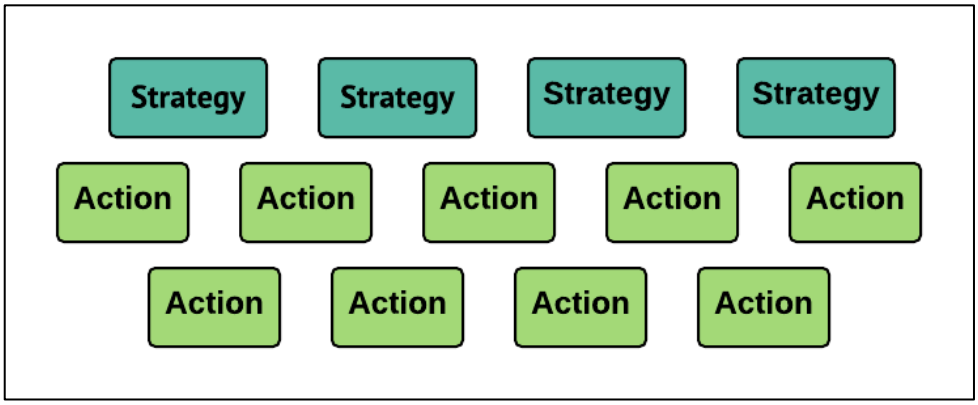


Figure 8: Strategies and actions listed with no goals



Climate change impacts addressed

All of the cities studied are coastal cities, but the adaptation plans address many potential climate change impacts in addition to sea level rise and coastal flooding (see Table 3). Of the 355 plan elements (goals, targets, strategies, actions and indicators) analyzed, 252 are not specific to a single climate hazard, but address broader issues of preparedness and resiliency. For example, these elements focus on general preparedness, disaster response, or other elements of resilience, such as economic issues, communication,

or vulnerable populations. Of the elements that are specific to a particular climate hazard, a plurality address sea level rise (32 elements) and flooding (27 elements). Cities are also addressing heat (19 elements) and drought (18 elements).

The interview results confirm what was seen in the plan analysis on this topic. All of the city staff described sea level rise as a risk they are addressing. Representatives from six cities said that their adaptation strategies also focus on heat, four mentioned other types of flooding, and three mentioned storms. Wildfires, drought, wind, and earthquake were each mentioned by one city official. In addition, approximately half of the people interviewed said that equity is an important focus of their adaptation efforts.

Table 3: Climate impacts addressed in adaptation plans

Climate impact	Number of plan elements
Sea level rise	32
Flooding	27
Heat	19
Drought	18
Wildfire	4
Earthquake	2
Storms	1
General preparedness or resilience	252
Total	**355**

Tracking implementation

All of the cities in the study track the implementation of strategies or actions laid out in their adaptation plans. They do this through either interim progress reports or tracking the progression and completion of individual actions. The Baltimore and Miami-Dade plans include implementation tables that list indicators or interim actions for specific actions or strategies. The Baltimore table includes indicators for many of the granular actions

underlying the strategies; however, indicators are not included for the strategies or goals. The indicators for adaptation strategies in Miami-Dade's plan are all listed as "TBD through implementation" or "achievement of milestones." Boston tracks the implementation of its Climate Action Plan online through an interactive table. However, almost all of the updates on implementation for the climate adaptation strategies are listed as "Coming Soon." (Greenovate Boston 2015).

In an interview, a representative from Baltimore noted that the city uses a "stoplight" system for tracking implementation. This system demonstrates whether an action has not been started (red), is in progress (yellow), or has been completed (green). Although they did not use the same term, city staff from Boston and Oakland described similar processes for tracking implementation. Since this type of system only shows whether or not actions have been completed, it does not leave room for other information about program effectiveness. Although Boston is beginning to use this kind of system for its Climate Action Plan, the interviewee from Boston noted that the Environment Department has not decided if it will pursue a similar approach for its adaptation-specific Climate Ready Boston plan, which is currently being developed.

Chula Vista, Miami-Dade and New York all issue regular progress reports about plan implementation. Approximately every two years, Chula Vista publishes either a progress report or a new plan. Similarly, Miami-Dade's sustainability plan is on a five-year cycle for revisions, and the county publishes progress reports in the interim years. City law requires New York to annually issue a progress report on its comprehensive sustainability strategy (and to update the strategy every four years) (The New York City Council 2008). The most

recent progress report on OneNYC was released on Earth Day, April 22, 2016. In it, the city reports on progress made on the initiatives laid out in the plan.

Some cities are tracking implementation through the process of updating their adaptation plans. Oakland and Virginia Beach are both currently updating their adaption-related plans, which involves determining what strategies and actions from the current plans have been implemented or completed. Finally, some cities have internal structures to track the implementation of an adaptation plan or of specific projects. New York has an internal system for tracking the implementation of specific projects, while New Orleans has an internal system for tracking quarterly milestones.

Use of indicators

Although all of the cities are to some extent tracking the implementation of their adaptation efforts, most are not using indicators to do so. Moreover, most cities are not using indicators to track the effectiveness of their efforts in addressing the impacts of climate change.

Only two cities – Chula Vista and New York – actually include indicators in the body of their plans, as opposed to in an appendix or table only. New York's plan also has three targets, while Miami-Dade's has one. Of the 37 indicators and four targets listed, the large majority are process indicators (see Table 4). Process indicators are categorized into inputs, which include resources that contribute to the implementation of a program (such as money or staff time), and outputs, which measure the products of a program or policy (such as the number of people served by a program or the number of sites where projects were implemented). The process indicators include 31 output indicators and five input

indicators. The plans cumulatively contain only five outcome indicators. These outcome indicators address how climate change is affecting the community as opposed to how the strategies and actions are being implemented. They include temperature reduction from cool paving strategies, hours of weather-related power outages, disaster-related displacement, and social vulnerability.

Several adaptation plans mention that the city intends to develop adaptation indicators. Baltimore, Boston, New Orleans, New York and Norfolk's plans all contain a goal or strategy of developing adaptation indicators. Several interviewees described working to develop or revise indicators to measure the effectiveness of their adaptation strategies. Kristin Baja, a Climate and Resilience Planner in Baltimore stated that the Sustainability Office is currently in the process of going through its adaptation plan and trying to develop more "solid" metrics for each of its strategies. It seeks to include both quantitative and qualitative indicators that will be able to demonstrate the success of its strategies.

Jared Genova, Resilient NOLA Project Manager, noted that his department is working with New Orleans' Office of Performance and Accountability to develop a metrics system to track outcomes in addition to outputs. The department plans to use both qualitative and quantitative indicators, and incorporate these into a "dashboard" that can be viewed by the entire community. Norfolk's effort involves first trying to define resilience, and then selecting indicators that show if the city is moving towards it. The resilience office is still at the beginning stages of this effort, but noted that it will involve modeling systems rather than "tracking things."

