Adaptation Strategies in San Francisco Bay Area Local Climate Action Plans

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ABSTRACT

Local climate action plans (CAPs) organize a city's efforts to mitigate greenhouse gas emissions, but they can also incorporate adaptation strategies to help cities develop resilience against impending climate change impacts. The benefits and prevalence of adaptive planning as a climate solution has yet to be fully explored. I created a scoring matrix based on eight components of adaptation to evaluate fifteen climate action plans in the San Francisco Bay Area. I found that mitigation currently takes precedence over adaptation in CAPs and cities' adaptation strategies are often poorly suited to their local environments, but city governments are recognizing the benefits of adaptive planning through local partnerships and public outreach programs. However, most have not committed to adaptation efforts that require more intensive effort or funding. I also found correlation between adaptation and political attitudes of cities' residents, which can influence the implementation and progress of climate change adaptation plans. Some CAPs are responding to larger regional or state legislation regarding climate change, while others are largely motivated by the desire for a more sustainable community. The presence of co-benefits between mitigation and adaptation in CAPs may provide an opportunity for local governments to pursue adaptive planning. I conclude by offering a comprehensive set of best practices for including adaptation in future revisions and adoptions of CAPs.

KEYWORDS

climate resilience, co-benefits, mitigation, sustainable development, urban planning

INTRODUCTION

Climate action plans (CAPs) can alleviate local effects of climate change by identifying climate change risks and setting goals for addressing targeted climate issues (Hoornweg et al. 2011). Cities demand a lot of energy for transportation, buildings, industry, and other uses, producing greenhouse gas (GHG) emissions that damage human health and local environments (IPCC 2013). CAPs can decrease anthropogenic GHG emissions in a city by setting priorities and identifying actions to reduce energy demand and implement energy efficiency projects. Many cities have implemented CAPs in response to growing climate change awareness over the last decade, despite the lack of a standardized method or format for developing a CAP (Millard-Ball 2012; Bassett and Shandas 2010). Some cities have adopted CAPs after joining non-profit initiatives such as the Cities for Climate Protection (CCP) campaign from ICLEI – Local Governments for Sustainability.[1] Since the CCP campaign's inception in 1993, many cities have partnered with ICLEI to implement measures for local sustainability and in California, more than 180 cities have joined the CCP (Millard-Ball 2012).

Climate actions can be categorized as either *mitigation* or *adaptation* strategies. Mitigation address damages already set in motion and cuts the level of direct GHG emissions through policies such as fuel efficiency standards or cap-and-trade programs (IPCC 2014a). Adaptation involves actions taken to develop infrastructure that responds to or avoids further climate change and warming effects (IPCC 2014b). For example, Santa Cruz, California's "Climate Adaptation Plan" aims to "adapt to climate change impacts while maintaining the community's environmental, social, and economic health (City of Santa Cruz 2012)." This involves strategies such as protecting against sea level rise and extreme storm events. As local climate action planning gains traction, it is important to identify best practices and means of assessing plans for continued improvement.

In California, regional and statewide policies can encourage the inclusion of climate action planning in a city's general plans. The Global Warming Solutions Act of 2006 (AB32) is a landmark law that outlines the state's goal of reducing GHG emissions to 1990 levels by 2020. In addition to implementing energy efficiency solutions across California, AB32 requires local

[1] The CCP has been defunct for several years, but many cities still work with ICLEI and use their emissions inventory software, Clearpath. In California, this is in partnership with SEEC – Statewide Energy Efficiency Collaborative, an alliance between utilities and local government non-profits, headed by Pacific Gas & Electric (SEEC 2013).

governments to take action by setting GHG reduction targets on par with or better than statewide goals (CA Air and Resources Board 2006). Similarly, the Sustainable Communities and Climate Protection Act of 2008 (SB375) also seeks to reduce locally-produced emissions from passenger vehicles by setting regional reduction targets. The law further mandates regional metropolitan planning organizations (MPOs) to develop "sustainable communities strategies" (SCSs) addressing environmental issues of transportation, housing, and land use. These SCSs and their outcomes affect how much funding each MPO will receive for implementing planned actions (CA Air and Resources Board 2008). Plan Bay Area, which was adopted in 2013, is the San Francisco Bay Area's SCS as required under SB375. The plan includes several policy goals, primarily in the areas of transportation and residential development (SF Bay Area MTC 2013). However, while GHG reduction, transportation, and land use mitigation often addressed in local California climate policy due to these statewide requirements, climate adaptation as a critical area is neglected. In California, adaptive planning is not mandated by any state or regional policy, so adaptation goals are only included in CAPs at the discretion of local jurisdictions. The California Climate Adaptation Strategy promotes adaptation research and solutions across several major social and economic sectors to support the need for climate adaptation but remains supplemental to AB32 (CA Natural Resources Agency 2009; Moser et al. 2012). For local governments, the state's climate change website (climatechange.ca.gov) also offers the California Adaptation Planning Guide as a resource of proposed locally-based strategies and the climate assessment tool Cal-Adapt (CA Emergency Management Agency 2012). However, these resources exist separately from the mandates of AB32 and SB375, so their use is optional for cities. Yet in the face of severe climate change, developing climate resilience is essential to the long-term sustainability and viability of a city's infrastructure, resources, and community. Local and regional governments may be aware of climate change, but may not be prepared to analyze or address its local impacts. As a result, their CAPs often do not comprehensively address specific risks the city might face (Baker et al. 2012).