Table 4: Indicators listed in climate adaptation plans

City	Indicator	Associated target (if applicable)	Type of indicator (input, output or outcome)
Chula Vista	Amount of incentive funds distributed for retrofitting existing buildings with onsite water collection and reuse systems		Input
Chula Vista	# of wildfire education materials distributed		Input
Chula Vista	# of surveys conducted within the Otay Ranch Preserve to document potential vegetation and species diversity changes as a result of climate change		Input
Chula Vista	# of brochures that have been prepared for the OVRP that include information about climate adaptation programs and opportunities		Input
Chula Vista	# of surveys performed to monitor shifts in local species range and diversity resulting from climate adaptation.		Input
Chula Vista	Total square feet of paved surfaces incorporating cool paving technologies		Output
Chula Vista	# of new projects incorporating the new shade tree standard		Output
Chula Vista	# of new residential units incorporating cool roofs		Output
Chula Vista	# of new residential units incorporating a gray water stub-out		Output
Chula Vista	# of new commercial buildings incorporating indoor dual plumbing for recycled water		Output
Chula Vista	# of construction sites conserving and re-using pipe-flushing water		Output
Chula Vista	# of developments taking advantage of incentives to incorporate LID features in their projects		Output
Chula Vista	# of gallons of urban runoff diverted for reuse		Output
Chula Vista	# of properties upgrading or adjusting their irrigation systems to prevent over-watering runoff or over-spray		Output
Chula Vista	% increase in community awareness from outreach and education (based on surveys)		Output
Chula Vista	# of residents & businesses subscribed to notification system (through Nixle, Lyris, & other messaging distribution methods)		Output
Chula Vista	# of interpretive centers/stations in the OVRP that include information about climate adaptation programs and opportunities		Output
Chula Vista	# of linear feet of new state of the art irrigation systems installed within CFD areas		Output
Chula Vista	# of low flow, web-based smart controllers, master valves, and flow sensors		Output

	installed within CFD areas		
Chula Vista	# of square feet of turf and other groundcover materials within CFDs converted to drought tolerant or drought resistant plant materials		Output
Chula Vista	# of square feet of mulch applications utilized in CFDs		Output
Chula Vista	# of habitat restoration areas within the OVRP where climate change impacts were incorporated into project designs		Output
Chula Vista	# of development projects complying with the new standards		Output
Chula Vista	# of businesses participating in the FREBE and CLEAN Business programs annually		Output
Chula Vista	Value of municipal environmentally-preferred purchases annually		Output
Chula Vista	# of businesses which are located in Chula Vista offering "green" products or services		Output
Chula Vista	Temperature reduction of cool versus traditional paving materials in test areas		Outcome
Miami-Dade	FEMA flood rating	Rating of 5	Output
New York	Capacity of accessible emergency shelters	120,000	Output
New York	Rate of volunteerism among New Yorkers	25 percent by 2020	Output
New York	Percentage of households in the 100-year floodplain with flood insurance policies		Output
New York	Square footage of buildings upgraded against flood risk		Output
New York	Number of homes elevated through the Build it Back program		Output
New York	Percentage of patient beds at hospitals and long-term care facilities in the 100-year floodplain benefiting from retrofits for resiliency		Output
New York	Linear feet of coastal defenses completed		Output
New York	Acres of coastal ecosystems restored		Output
New York	Number of residents benefiting from coastal defenses and restored ecosystems		Output
New York	Customer-hours of weather-related utility and transit service outages		Outcome
New York	Disaster-related long-term displacement of more than one year of New Yorkers from homes	Eliminate by 2050	Outcome
New York	Social Vulnerability Index for neighborhoods across the city		Outcome
New York	Average annual economic losses resulting from climate-related events		Outcome

The resilience chapter in OneNYC already includes a combination of output and long-term outcome indicators. An interviewee from the Mayor's Office of Recovery and Resiliency reported that the city, along with the New York City Panel on Climate Change (NPCC), is developing a methodology to design and test resilience indicators. This involves doing risk and economic loss modeling, which the city will eventually connect with its programs to demonstrate their effectiveness in addressing climate impacts. In the OneNYC 2016 Progress Report, the city reported that this work with the NPCC will allow it to report on several of its outcome indicators – disaster-related long-term displacement, the Social Vulnerability Index, and average annual economic losses resulting from climate-related events – beginning in 2017. The Progress Report provides data on the other indicators listed in the plan for 2016 and the previous time the indicator was reported, allowing the reader to see if progress has been made.

All of the cities that are currently developing adaptation indicators are working with outside organizations to do so. New Orleans and Norfolk are working with the Rockefeller Foundation 100RC program, while Baltimore is working with the Urban Sustainability Director's Network (USDN). New York is collaborating with the NPCC, an independent scientific body that advises the city on climate risks.

Several cities are tracking the effectiveness of specific adaptation strategies or actions in addressing climate impacts instead of or in addition to developing indicators for the adaptation plan overall. For example, the Baltimore Office of Sustainability has partnered with Johns Hopkins University, Maryland Institute College of Art and local community groups to create a map of the heat island effect in the city, using both satellite

data and on the ground sensors and reporting. This data will be monitored to see the effect of heat mitigation efforts on the heat island effect (Baltimore Office of Sustainability 2016).

Interviewees reported that similar efforts are taking place in Miami-Dade and New Orleans on the issue of water management. Water management departments are tracking the effect of particular changes and interventions on flood risk and pumping capacity, for example. Jared Genova stated that New Orleans plans to link this water management data with social indicators to show progress on broader social and community development goals, but that this has not been done yet.

Interviewees from three cities – Boston, Chula Vista, and Oakland – did not mention working to develop indicators to measure the effectiveness of their adaptation strategies. Notably, these are all cities that include adaptation as part of a broader climate action or sustainability plan. These cities seem to have not considered how to measure the effectiveness of adaptation specifically. Virginia Beach is undergoing a major effort to develop sustainability indicators that link its sustainability work to the city's overall vision plan. City staff noted that adaptation indicators might be added to this, but that sustainability indicators are the top priority.

Chula Vista includes a number of adaptation indicators in its plan, but it is not actively monitoring each one due to time and resource constraints. Instead, indicators are tracked as policies are taken forward and implemented. Cory Downs, a Conservation Specialist in the Public Works Department, described the constraints his department faces in using the indicators as ones of staff time and resources as well as data

availability.[8] However, the city is working to provide more staff time for tracking indicators and is planning to bring on consultants to help with some aspects of this.

Rationale for using indicators

Several interviewees described the importance using indicators or their rationale for doing so, suggesting that cities recognize the value of using adaptation indicators even if they do not currently have them in place. Several interviewees specified that indicators can hold governments accountable and measure progress towards achieving goals, as well as increase transparency to the public. Kristin Baja of Baltimore explained that her office is accountable to the people who participated in the development of the adaptation plan as well as those who will be affected by climate change impacts:

> We went through an extensive community engagement and outreach process. We went into the communities most vulnerable to the impacts that we're anticipating seeing and really got a lot of buy-in from residents, from businesses and institutions, and buy in from our partners in implementation. In order for us to be able to report back to them how we're doing and how we're meeting their goals and how we're making their lives better, we have to be able to track the success of each action or strategy that we've put into place in partnership with them.

Interviewees also stated that indicators can help cities demonstrate the benefits of adaptation and the effectiveness of adaptation strategies, including cost-effectiveness, lessening climate impacts, and creating a more resilient city overall. Explaining why New Orleans plans to track the effectiveness of adaptation strategies in lessening climate impacts, Jared Genova stated, "Virtually everything that we're doing has climate

[8] Downs noted that the constraints of staff time and data availability are linked because identifying and ensuring a high quality and regular data source can take significant amount of staff time.

implications and is exacerbated in some way or another by climate change. So if we're not tracking that, then it's pretty irresponsible."

Virginia Beach's rationale for developing indicators differs from the explanation offered by the other cities. It is using indicators to align its sustainability plan with its 2040 Vision Plan and eventually to tie this in with the budget process. Clay Bernick, the Environment and Sustainability Administrator, explained:

> The city, and most communities, I imagine, track a lot of different things that they're doing, but we had never really looked at them in terms of having them align with a larger vision before. So this effort has focused in on trying to assess whether we are really tracking the right metrics or not. And if we aren't, which ones should be added to the mix, which ones should be retired from the mix.

Although the indicators that are being developed now are not specifically focused on climate change adaptation, Bernick added that the whole process of using indicators to guide decision-making makes it likely that adaptation indicators will be added in the future.

Barriers to using indicators

Interviewees mentioned a variety of barriers preventing them from developing or using adaptation indicators. These barriers relate to resources, information, technical challenges and organizational structure. No single barrier was mentioned by a majority of interviewees. The literature tends to focus on the technical challenges of adaptation measurement and evaluation, such as the uncertainty and long-time horizon associated with climate change (Ford et al. 2013; Bours, McGinn, and Pringle 2014a; DEFRA 2010; Climate-Eval 2015; Pringle 2011; Spearman and McGray 2011). However, the barriers that cities face in developing adaptation indicators are much broader than this. The barriers

mentioned in the interviews suggest that even if the technical issues were addressed, many cities would not be able to easily use adaptation indicators.

Barriers related to resources include staff availability, money required to collect and track data, data availability and the time-consuming process of tracking indicators. Shayna Hirshfield-Gold, an Energy Policy Analyst from Oakland, explained how time consuming it can be to track plan implementation:

> There are so many different departments and divisions throughout the city with implementation responsibilities. Many of the actions have bifurcated responsibility across multiple departments, community groups, or regional government entities outside of the city, so tracking ends up being many, many little pieces spread across all these different people, divisions, and organizations. It's a lot of wrangling people, tracking innumerable metrics, and constantly going out to say where are you, what has been done, are you working with so and so, and are you tracking your own metrics.

A major barrier related to information, mentioned by representatives from four cities, is the lack of standardization of adaptation and resilience metrics. Without a standard set of indicators to draw from, cities must create their own indicators, making it a much more time-consuming and arduous process. In developing its indicators related to adaptation, New York realized that it would be one of the first if not the first U.S. city to do this. Recognizing its role as a leader in this field, the city chose to publish adaptation indicators in its strategic plan, even though it is still working towards revising and strengthening the methodology for some of these indicators.

Interviewees also discussed several technical challenges related to adaptation M&E. These include demonstrating that adaptation actions have prevented negative impacts from occurring, quantifying the impact of less technical programs such as education, measuring dynamic natural systems, and quantifying the value of ecosystems. The challenge of demonstrating the counterfactual of what would have happened absent the

adaptation actions is discussed in the literature (OECD 2015; Pringle 2011; Climate-Eval 2015; Spearman and McGray 2011) and plays out in practice. Kristin Baja of Baltimore elaborated:

> If you take an action to prevent something from happening, that actually saves lives and protects property, how do you quantify that you have actually done that, because it's something that you're actually preventing. We've been coming up with metrics for success around things we want to accomplish, but actually being able to show that we've successfully adapted or created a more resilient system is a difficult thing to track and also a really difficult thing to be able to point to numbers and financial savings because you don't have those costs when the impact is prevented.

Finally, interviewees revealed organizational challenges related to developing adaptation indicators. Since adaptation is so interdisciplinary, responsibility is often divided between a number of different departments. This creates ambiguity around who should be responsible for developing or tracking indicators. Some cities have not defined what they see as "successful" adaptation or what levels of risk they would be willing to live with. With no clear objectives, it is difficult to set adaptation targets and choose associated indicators. Katherine Hagemann, Miami-Dade's Sustainability Initiatives Coordinator, explained that her office is facing this challenge:

> One of the challenges for metrics is that there's not necessarily consensus on what we're trying to achieve with adaptation. Let's take for example flood risk. No one wants a community to be at risk of flooding. But the appropriate level of risk is something that's a bit undefined. Different agencies or individuals have different tolerances for risk.

Some cities are prioritizing implementing particular projects rather than tracking the effectiveness of an adaptation strategy overall. Mia Goldwasser, Boston's Climate Preparedness Program Manager, explained how she anticipates that Climate Ready Boston, the adaptation plan that her office is currently developing, will be implemented:

> After developing a set of recommendations in a plan, there are many steps to take to actually get to implementation, such as identifying which projects we can advance, and a need for further planning, design renderings, and/or engineering. At that point, if not before, the project can leave the hands of the Environment Department to agencies with particular implementation jurisdiction... So tracking the effectiveness of the plan as a whole needs to be balanced with resources available to actually make a few of the priority projects happen.

The flipside of accountability as a benefit of using indicators is that with indicators, cities are accountable even if they do not achieve their desired goals or outcomes. Cory Downs noted that in Chula Vista:

> We are focused on impacts that are within our control. Sometimes its hard to track some of the impacts of climate change because whether our programs are as successful as we want or not, some of those impacts are going to occur regardless. We're nervous of linking some of those larger impact metrics to our plan and prefer to use program level metrics that provide a better perspective on how that particular measure is working in our community.

Working with outside groups

Many cities reported relying on the expertise and capacity of outside groups, which may help to address some of the barriers to using indicators discussed above. Almost all of the cities in the study work with local, regional, national or international organizations on adaptation planning. These groups help with modeling climate impacts, conducting regional planning, pooling resources and developing indicators (see Table 5). For example, Miami-Dade's Chief Resilience Officer Jim Murley noted in a webinar that the Southeast Florida Regional Climate Change Compact is critical to the county's adaptation planning efforts, stating that, "Anything we're doing in Miami-Dade…wouldn't be nearly as successful without the opportunity to work with our neighbors through this compact" (Murley 2016).

Table 5: Local and regional adaptation efforts

City	Local/regional Group	Purpose
Boston	Boston Harbor Association Boston Metro Mayor's Task Force	Development of indicators Regional infrastructure
Chula Vista	San Diego Foundation San Diego Climate Collaborative	Climate impacts Regional planning
Miami-Dade	South East Florida Regional Climate Change Compact	Regional policy and programs
New York	NYC Panel of Climate Change NYC Climate Change Adaptation Task Force	Climate impacts, indicators Regional Infrastructure
Oakland	Bay Area Conservation and Development Commission	Climate impacts

New Orleans and Norfolk are relying on the Rockefeller 100RC program for resources related to developing indicators and other resilience strategies. New York's OneNYC plan notes that the city is working with 100RC on resilience indicators, but this was not mentioned in the interviews. New York is also working with the New York City Panel on Climate Change (NPCC) on developing adaptation indicators.

Several cities, including Baltimore, Boston, and Miami-Dade work with USDN on developing indicators as well as other forms of technical assistance. For example, Katherine Hagemann noted that USDN helped Miami-Dade to quantify the benefits of transit-oriented development, which was included as part of its sustainability plan, by providing it with an example of how another city approached this issue. Baltimore is one of the pilot cities where ND-GAIN's Urban Adaptation Assessment indicator framework is being tested. On

other adaptation planning issues, Miami-Dade works with C40 and ICLEI, while New Orleans is part of the Compact of Mayors.

Chapter 6: Analysis of Adaptation Indicator Frameworks

Despite the proliferation of frameworks supporting adaptation indicators, most of them are not being used by the cities in this study. Of the adaptation indicator sets and supporting frameworks discussed in Chapter 3, I propose that three types would be most useful to cities that are undergoing adaptation planning. First, a *top-down index* would involve an external evaluation of a city's adaptation programs, allowing a city to compare itself to it peers or to some other standard without investing time or resources in developing indicators. Secondly, a *community assessment* would provide a city with a predetermined set of indicators, but allow it to go through the process of assessing its own adaptation or resilience using local data. Finally, a *guiding framework* would give a city support in developing its own indicators, which it could tailor to its local context or climate planning goals.

I reviewed 31 indicator sets and frameworks in these three categories related to the topics of adaptation, resilience, and disaster response (see Appendix D; many of the frameworks are also described in Chapter 3). Many of these frameworks are recent developments: six were completed in 2015 or the first part of 2016, and four are still under development.

Interviewees discussed several of these frameworks, suggesting that although they may have not used them to develop indicators, they are familiar with some of the frameworks. Representatives from Baltimore and Boston discussed their involvement with the USDN adaptation metrics project. Kristin Baja, a planner from Baltimore, mentioned that she is looking to the USDN project for guidance as she develops new adaptation metrics. Staff from cities that are part of the Rockefeller 100 Resilient Cities (100RC)

program, in particular New Orleans and Norfolk, discussed Rockefeller's City Resilience Index. Katherine Hagemann of Miami-Dade County mentioned C40 as an organization that the county is working with on climate adaptation, but did not discuss C40's evaluation framework specifically. Finally, several of the experts I spoke with brought up the ND-GAIN Urban Adaptation Assessment. Baltimore is one of the pilot cities for this project, and when asked in the interview Kristin Baja said that she is working with ND-GAIN on it.