Adaptation strategies in CAPs may have mitigation co-benefits, or strategies with more than one benefit that alleviates climate change or reduces GHGs (IPCC 2014a). Co-benefits like water conservation and transit-oriented development address both mitigation and adaptation because they limit emissions while orienting social or physical systems to greater sustainability. The California Adaptation Planning Guide discusses co-benefits as an important and desirable

factor in evaluating and prioritizing climate action strategies (CA Emergency Management Agency 2012). But while some climate change solutions address both mitigation and adaptation, others are less complementary. For example, water desalination technologies may reduce the demand for freshwater resources, but their energy-intensive operation undermines mitigation (Bedsworth and Hanak 2008). Thus, planners must be aware of how strategies affect a city's mitigation and adaptation goals.

The full range of benefits associated with adaptation remains uncertain (Füssel 2007). Policymakers have been slow to act on a city's identified climate vulnerability problems, forming a knowledge gap called the "adaptation deficit" between the potential of the well-adapted city and its current ability to plan for climate recovery and prepare for future climate change (Burton 2009). Adaptation deficits may be attributed to incomplete knowledge about how climate change affects local environments, hindering the development of fully comprehensive CAPs (Tang et al. 2010). Ekstrom and Moser (2014) found that institutional obstacles, local attitudes, and limited financial resources may also slow the progress of adaptation CAPs. Finally, the lack of a universal or standardized format for writing CAPs could be either an advantage or a pitfall for local governments attempting to establish climate action goals. Due to the emergence of adaptive planning and CAPs as pathways towards local sustainability, it is important to identify ways to integrate and improve adaptation strategies in climate planning and implementation.

I investigated the inclusion and characteristics of adaptation in CAPs of selected towns and cities in the San Francisco Bay Area, focusing on the following questions:

1) To what extent are Bay Area cities focusing on adaptation strategies in their CAP?
2) What are the most common adaptation elements present in these CAPs and why?
3) What influences the inclusion of adaptive planning in these CAPs?

To answer these questions, I identified the elements of well-developed adaptation plans drawing on existing literature to create a quantitative scoring matrix to test a sample of Bay Area CAPs for the presence of these specified components of successful adaptation strategies. The used the matrix to score each city's CAP adaptation strategies based on criteria demonstrating thoughtfulness and depth in adaptation planning. These criteria to quantitatively evaluated Bay Area CAPs and generated a numerical "adaptation score" ranking the level of breadth and depth in the plan. I then examined relationships between adaptation efforts in CAPs and the physical and demographic characteristics across jurisdictions. Finally I identified ways in which CAPs

were successful or deficient in addressing adaptation and developed a set of best practices to incorporate adaptation in adoptions or revisions of CAPs.

Study site background

The San Francisco Bay Area, located on the coast of Northern California, includes 9 counties and is home to more than 7.5 million people. The weather is mild, with a Mediterranean climate featuring warm, dry summers and moderate, rainy winters (Pacific Energy Center 2006). Average population density is 1,065 people per square mile, but this encompasses a variety of urban settings from dense metropolitan cities like San Francisco or Oakland to more suburban and rural towns like Brentwood or Danville (U.S. Census 2014).

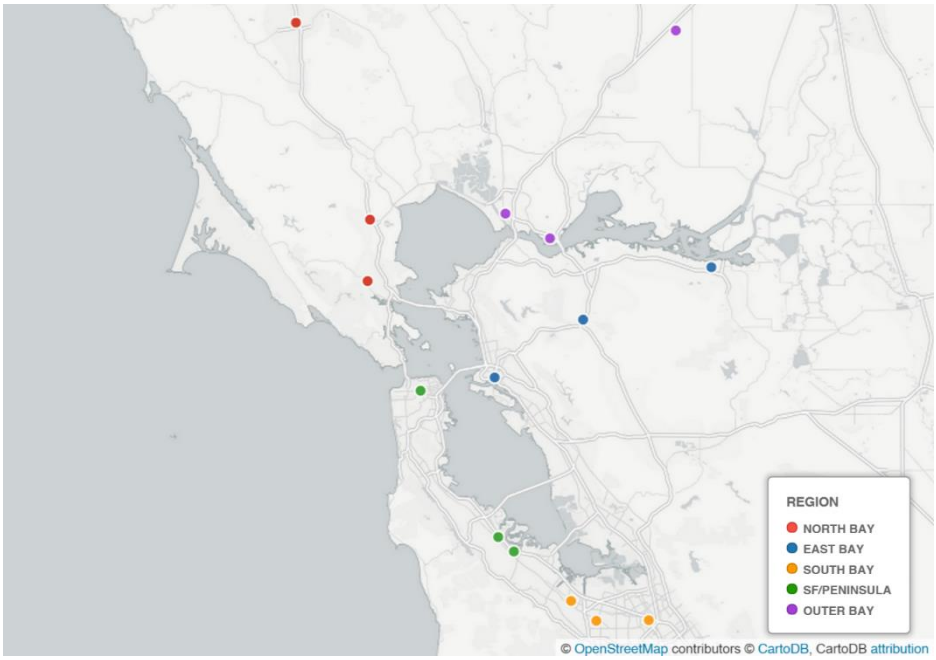
The Third Climate Change Assessment in California (Moser et al. 2012) evaluates some of the main impacts facing the Bay Area. These include increased frequency of extreme heat events and more severe and persistent drought, which will negatively affect the public health of urban populations. In addition, sea level rise and depletion of the Sierra Nevada snowpack will contribute to strained water resources in the Bay Area. These environmental changes will affect all communities, but children, the elderly, and low-income populations are especially vulnerable, as they may be less able to adaptive to sudden environmental shifts (Mazur et al. 2010). Climate change's varying impacts on populations may further exacerbate economic and social disparities in the Bay Area, so equity considerations in the public policy and urban planning process are essential (Shonkoff et al. 2011).

METHODS

Study site selection

To create a representative sample set of the Bay Area's diverse city settings, I used a stratified random sampling method and selected fifteen cities based on their location and urban type. To standardize my selection, I defined a "city" or "municipality" as an incorporated area under local jurisdiction, following the U.S. Census Bureau's (2010) classification of municipal

governments. I divided the San Francisco Bay Area into five sub-regions: North Bay, San Francisco/Peninsula, East Bay, South Bay, and Outer Bay (Figure 1). Within each sub-region, I used the California State Association of Counties' Institute for Local Governments (ILG) list to identify rural towns, suburbs, and urban cities. In total, I selected fifteen Bay Area cities with completed or in-progress CAPs (ILG 2013).



North Bay	East Bay	South Bay	SF/Peninsula	Outer Bay
San Rafael	Oakland	San Jose	San Francisco	Vallejo
Santa Rosa	Walnut Creek	Sunnyvale	Redwood City	Benicia
Novato	Antioch	Mountain View	San Carlos	Dixon

Figure 1. The San Francisco Bay Area was divided into five regions and three cities were selected from each sub-region**.** The cities and their locations are identified in this map.

I then downloaded the most recent CAP from each city's government website (Appendix A). To obtain general background information on each city, I used the U.S. Census Bureau database to select physical and demographic characteristics that I hypothesized might have some correlation patterns with the presence of adaptation planning strategies (Table 1).

Table 1. The chosen background characteristics of fifteen sampled Bay Area cities. See Appendix B for detailed characteristics of all cities.

Characteristic	Description	Source
Population	Number of people	U.S. Census, 2010
Area	Square miles	U.S. Census, 2010
Density	Persons per square mile	U.S. Census, 2010
Median Income	USD ($)	U.S. Census, 2010
Median Home Value	USD ($)	U.S. Census, 2010
Political Attitudes	% registered Democrat; % registered Republican; % without party preference	California Secretary of State, Report of Voter Registration by County, September 5, 2014
ICLEI – Cities for Climate Protection Campaign	Whether city is enrolled in ICLEI's CCP	ICLEI – Local Governments for Sustainability, July 2012
Coastal Area	Whether city borders coastline or San Francisco Bay shoreline	Refer to map

Scoring matrix

I created a scoring matrix in Microsoft Excel (2013) based on indicators or criteria demonstrating thoroughness and depth of adaptive planning. To select the criteria, I researched best practices in adaptation within academic literature and examined CAPs outside the Bay Area that incorporated adaptation strategies and methods. I determined that each of the selected criteria had to address specific adaptation solutions, but had to be general enough to be applicable to cities of all types. I chose eight important components of CAPs that contribute to well-defined adaptation strategies as my criteria and defined my rationale and strategies for each one (Table 2). Additionally, I consulted professors and graduate students at UC Berkeley who are involved in local climate planning processes to review the quality of my criteria and form of my matrix.