In this section, I will review the frameworks developed by C40, ND-GAIN, Rockefeller and USDN to assess their utility to U.S. cities. Although cities could select numerous other frameworks to assist them with developing indicators, the fact that these ones were mentioned in the interviews signifies that more cities may be aware of and likely to use them. Moreover, these frameworks are illustrative of the three types of frameworks that I propose are most useful to cities wanting to use adaptation indicators: the ND-GAIN Urban Adaptation Assessment is a top-down index, the C40 Climate Risk and Adaptation Framework and Taxonomy (CRAFT) and Rockefeller City Resilience Index are community assessments, and the USDN project is a guiding framework (see Table 6 for a summary of the frameworks) ("Urban Adaptation Assessment" 2015; C40 Cities, n.d.; The Rockefeller Foundation and Arup 2015a; Institute for Sustainable Communities et al 2016). In addition, these four frameworks are new tools available to cities. The USDN report was released in early 2016, while the other three frameworks are still under development.

In the following sections, I assess whether these frameworks can help cities overcome the main barriers and challenges to using indicators raised in the interviews and the literature: staff time and resources; data availability; defining successful adaptation; balancing comparability between cities with the ability to tailor indicators to the local

context; cities' familiarity with the frameworks; and the long time horizon and uncertainty associated with climate change (see Table 7 for a summary of this analysis).

Table 6: Summary of frameworks analyzed

Framework name	Organization/author	Type of framework	Purpose	Summary
Urban Adaptation Assessment	Notre Dame Global Adaptation Index and the Kresge Foundation	Top-down index	Scale down the country index that ND-GAIN has already developed to the urban level. Facilitate investment and policy interventions where they are most needed and compare vulnerability and adaptation progress across cities.	Indicators address readiness to adapt, vulnerability of lives and livelihoods to climate change, and adaptation planning efforts. Index is being piloted in five U.S. cities and will eventually be expanded internationally.
City Resilience Index	Rockefeller and Arup	Community assessment	Describe what makes a city resilient and provide cities with a way to assess their own resilience and make decisions based on it.	Proposes 12 goals that describe the outcomes of a resilient city and high-level indicators for each goal. Developing a series of prompt questions that cities can answer to assess their own resilience.
Climate Risk and Adaptation Framework and Taxonomy (CRAFT)	C40	Community assessment	Provide a standardized reporting framework for cities to report information on and actions taken relating to local climate hazards and impacts, risk and vulnerability assessments, and adaptation planning and implementation. Allow cities to benchmark their performances against global averages and leaders and identify other cities that are facing similar climate risks.	Includes prompts for cities to submit information related to reporting of climate hazards and implementation, means of monitoring and evaluating adaptation planning progress, and priorities for adaptation planning. Reporting platform can be accessed through CDP Cities and the Carbonn Climate Registry tools.
Adaptation metrics project	Urban Sustainability Director's Network (USDN)	Guiding Framework	Help cities determine how to develop adaptation indicators that are customized to their communities and address specific adaptation goals.	Evaluates existing frameworks for adaptation indicators, provides guidance on selecting indicators, and provides cities a list of adaptation indicators that have been proposed or used elsewhere.

Table 7: Ability of frameworks to address adaptation indicator barriers

	Indicator barriers addressed							
Framework	**Staff time and resources required**	**City responsible for data collection**	**Includes clear definition of success**	**Comparability between cities**	**Ability to tailor to local context**	**Exposure of cities to the framework**	**Addresses long time-horizon of climate change**	**Addresses uncertainty of climate change**
ND-GAIN Urban Adaptation Assessment	Low	No	No	High	Low	Medium	No	Yes
Rockefeller City Resilience Index	Medium	Yes	Yes	Medium	Low-medium	High	No	No
C40 CRAFT	Low-medium	Yes	No	Medium	Low-medium	High	No	No
USDN Adaptation metrics project	High	Yes	No	Low	High	Medium	No	Yes

Staff time and resources

Developing indicators can be time consuming, and city staff reported that they often do not have the capacity to choose indicators, collect data and track progress. Adaptation indicator frameworks have the potential to reduce the staff time required to develop indicators by providing a set of indicators for cities to use, simplifying data collection, or helping cities use indicators effectively. The four frameworks reviewed vary in terms of the staff time and resources that would be required to implement them.

USDN's report provides guidance on developing indicators, but does not prescribe what indicators should be used. The guidelines and sample indicators provided in this report could simplify and de-mystify the process of developing indicators. However, city staff would still have to put in time and resources to select indicators, determine how to measure them and collect data.

The Rockefeller City Resilience Index provides guidance on what to measure, but not how to measure it. An online platform, to be released in 2016, will lead cities through constructing the indicators based on prompt questions (either quantitative questions or qualitative questions using a sliding scale). Therefore, cities would not have to spend time deciding what to measure, but they would have to collect the data required to answer these prompts.

A major advantage of C40's CRAFT tool is that cities may already be reporting their climate mitigation efforts through CDP or Carbonn, the reporting platforms for CRAFT. Adding their adaptation efforts to this would require minimal additional work for the cities that are reporting their mitigation efforts through this platform. In addition, the CRAFT tool

is required for compliance with the Compact of Mayors, a global coalition of cities that have agreed to take action on climate mitigation and adaptation. 124 U.S. cities are part of the Compact; for those cities, using this framework will not require any additional work beyond what that program requires. Still, like with the City Resilience Index, cities would have to collect the data required to answer the questions in the CRAFT tool.

Since the ND-GAIN index is a top-down framework, the cities themselves will not be doing the assessment. Therefore, it will not require any additional city staff time.

Data availability

Interviewees said that lack of access to data was a barrier to using adaptation indicators. If cities choose indicators that do not have existing, freely available data sources to measure them, it is unlikely that these indicators will get used. The four frameworks have different requirements for what data must be collected and who collects it.

As a top-down framework, the ND-GAIN index uses data that is available across many cities, such as national datasets. The other three frameworks would require a city to collect its own data, but they vary on the specificity and complexity of what would be required. The CRAFT tool asks questions mainly about progress on adaptation planning and evaluation of climate risks, so this would not require cities to collect data beyond being aware of what their city has done. The City Resilience Index has not been finalized, so it is unclear how involved the data collection process will be for cities. However, the Rockefeller Foundation does state that the indicators will be "based on data that is already available and aligned with

variables used today by cities to measure other aspects of urban performance" (The Rockefeller Foundation and Arup 2015b).

The amount of data required with the USDN framework would depend on the indicators that each city chooses. However, the report encourages cities to "choose achievable over comprehensive" (Institute for Sustainable Communities et al 2016) and suggests that if cities do not have the capacity to collect data for a particular indicator, they should forgo including that indicator in their set.

Clear definition of success

Several of the city staff members interviewed mentioned that developing adaptation indicators is difficult because their city does not have a clear agreement of what "successful" adaptation looks like. Chapter 3 reviewed several proposals of criteria for successful adaptation or resilience, but noted that there are no agreed upon standards for this. Still, indicators should be developed with some goal in mind, or else they will just be ad hoc measures that do not truly capture a city's progress towards adaptation.

Of the frameworks, the City Resilience Index presents the clearest definition of success, with a description of seven characteristics of resilient cities and twelve goals that describe the outcomes of resilient cities; the indicators underpin each of these goals. CRAFT is more focused on process than an endpoint; it evaluates success based on how far along cities are in assessing risks and planning for adaptation.

One of the recommendations in the USDN framework is to "match indicators to adaptation visions and goals" (Institute for Sustainable Communities et al 2016). Although the definitions of successful adaptation may differ by city, all indicators should be tied to

the definition that the city comes up with. The ND-GAIN Assessment does not include a definition of adaptation success aside from an implied one of reducing vulnerability and increasing readiness.