Table 2. Scoring matrix criteria and rationale and description of qualifying strategies. Each criterion has a bolded abbreviation that I will use to refer to it in the results and discussion.

Criteria	Rationale for selection	Criteria Strategies
What criteria should be addressed in effective climate adaptation?	*Why was this criterion selected?*	*What strategies would earn points towards that criterion?*
1. DEFN: Defines and understands adaptation planning within the city's local climate & geography	CAPs need to be responsive towards solutions that best address the local environment	0 points for no mention; 1 for a broad or unrefined definition; 2 for identifying and defining adaptive planning and mentioning local landscape influences
2. INFO: Efforts to expand information base and analysis on local risk and vulnerability	Information on how local climate is affected is uncertain, and the local government needs to stay updated to make informed decisions.	Providing action goals for gaining knowledge and pursuing research and analysis to close that gap; holding public forums to address civilian concerns; working with local think tanks, universities, consultancies etc.
3. UHI: Strategies to reduce the urban heat island effect	The urban heat island effect will intensify in cities as surface temperatures rise	Urban forestry, reflective surfaces, cool roofs, reducing waste heat for adaptive goals.
4. RISK: Climate disaster risk management plan	Cities are at-risk for extreme climate events, and need to have an emergency plan in the case of an event occurring.	Risk assessment modeling of local environment to identify largest threats; strategies addressing sea level rise & flooding, drought adaptation, heatwave adaptation etc.
5. EDUC: Spreading awareness of climate change issues through educating the public and engaging stakeholders	Public education and community engagement on climate change can inspire individuals to make behavioral changes to reduce climate-intensive activities	Educating the public and government officials on local climate change risks; engaging affected stakeholders from public and private sector
6. BIO: Natural habitat and biodiversity conservation efforts	Local native species of flora and fauna are impacted by climate change and urban development, and efforts should be taken to preserve their livelihood	Natural habitat and parks preservation; protection of local native species; ecosystem resiliency and land management methods
7. WATER: Strategies for water resource management	Water resources are threatened by climate change as sea levels rise and freshwater systems are depleted	Identifies water quality and/or quantity risks; green landscape and irrigation techniques in public spaces; behavioral water consumption education; sea level rise and flood management methods
8. DEVL: Strategies for social and economic development and adaptations	Climate change makes businesses, societies, and disadvantaged populations vulnerable to its effects.	Affordable housing; sustainable business development programs; environmental justice; public health considerations

To use the model, I read each CAP and assigned points for the progress each city had committed toward each of the eight criteria using the United Nations Framework Convention on Climate Change (UNFCCC)'s adaptation model, which defines the process of adaptive planning

through five main steps (UNFCCC 2014). Criterion 1 in my matrix asks for a definition of climate adaptation for which I created my own scoring assignment, giving 0 to 2 points for the CAP's definition of adaptation in response to local environment. For criteria 2-8, I assigned points using the UNFCCC system (Table 3).

Table 3. Description of scoring system used to rank CAPs.

Points	Element	Description
0	None	Climate action plan does not state any action taken in this criterion.
1	Observation	Climate action plan observes a local climate change situation or effect for criterion and recognizes it as an issue to be addressed.
2	Assessment	Climate action plan identifies options for addressing criterion and evaluates costs, benefits, and risks of different strategies.
3	Planning	Climate action plan states a strategy or plan for adaptation stated in the criteria.
4	Implementation	Climate action plan states plans and actions for the criterion are currently being implemented or will be implemented within the next 2-3 years.
5	Monitoring & Evaluation	Climate action plan states completion of the strategy and includes remarks on its effects

After assigning values to each criterion individually, I summed each city's points to calculate an "adaptation score" summarizing the efficacy of each CAP in adaptation planning. A higher score represented a more advanced and successful level of adaptation planning. An ideal and fully recognized climate adaptation plan would address all the criteria in my matrix up to the Monitoring & Evaluation phase and achieve the full score of 37 points. The adaptation score allowed me to document each city's level of progress in planning adaptation strategies as well as compare criteria and scores across cities. After calculating an adaptation score for each of the cities, I used regression analysis in Microsoft Excel's Data Analysis tool to study the strength of the relationships between the score and the various background characteristics I selected. I completed single-variable regression against eight physical and demographic features: population; area; density; median income; median home value; and political party affiliation of registered voters. Additionally, I performed multi-variable regression on population factors, political factors, financial factors, and finally, the entire set of factors, to see if any particular type of characteristic could be a main driver of adaptive planning.

RESULTS

Summary of Findings

Across all sample cities, the average adaptation score was 18.4 out of 37 points, or 49.7% of the total possible score (Table 4). The highest scoring cities were San Rafael (26 points), Oakland (26 points), and San Francisco (26 points), while Dixon (5.5 points), San Jose (8 points), and Novato (8 points) earned the lowest scores. Across all cities, [#8.DEVL] social and economic development (3.00 points), and [#5.EDUC] community and stakeholder engagement and outreach (3.13 points) scored highly. [#6.BIO] Natural habitat and biodiversity preservation (1.17 points) and [#4.RISK] climate disaster risk planning (1.80 points) received the lowest scores.

Table 4. The completed adaptation scoring matrix shows each city's score for each element of adaptation and its total adaptation score out of 37 points. The bottom row shows an average score for each element across all cities.

	1 DEFN	2 INFO	3 UHI	4 RISK	5 EDUC	6 BIO	7 WATER	8 DEVL	Total
San Rafael	1	4	4	3	4	3	3	4	26
Santa Rosa	2	4	4	3	4	0	2	3	22
Novato	0	1	1	0	2	2	2	0	8
Oakland	2	4	4	3	4	1	4	4	26
Walnut Creek	1	4	3	0	4	1	3	4	20
Antioch	0.5	0	2	1	3	0	0	4	10.5
San Jose	0	0	0	0	4	0	0	4	8
Sunnyvale	2	4	3	3	4	0	2	3	21
Mountain View	1.5	3	0	3	4	2	2.5	3	19
San Francisco	2	4	4	2	4	4	2	4	26
Redwood City	1	4	2	2	4	2	2	3	20
San Carlos	2	3	4	3	4	0	4	4	24
Vallejo	2	4	4	3	4	0	2	4	23
Benicia	1.5	3	0	1	4	2.5	4	1	17
Dixon	0.5	2	3	0	0	0	0	0	5.5
AVERAGE	1.27	2.93	2.53	1.80	3.53	1.17	2.17	3	18.4

CAP Definitions and Components

The definition of adaptation varied across all CAPs scored. While some CAPs had a clear adaptation component or section, other CAPs didn't mention the word "adaptation." Cities averaged 1.27 out of a possible 2 points for including a definition for adaptation in their CAP. To receive 2 points, a CAP needed to explicitly define "adaptation" and identify climate change risks

that affect the city on a local scale. For example, Oakland's CAP defined "adaptation" as "activities that can help our community adapt to the impacts of climate change (City of Oakland 2012)." It also described specific local impacts from climate change such as sea level rise and increasing extreme heat events affecting the city's vulnerable low-income neighborhoods. Oakland's description received the full 2 points in the scoring matrix. However, few plans identified their largest climate threats on a local context like Oakland's CAP did. Cities that received full points for clearly addressing adaptation had an average adaptation score of 23.67, compared to the overall average score of 18.4 among all plans and 8 among plans not mentioning adaptation at all. Overall, cities generally prioritized mitigation over adaptation in the content of their CAPs. Several plans described only the climate impacts threatening Northern California region. Sunnyvale and Santa Rosa's CAPs cited the primary climate change impacts from the California Climate Adaptation Strategy report: increased wildfire risk, negative impacts to wildlife, deteriorating public health, decreased supply of fresh water, and increasing sea levels. Other plans listed local climate threats, but did not cite adaptation as a potential solution or did not provide a clear definition of adaptation as a way of addressing this issue. For example, Benicia's CAP discussed the same climate change risks as Sunnyvale's and Santa Rosa's, but the focus of Benicia's CAP was entirely on mitigation (City of Benicia 2009).