Specificity vs. comparability

There is a tension in choosing an indicator framework between the ability to tailor indicators to a city's context – including the specific climate threats it faces and adaptation goals it has developed – and the ability to use indicators to compare cities. Of the frameworks, the USDN approach is the only one that will allow a city to tailor indicators to its own context; as a result, this will not allow for comparison between cities. With the CRAFT and City Resilience Index tools, cities will use the same set of indicators or respond to the same questions, so comparison will be possible. However, if cities report data differently or use different methodologies from each other to collect data, the potential for comparison may be weakened. With the ND-GAIN index, an outside evaluator would measure the indicators for each city, ensuring comparability.

Exposure

To minimize confusion and enhance comparability, there is an advantage to many cities using the same adaptation indicator framework. In order for this to happen, cities must be aware of the framework's existence. Since the City Resilience Index is being developed as part of the Rockefeller 100RC program, it is likely that all of the cities in that program will be exposed to the index. In addition, the Rockefeller program's prominence in the area of resilience makes it likely that if 100RC cities start using this framework, others will follow.

The CRAFT tool will be required for all cities that are part of the Compact of Mayors – 124 in the U.S. and 476 worldwide ("Compact of Mayors" 2016). In addition, it will be visible to all cities that disclose their emissions reduction and sustainability efforts through CDP, so cities that are not part of the Compact of Mayors might also choose to participate (CDP 2016). USDN's membership includes over 120 sustainability directors from the U.S. and Canada (Urban Sustainability Directors Network 2016); unlike the other frameworks, USDN's will probably not have a global reach. However, as mentioned in the interviews, member cities do look to USDN for guidance on issues like this, so it is likely that they will turn to the report if they are working to develop indicators.

An advisory group of 35 adaptation practitioners and researchers from the U.S. is providing guidance on the development of the ND-GAIN Urban Adaptation Index. Initially it will not be global in scope, although it might be expanded. The Notre Dame Global Adaptation Index, which is at the country scale, is already well known, so a new framework by the same organization may get some attention globally.

Long time-horizon and uncertainty

Although these issues were not raised in the interviews, the literature focuses on the long-time horizon and uncertainty associated with climate change as barriers to developing adaptation indicators. Both ND-GAIN and USDN propose designing indicators that address uncertainty through considering the probability of different climate scenarios (e.g., business as usual vs. a lower emissions scenario) and evaluating how systems will respond to a range of impacts (e.g., a 10 year, 100 year, and 1,000 year flood). None of the

frameworks specifically discuss developing indicators that will show results over a long time period.

Chapter 7: Recommendations and Conclusions

Benefits and drawbacks of adaptation indicators

In recent years, many U.S. cities have developed climate adaptation plans, but progress implementing these plans has been limited. Indicators can help cities track the implementation and effectiveness of their adaptation strategies, but to date there has not been an analysis whether U.S. cities are actually using indicators in their adaptation planning. In this thesis, based on an analysis of adaptation plans and interviews with staff in nine large coastal cities in the United States, I found that most cities are not using indicators to measure their adaptation efforts, although several cities are considering developing them.

This research also found that adaptation indicators face some challenges. First, in-depth interviews revealed that cities face many barriers to using indicators, including limited time, resources and data availability and the lack of an agreed upon set of adaptation indicators. In addition, the literature highlights that due to the complex, long-term and uncertain nature of climate change, adaptation indicators face technical challenges that some other types of indicators do not (Ford et al. 2013; Bours, McGinn, and Pringle 2014a; DEFRA 2010; Climate-Eval 2015; OECD 2015).

Moreover, indicators themselves are controversial. The literature demonstrates that their selection is often based on data availability or the interests of the authors rather than on more objective criteria, such as the SMART principles that suggest that indicators should be Specific, Measurable, Attainable, Relevant, and Trackable (Binnendijk 2000; Bossel 1999). Due to political and resource considerations, once indicators are selected they may

not be used to guide decision-making. Finally, some believe that indicators can be an oversimplification and do not always give a complete picture of what is actually happening in a place (Meadows 1998).

A key question for cities is whether the benefits of using indicators are worth these drawbacks. An advantage of using indicators is that they allow cities to track the effectiveness of their adaptation strategies in preparing the community for the effects of climate change. Indicators provide cities with the information they need to learn from experience and to strengthen their adaptation efforts for the future. In addition, without indicators, cities may have difficulty understanding how adaptation efforts are affecting different elements of the community, such as vulnerable populations. Finally, indicators could allow cities to objectively compare themselves to other communities and learn where they are excelling and where they are falling short.

These benefits that cities get from using adaptation indicators seem to in most cases outweigh the drawbacks. However, that does not mean that selecting and using adaptation indicators will be easy for cities. In the next sections, I propose techniques that could help cities develop quality indicators and reduce some of the barriers to using adaptation indicators. I also discuss strategies that nonprofit and research organizations could pursue to help cities with developing indicators and to advance the state of knowledge about adaptation indicators.

Recommendations for cities

Tie indicators to targets to track progress and promote accountability

Interviews revealed that many city employees believe that indicators are valuable because they can hold governments accountable and measure progress towards meeting a city's adaptation goals. However, only one city in the study – New York – has tied some of its indicators to specific targets.[9] Other cities do not include targets in their adaptation plans. Connecting an indicator to a specific target follows the results-based management approach, which allows organizations to assess how well their stated objectives are being met through setting targets, selecting indicators, and analyzing progress towards achieving the targets through collecting data on the indicators (Binnendijk 2000). When indicators are tied to a target, as in this approach, they will help cities see if they are meeting their objectives. This can also facilitate accountability, as the public will easily be able to see whether the government is on track to meet its targets.

Cities should consider including targets in their adaptation plans as well as indicators to measure them. This may require a bit of up-front work for cities, as very few cities to date have included targets in their adaptation plans. Setting targets will involve understanding what is feasible for a city to do and what is necessary to limit the impacts of climate change. It may also involve conducting outreach to different departments, stakeholder groups and the public about what they believe these targets should be. This up-front work of setting targets will ensure that adaptation plans are more directed

[9] For example, New York's plan states that it will increase the capacity of accessible emergency shelters to 120,000; in this case the capacity of emergency shelters is the indicator and 120,000 is the target.

towards the city's adaptation priorities, rather than containing ad-hoc collections of initiatives.

However, in some cases there may be a tradeoff between including a target in an adaptation plan and being flexible to address the uncertain impacts of climate change as we get more clarity about what those impacts will be. For example, Philadelphia's plan to address combined sewer overflows has a goal of capturing the first inch of stormwater through green infrastructure in much of the city (Philadelphia Water Department 2011). However, as climate change leads to more heavy precipitation events, there may be more situations in which the city gets more than one inch of rain at one time, limiting the effectiveness of this green infrastructure to prevent combined sewer overflows.[10]

One way for cities to address the challenge of setting targets under conditions of uncertainty is to frequently revise their adaptation plans, so that targets keep up with the latest scientific knowledge about climate impacts. Another approach is to set ambitious targets that would address the upper range of projected climate impacts; this may be particularly feasible when adaptation actions have co-benefits like emissions reductions or cost savings.

Use indicators to track both implementation and effectiveness

Although all of the cities studied are to some extent tracking the implementation of their adaptation efforts, most are not using indicators to track the effectiveness of these efforts. Chula Vista and New York are the only two cities that actually include indicators

[10] The Philadelphia Green City, Clean Water plan was developed to address stormwater runoff and combined sewer overflows, not climate change, so it is not surprising or exceptional that it does not include consideration of future climate impacts. This example is meant to illustrate a challenge that cities may face if they set targets that are not flexible to future impacts of climate change.

within their adaptation plans, while several other cities have plans to develop them. The large majority of the indicators in these two cities' plans are process indicators, which measure the progression towards the achievement of an outcome, but do not guarantee or measure the final outcome itself. The small remainder of indicators – five out of 41 – are outcome indicators, which demonstrate the effects of a program or whether or not a particular objective has been achieved.

Both types of indicators present benefits and drawbacks for cities. Process indicators demonstrate whether cities are doing what they say they are going to do, promoting government accountability. They may also be easier for cities to select and use, since they avoid some of the challenges associated with outcome indicators, namely the long timeframe required to see if adaptation actions are reducing vulnerability to future climate change and the difficulty of attributing reductions in vulnerability to particular adaptation efforts.