Cities did not focus equally on all elements of adaptation, and the scoring matrix results reflected the ones they prioritized more heavily in the CAP (Figure 2). The criterion with the highest average score was [#5.EDUC] public education and community engagement, which was addressed in 14 out of 15 plans. The average score was 3.53 out of 5, meaning that most cities either planned to include a climate education program or already had one. Several cities stated that they began implementing this component already as part of the CAP development process, to ensure that the CAP would address citizens' environmental concerns. Cities that used a community-based governance approach to design their CAPs held workshops and convened green committees composed of citizens and city staff. For example, the Oakland Climate Action Coalition provided a platform for multiple stakeholder groups to discuss their priorities and needs in reference to the city's CAP as it was being written, reflecting a concerted effort in community engagement. Experts, organizers, and staff from over 30 organizations came together to research the impacts of climate change on Oakland's landscape and deliver potential adaptation solutions for Oakland's CAP (Garzón et al. 2012). Some CAPs, such as San Rafael's and San Francisco's,

mentioned plans for formalized public outreach and education programs to inform all its citizens of climate change risks. A related strategy, [#2.INFO] forming research-based partnerships to expand a city's information base on climate change, was described in 13 plans and received an average of 2.93 points. All cities collaborated with an organization, non-profit, utility company, or private firm, to research and implement some of the sustainability measures outlined in their CAP. However, the extent to which cities sought assistance from other groups or climate experts tended to vary. Some local governments took on climate action planning entirely within their planning department, while others outsourced the research and analysis to a private environmental consulting firm. Planners in many cities consulted local residents during the CAP development process, but not all cities demonstrated a level of partnership or cooperation as high as Oakland's. Some cities, like Antioch, had only a few partnerships associated with their CAP, instead focusing on implementing mitigation strategies and ignoring adaptive planning.

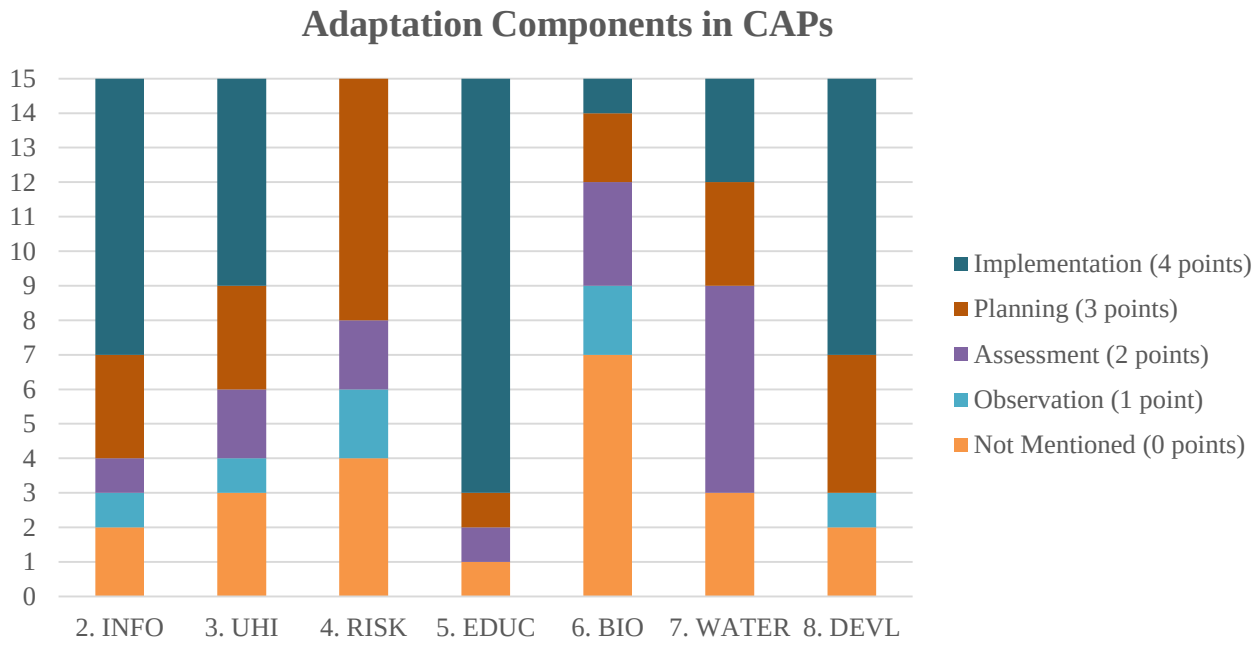


Figure 2. This graph shows how CAPs addressed adaptation elements, based on the UNFCCC scoring scale. The criterion for [#1.DEFN] the definition of adaptation was not included in the graph because its scoring system did not follow the 0-5 scale that the other criteria did.

Cities received the lowest scores for [#6.BIO] natural habitat and biodiversity conservation, which was mentioned in only 8 of 15 plans, usually to a very limited scope. The average score was 1.17, indicating that Bay Area cities are doing little to address this criterion beyond observing and commenting on the damages. Most of the plans in my study acknowledged

the effects of climate change on native species, but did not present any ways to address that threat. For example, Benicia's CAP identified threats to natural vegetation and wildlife as a climate change effect. Strategies like drought-tolerant landscaping and urban forestry were explored in its CAP, but not given attention. Tougher habitat restoration efforts were ignored in most CAPs, and mentioned in only Mountain View's and Oakland's.