However, process indicators alone do not serve an important function of adaptation indicators: demonstrating how effective adaptation strategies are at lessening the impact of climate change on a community. In other words, not only has the adaptation plan been implemented, but also is it working? Process indicators could give the impression that a city is doing a lot to address climate change, but these strategies may not actually be effective. To measure effectiveness, it is valuable for cities to select some outcome indicators in addition to process indicators. Although outcome indicators may be more complicated to develop, cities can learn from others who have attempted to do this, such as New York, as well as from guiding frameworks and indicator sets that include outcome

indicators, such as the Rockefeller City Resilience Index or the USDN adaptation metrics project.

Think through feasibility before selecting indicators

Several interviewees reported that limited resources, including money, time and data availability, are a major barrier to developing and tracking indicators. Including too many indicators in a plan may reduce the ability of a community to successfully track them (Institute for Sustainable Communities et al 2016). For example, Chula Vista, included 27 indicators in its plan, but is not tracking many of these due to resource constraints. If indictors are not being used to measure adaptation strategies or to guide future decision-making, there is very little value in including them in an adaptation plan.

To ensure that indicators are used effectively, before selecting indicators cities should think through whether they have the data availability, staff time, resources and political buy-in to use them in a meaningful way. If they do not, cities could select a small number of indicators that they do have the capacity to use, or forgo selecting indicators until they have the capacity to track them.

Pursue strategies to help overcome limited resources

There are also numerous strategies that cities can pursue to overcome limited resources – money, time, information, etc. – that may be preventing them from developing indicators. These include working with outside groups, developing indicators at the regional scale, developing indicators to measure a specific strategy rather than overall adaptation, utilizing data that the city is collecting for other purposes, and learning from

other cities that have developed indicators, even if those cities face different climate risks. These recommendations are discussed in more detail below.

Work with outside groups

Several interviewees reported working with regional groups, nonprofits and foundations on their adaptation planning efforts. Some of these groups have expertise in developing indicators. New York is working with the New York City Panel on Climate Change (NPCC) to develop a methodology for tracking its outcome indicators. Cities that are part of the Rockefeller Foundation's 100 Resilient Cities network will have access to the City Resilience Index when it is published. Several cities, including Baltimore, Boston, and Miami-Dade work with USDN on developing indicators as well as other forms of technical assistance on adaptation. In addition, some cities are working with local institutions that have specific capabilities, such as universities, on developing or tracking indicators. For example, Baltimore is working with local universities to measure the heat island effect in the city.

Cities that do not currently rely on these types of outside groups to develop indicators may want to consider doing so. Working with these groups reduces the burden on the city to start from scratch in the process of developing indicators, something that could be extremely time consuming. It also allows cities to learn from experts who have experience developing adaptation indicators, increasing the likelihood that the indicators chosen would have some of the characteristics of high quality indicators discussed in Chapter 3, such as being measurable, specific, and trackable.

Develop indicators at the regional scale

Five of the cities in the study reported working with regional groups on adaptation planning (see Table 5), but this work is typically not related to indicators. Adaptation indicators have been developed at the regional scale in some places, although not in any of the cities in this study. For example, planners in the San Francisco Bay Area began to develop regional indicators with a 2014 white paper that proposes some preliminary resilience indicators for the region (Tam and Seville 2014).

There are several reasons why the regional level may be an appropriate scale at which to develop adaptation indicators. First, many cities already have adaptation planning efforts at the regional level, suggesting that a new entity would not need to be created to develop indicators at this scale. Moreover, a region likely faces similar climate impacts throughout and often develops region-wide adaptation strategies. A region could develop a set of shared indicators that would be tracked at the municipal or neighborhood level. These regional indicators would demonstrate how different parts of the region are adapting differently and where more effort should be focused. They would also show the effectiveness of both regional and local adaptation strategies. This approach would reduce the burden on individual municipalities to create their own indicators, while also facilitating comparison between places within a region.

Use indicators to measure a specific strategy rather than overall adaptation

Several cities in the study are using indicators to measure the effectiveness of specific adaptation strategies, rather than overall adaptation or resilience. For example, Baltimore has used this narrow approach to measure the heat island effect and Miami-Dade

and New Orleans have done so with their water management strategies. Focusing on specific climate impacts or strategies can address one of the challenges of adaptation indicators that several interviewees raised – the challenge of defining successful adaptation. Although it may be difficult to define successful adaptation overall, cities should be able to determine what constitutes success for particular strategies. Therefore, if they do not find it feasible to develop indicators to measure overall adaptation, cities can still utilize indicators in this more limited way or as an interim step to developing indicators of overall adaptation.

Minimize data collection by using data collected other purposes

An interviewee from New Orleans reported that rather than planning to collect all new data for its resilience indicators, the city is looking at the many pieces of data it already collects and evaluating whether this data can also measure resilience. The Rockefeller City Resilience Index states that its indicators will be based on data that is already available and that cities may already be using to measure other elements of urban performance (The Rockefeller Foundation and Arup 2015a). To minimize the data collection associated with using adaptation indicators, cities should consider pursuing this approach of incorporating data that they are already collecting for other purposes into their adaptation indicators. For example, social demographic information can measure adaptive capacity, while the age of municipal-owned buildings may be a proxy for their vulnerability to climate impacts.

Share indicators with other cities – even those with different climates

Analysis of the adaptation plans revealed that many elements in the plans address general preparedness and resilience rather than specific climate impacts. This suggests that cities with different climates may be able to share adaptation strategies – and methods for measuring them – with each other. Rather than only learning from cities with the same climate, cities can look to leaders in developing indicators, such as New York, and model general preparedness and resilience indicators after them.

Devote more money to adaptation planning

Several interviewees mentioned money, and relatedly, staff availability, as barriers to developing indicators. Most of the cities in the study only have several people working on adaptation, many of whom also have other job responsibilities. These limited resources make it difficult for cities to develop indicators, but more alarmingly, they make it unlikely that adaptation will proceed at the speed and scale necessary to reduce the vulnerability of communities to the impacts climate change.

An obvious step that cities can take to overcome this challenge of limited resources is to devote more – in some cases much more – of their budgets to climate adaptation. This would allow cities to actually implement the strategies laid out in their adaptation plans. A side benefit would be that cities would have the resources required to develop and use indicators to track the effectiveness of their adaptation efforts, further increasing the likelihood that adaptation efforts will effectively address the impacts of climate change. In an age of limited municipal budgets it may be difficult to find the funds to spend more on

adaptation. Political pressure to address climate change will likely be required to convince policymakers to devote more money to this issue.

Utilize existing frameworks and indicator sets

Cities can benefit from using frameworks and indicator sets that have already been developed. Chapter 6 reviewed several adaptation indicator frameworks mentioned by city staff in the interviews. These frameworks fall into the categories of top-down indexes, which facilitate comparison between places and rely on an external evaluator; community assessment tools that guide communities through measuring their own adaptation progress using a set of predetermined indicators; and guiding frameworks that lead cities through the process of developing adaptation indicators, without necessarily prescribing what indicators they choose.

It is difficult to say which type of framework is "best" because each offer advantages and disadvantages to cities. Before selecting a framework, cities should identify the purpose for which they would like to use indicators and the constraints that they face. If a city's goal is to minimize city staff time and compare its progress to that of other cities, it should choose a top-down index such as the ND-GAIN Urban Adaptation Assessment.[11] However, if a city does choose to rely on an index, it should be aware of the fact that by aggregating multiple indicators, indexes often mask sectoral and spatial variation within a community. Becoming familiar with an index's methodology can help a city understand what the index might not be showing and how they can get this information.

[11] An index requires an outside evaluator, so cities should choose an index that already includes their city or communicate with the people developing the index to see if they can be included.

If a city wants to allow for comparison with other cities but use local data, it could select a community assessment tool, such as the City Resilience Index or the CRAFT tool. Finally, if it wants to tailor indicators to its local climate or planning context, a city could use a guiding framework such as the one designed by USDN to help it with doing so.

Recommendations for external organizations

Conduct outreach to cities about existing indicator frameworks

In addition to the many ways that cities can alter their practices to facilitate the effective use of adaptation indicators, external organizations have a role to play as well. There is a proliferation of adaptation indicator frameworks and indicator sets, many of which are developed by non-profits or research organizations. Despite the fact that so many different frameworks exist, more and more are created each year. It seems as though organizations often develop new frameworks to address perceived methodological shortcomings or issue area gaps of the existing frameworks.

However, the interviews demonstrate that cities are aware of only a fraction of these frameworks, particularly ones that are developed by organizations that are already active in adaptation planning. Barriers to using adaptation indicators cited multiple times in the interviews include limited time and resources, the lack of an agreement on what constitutes "successful" adaptation, and an organizational structure that makes it difficult to develop indicators. Cities did not mention inadequate indicator sets developed by others as a barrier; if cities did mention these external indicator sets and frameworks it was because they were helpful to the city in thinking about adaptation indicators, not because

the frameworks left out particular categories of indicators or failed to address particular methodological challenges.

This suggests that if cities are not using existing adaptation frameworks, it is likely because they are not aware of the frameworks or their relevance, rather than due to perceived shortcomings of the content of the frameworks. To address this information gap, external organizations could prioritize showing cities why they should develop indicators and how these tools can help them over creating additional, slightly different frameworks. If organizations are interested in having cities utilize their indicator frameworks, they may have to do some direct outreach. Recognizing that government employees have many competing priorities, external organizations could directly contact city staff and inform them about these frameworks and how they could use them in their adaptation planning. Without this kind of direct outreach, it will be more difficult for cities to learn about these frameworks and how they can help them.

Facilitate sharing of successful use of indicators across cities

As discussed above, cities can benefit from sharing adaptation indicators with each other. Since many adaptation plans have elements that address general preparedness and resilience rather than specific climate impacts, cities can share indicators with each other even if the climate risks they face differ. Nonprofit organizations and foundations can create spaces for cities to share what is working well and what is difficult about using adaptation indicators. Several organizations, including the Rockefeller Foundation and USDN are already playing this convening role around adaptation in general, and have started to address indicators. Since incorporating indicators into municipal adaptation

planning is not yet widespread, these and other organizations should continue convening cities around this topic and encourage them to share indicators and strategies for developing and using them.

Develop strategies for using indicators that cover a long time horizon

None of the four frameworks reviewed in detail in Chapter 6 address the long time horizon associated with climate change, although this is raised in the literature as a major challenge with adaptation indicators. Although climate adaptation initiatives often have a long time horizon and the effects of an intervention may not be seen for decades, most programs and evaluations of them focus on the short term (Ford et al. 2013; Bours, McGinn, and Pringle 2014a; DEFRA 2010; Climate-Eval 2015). There is a need to develop indicators that address both the short-term implementation of adaptation efforts and their long-term effects. Organizations could play a role in developing individual indicators or combinations of indicators that address both short and long time timeframes.

Conduct research on effectiveness of indicators

Finally, there is a lack of knowledge about the effect of using adaptation indicators. Do indicators really help cities learn and develop better adaptation strategies, as the interviews and literature suggest? The use of indicators in adaptation planning has been minimal so far, so it has been difficult to assess the impact of using indicators. As more and more cities develop adaptation indicators, there is room for researchers to evaluate whether or not using indicators helps cities to better prepare for and cope with the effects of climate change.

Conclusion

Although the use of indicators in adaptation planning is thus far limited, some cities are planning to develop indicators to measure the effectiveness of their adaptation strategies. There is value for cities to use adaptation indicators to promote accountability, determine what adaptation strategies are working well, and develop more effective adaptation strategies for the future. Approaches like connecting indicators to targets, selecting both process and outcome indicators, and selecting a manageable number of indicators can help cities use adaptation indicators in a meaningful way. Cities can overcome the limited resources they have for adaptation indicators by working with outside groups, developing indicators at the regional scale, and using data that is already being collected for other purposes, among other strategies. Non-profit and research organizations can play a role in helping cities develop indicators and advancing the state of knowledge about adaptation indicators.

Several of the cities in this study are developing adaptation indicators or plan to do so in the next few years. As adaptation planning becomes more prevalent and cities have the opportunity to learn from these early adopters, it is likely that other cities will follow suit. In several years, adaptation indicators may come to resemble sustainability indicators, with common indicator frameworks and agreed-upon methods for measuring success. However, it is important that cities keep in mind the value of indicators, and not report on indicators just for the sake of doing so. Instead, cities should use adaptation indicators to understand what is working, how they need to adjust their strategies, and ultimately how they can better address the impacts of climate change.

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Appendix A: Interview Guide

The following questions were asked in the interviews with city staff. As these were semi-structured interviews, if interviewees brought up topics not included in this interview guide, I pursued these topics and asked further questions if I thought they were relevant

1. What is your role within the city of [CITY] and your primary responsibilities in relation to climate adaptation planning?

2. What are the main climate adaptation efforts that [CITY] is undertaking?
    a. What climate risks do these efforts address? (e.g., flooding, heat, etc.)
    b. Do you coordinate with other agencies on this? Which ones?
    c. (If not brought up yet) How do these efforts relate to the climate adaptation plan?

3. Does [CITY] track the implementation of its climate adaptation plan?
    a. If so, how?
    b. If not, why? Are there any barriers to doing so?
    c. If not, is this something your city plans to do in the future?

4. Does [CITY] track how well the plan is working to address the impacts of climate change? For example, do you have a way of evaluating whether the plan is lessening the impacts of sea level rise or storm surge on the community?
    a. If so, how?
    b. If not, why? Are there any barriers to doing so?
    c. If not, is this something your city plans to do in the future?

5. How will you determine if goals, targets, or actions in the plan need to be changed, and how will you go about revising them?

6. Does your city track data or use indicators for other government initiatives (e.g., sustainability, transportation, public safety)? If so, are there plans to add climate adaptation indicators to these?

7. Is there anyone else you think I should talk to about this topic?

Appendix B: List of Adaptation Plans Reviewed

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Appendix C: List of Interviews

City staff

Baltimore, MD: Kristin Baja, Climate and Resilience Planner. February 3, 2016.

Boston, MA: Mia Goldwasser, Climate Preparedness Program Manager. January 6, 2016.

Chula Vista, CA: Cory Downs, Conservation Specialist. January 27, 2016.

Miami-Dade County, FL: Katherine Hagemann, Sustainability Initiatives Coordinator. February 18, 2016.

New Orleans, LA: Jared Genova, Resilient NOLA Project Manager. January 29, 2016.

New York, NY: Carrie Grassi, Deputy Director for Planning at NYC Mayor's Office of Recovery and Resiliency. March 1, 2016; Confidential interview. March 7, 2016.

Norfolk, VA: Confidential interview. January 26, 2016.

Oakland, CA: Shayna Hirshfield-Gold, Energy Policy Analyst. January 25, 2016,

Virginia Beach, VA: Clay Bernick, Environment & Sustainability Administrator and Whitney McNamara, Sustainability Planner. February 7, 2016.

Subject matter experts

Rachel Gregg, Lead Scientist, EcoAdapt. January 29, 2016.

Mike Crowley, Program Director, Institute for Sustainable Communities. February 1, 2016.

Meghan Doherty, Project Manager, ND-GAIN Urban Adaptation Assessment and Joyce Coffee, Managing Director, Notre Dame Global Adaptation Index. February 11, 2016.