Co-benefits for Adaptation

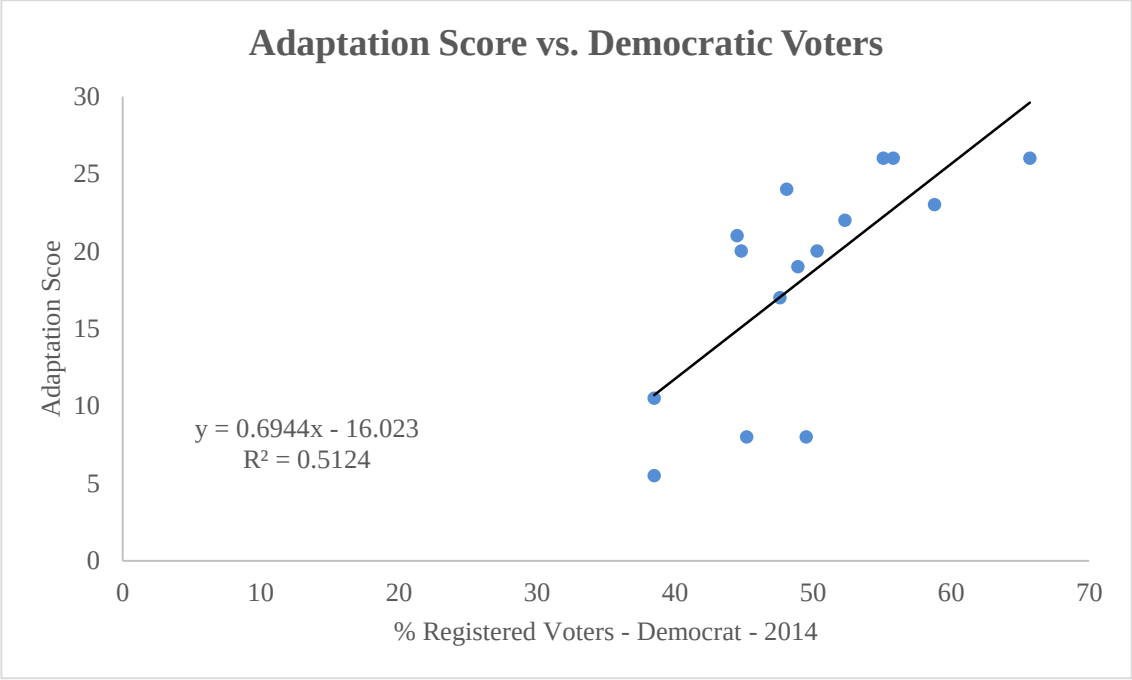
Results might show cities to have stronger adaptation strategies than they actually do because the co-benefits in strategies inflated scores and made it difficult to fairly score some of the adaptation criteria. Examples of strategies in the scoring matrix with co-benefits included [#7.WATER] water conservation strategies and [#8.DEVL] transit-oriented development. These were established in plans to mitigate carbon emissions but they can also help a city's climate and citizens adjust to the impacts of local climate change. Some plans explicitly identified strategies with crossover benefits for adaptation, while others did not recognize the co-benefits associated with the strategies they were implementing. For example, Sunnyvale's CAP distinguished co-benefits by using icons to represent water conservation, education opportunities, and other observed benefits. Conversely, Novato's CAP scored 8 points, yet adaptation was never directly mentioned in the plan's text. The points all came from having mitigation strategies with adaptation co-benefits.

Some CAPs had customized content or formats, which may have affected the way cities included adaptation strategies and co-benefits. For instance, San Jose, a central hub for Silicon Valley's technological innovation, has=d a Green Vision Plan focused on expanding and integrating clean technology into everyday infrastructure. Strategies such as installing LED streetlights and adding cleantech jobs were strongly emphasized in San Jose's Plan. However, other than some co-benefits from such efforts, the plan lacked coverage of solutions focusing directly on adaptation. The city of San Francisco has an extensive sustainability program and CAP centered on three main goals for the city's water, waste, and transportation systems. While this approach allowed for creative opportunities for San Francisco to address their climate action goals, it limited their ability to directly address adaptive planning strategies.

Adaptation and background characteristics

Participation in ICLEI's Cities for Climate Protection campaign did not have a large influence on the adaptation score. Among the eight sampled cities enrolled in ICLEI's CCP, the average adaptation score was 18.25. For the seven cities not in the CCP, the average adaptation score was 18.70. Comparing cities located on the Bay shoreline with cities inland did reveal a notable difference in the adaptation score. For eleven coastal cities sampled, the average score was 19.82, and 14.5 for four inland cities.