Appendix D: Adaptation Indicator Sets and Frameworks

Indicator set/framework name	Year released	Author/ organization	Location	Scale	Categorization	Purpose
Social Vulnerability Index	2003	Cutter, Boruff and Shirley	U.S.	Census-tract	Index	Constructs an index of social vulnerability to environmental hazards based on 1990 county-level socioeconomic and demographic data.
Hyogo Framework for Action	2005	UN International Strategy for Disaster Risk Reduction (UNISDR)	Global	Any	Guiding Framework	Outlines priorities for action for disaster response and describe the work and actions that are required by different sectors, actors and scales of government to achieve them.
Monitoring and Evaluation Framework for Adaptation to Climate Change	2007	United Nations Development Program (UNDP)	Global	Program	Guiding Framework	Guides UNDP staff in the design of M&E frameworks for adaptation initiatives; fulfill the mandates of two adaptation-focused funding programs mandated by the UNFCCC.
Preparing for Climate Change Adaptation Guidebook	2007	ICLEI	Global	City	Guiding Framework	Leads local governments through the various stages of adaptation planning, including measuring progress; combines with ADAPT, a cloud based software system for ICLEI members.
Argonne National Laboratory Resilience Index	2010	Argonne National Laboratory; U.S. Department of Homeland Security's Protective Security Coordination Division.	U.S.	Critical infrastructure	Index	Measures the resilience of critical infrastructure through developing an index based on interviews conducted at critical facilities.
Baseline Resilience Indicator for Communities	2010	Cutter, Burton and Emrich	Southeastern U.S.	County	Index	Develops an empirically-based disaster resilience index for measuring baseline resilience in communities; can be used to track changes in

Indicator set/framework name	Year released	Author/ organization	Location	Scale	Categorization	Purpose
(BRIC)						resilience over time or facilitate comparison between counties.
CARE - Participatory Monitoring, Evaluation, Reflection and Learning for Community-Based Adaptation Manual	2010	CARE International; IISD	Any	City/Program	Guiding Framework	Tailors M&E of adaptation to the local context; designed to incorporate M&E into community-based adaptation projects.
CityNet Climate and Disaster Resilience Initiative	2010	CityNet; Kyoto University; TDLC; SEEDS; UNIDSR	Asia	City	Index	Assesses the disaster resilience of Asian cities based on 125 variables; results based on surveys filled out by Asian cities.
Coastal Resilience Index	2010	Sempier et al; Sea Grant; NOAA	U.S. coastal communities	City	Community Assessment	Provides community leaders with a simple and inexpensive method of predicting if their community will reach and maintain an acceptable level of functioning after a disaster.
ADAPT Principles	2011	Villanueva; Strengthening Climate Resilience (SCR)	Any	Any	Guiding Framework	Proposes principles to facilitate the development of M&E frameworks for adaptation interventions.
Adaptation Fund Results Framework	2011	UNFCCC Adaptation Fund	Global	Project	Guiding Framework	For actual and potential Adaptation Fund–implementing agencies, provides instructions on how to design a project's logical framework and M&E system in a way that's aligned with the Fund's strategic results framework; presents a checklist for selecting indicators.
ADAPTMe Toolkit	2011	UKCIP	Any	Any	Guiding Framework	Leads adaptation practitioners through a process of developing an evaluation, including determining the purpose of the evaluation, determining the logic that underpins assumptions, overcoming challenges, and

Indicator set/framework name	Year released	Author/ organization	Location	Scale	Categorization	Purpose
						developing indicators.
Characteristics of a Safe and Resilient Community	2011	Arup and International Federation of the Red Cross	Global	City	Guiding Framework	Identifies characteristics of resilient communities; characteristics could be used in program design and M&E.
Climate Change Vulnerability Index	2011	Wheeler; Center for Global Development	Global	National	Index	Provides comprehensive information on climate change vulnerability for donor institutions that seek to provide financial assistance for adaptation to climate change on a national level.
Making Adaptation Count	2011	Spearman and McGray	Global	Any	Guiding Framework	Proposes a 6-step framework for developing M&E systems for climate adaptation; provides guidance for choosing indicators and example indicators.
Resilience Capacity Index	2011	Buffalo Regional Institute	U.S.	Regional	Index	Allows regional leaders to compare their region's capacity profile to that of other metropolitan areas, with a business lens.
Tracking Adaptation and Measuring Development	2011	Brooks et al; IIED	Global	Any	Guiding Framework	Proposes an approach to evaluating adaptation that combines assessment of how well climate risks to development are managed by institutions (upstream indicators) with how successful adaptation interventions are in reducing vulnerability and keeping development on track (downstream indicators).
Framework for Urban Climate Resilience	2012	Tyler and Moench	Asia, but can be applied globally	City	Guiding Framework	Develops an operational framework of resiliency for planning professionals focused on three elements of urban resilience - systems, agents, and institutions; demonstrates the use of the framework in Asian cities.
TANGO Resilience Assessment Framework	2013	Food and Agriculture Organization of the UN; World Food Program	Africa	City/Program	Guiding Framework	Integrates a livelihoods approach, a disaster risk reduction approach, and various elements of climate change approaches to address underlying causes of vulnerability.

Indicator set/framework name	Year released	Author/ organization	Location	Scale	Categorization	Purpose
Community-Based Resilience Assessment (CoBRA)	2014	United Nations Development Program (UNDP)	Africa	City/Program	Guiding Framework	Presents a framework for conducting a baseline assessment of resilience characteristics, assessing program/policy impacts, and conducting repeat assessments; proposes potential indicators of community resilience.
Theory of Change Approach	2014	Sea Change; UKCIP	Any	Program level	Guiding Framework	Proposes a theory of change approach for monitoring and evaluating climate adaptation programs.
Disaster Resilience Scorecard for Cities	2015	UN International Strategy for Disaster Risk Reduction (UNISDR)	Global	City	Community Assessment	Provides a set of questions and rating scales for cities to answer that will allow them to understand how resilient they are to natural disasters.
ND Global Adaptation Index	2015	Notre Dame Global Adaptation Index; Kresge Foundation	Global	National	Index	Ranks and compares countries on their vulnerability and readiness to respond to disasters; aims to help businesses and the public sector better prioritize investments for a more efficient response to global challenges.
Resilience Scorecard	2015	Berke et al	U.S.	City	Index	Focuses on identifying conflicts between local plans and vulnerability to hazards; aims to help integrate and improve local plans in ways that reduce losses from hazard events.
Climate Risk and Adaptation Framework and Taxonomy (CRAFT)	2016	C40	Global	City	Community Assessment	Standardized reporting framework for cities to report local climate hazards and impacts, risk and vulnerability assessment, adaptation planning and implementation, and monitoring and evaluation; reporting complies with Compact of Mayors.
States at Risk	2016	Climate Central; ICF International	US	State	Index	Uses a grading system to show to what extent U.S. states are prepared for current and future climate risks; grades are based on both the magnitude of the current and future threat and the action states have taken to prepare for them relative to other states.

Indicator set/framework name	Year released	Author/ organization	Location	Scale	Categorization	Purpose
USDN adaptation metrics project	2016	Urban Sustainability Director's Network (USDN)	U.S.	City	Guiding Framework	Helps cities determine how to develop adaptation indicators and guides them through this process.
City Resilience Framework and Index	2015-2016 (ongoing)	Rockefeller and Arup	Global	City	Community Assessment	Describes what makes a city resilient based on 12 goals with qualities and indicators within each one; will provide cities a way to assess their own resilience and make decisions based on it.
ND-GAIN Urban Adaptation Assessment Project	2015-2016 (ongoing)	Notre Dame Global Adaptation Index; Kresge Foundation	U.S.; to be expanded globally	City	Index	Scales down the country index that ND-GAIN has already developed to the urban level; aims is to facilitate investment and policy interventions where they are most needed and to compare vulnerability across cities.
City Resilience Profiling Programme	2016 (ongoing)	UN-HABITAT	Global	City	Guiding Framework	Provides national and local governments with tools for measuring and increasing resilience to multi-hazard impacts including those associated with climate change.
ISO/DTR 37121	2016 (ongoing)	International Organization for Standardization (ISO)	Global	City	Guiding Framework	Presents an inventory and review of existing indicators on sustainable development and resilience in cities; will include both a set of indicators and a certification; standard to cover 14 thematic areas across sustainability and resilience.