Plotting the adaptation score of each cities against several background features and running multi-variable linear regression analyses did not demonstrate any strong relationship between the strength of adaptation and population factors, financial factors, or political attitudes jointly (Appendix C). However, single-variable regression of the adaptation score on political affiliations yielded a correlation between the adaptation score and the political preferences of registered voters in the city. The adaptation score correlated positively with the percentage of registered Democratic voters and negatively with the percentage of registered Republican voters (Figure 3).



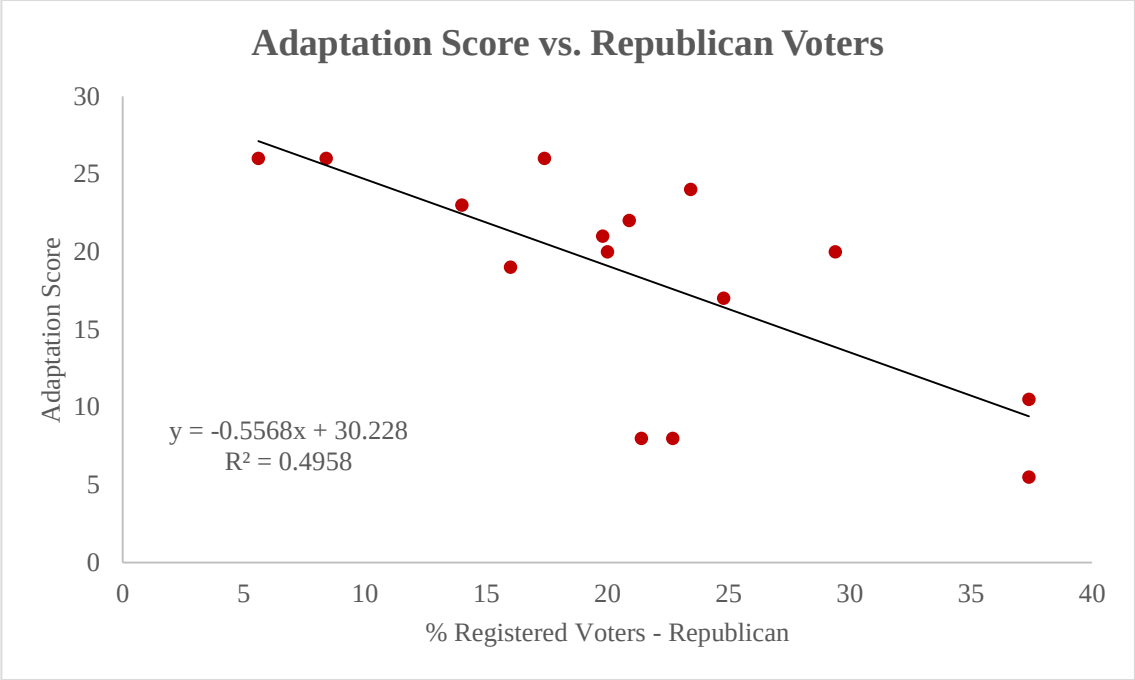


Figure 3. Adaptation score plotted against political affiliations of city residents show a positive correlation between adaptation score and the percentage of registered voters who indicated a Democratic Party affiliation, and a negative correlation between adaptation score and percentage of registered voters who indicated a Republican Party affiliation.

DISCUSSION

There is a great deal of potential for all cities to improve their climate adaptation and resilience efforts through their CAP, since none of them were close to a perfect adaptation score. Currently, cities are mainly focusing on mitigation strategies that are simple and achievable. This may be driven by a lack of understanding about local effects of climate change and limited guidance or encouragement to start adaptation. The co-benefits between mitigation and adaptation in many plans point to a possible avenue for cities to strengthen the adaptation component in CAP future revisions. Statewide guidance has supported mitigation efforts but not necessarily adaptation, while internal characteristics of a city's political and physical climate may also correlate with their level of adaptive planning.

Current Adaptive Planning Status

Most plans did not directly address adaptation and generally lacked the intention to discuss the topic in-depth, leading to lower adaptation scores. For the cities sampled, CAPs receiving full points for the definition of adaptation scored higher than average for the overall adaptation score. In all plans, mitigation dominated content and discussion. Some cities, like Benicia and Dixon, intended to focus mostly on mitigation strategies to reduce climate change, and this was made explicit in the body of their CAPs. Climate action plans may intentionally deal with strategies of mitigation before concerning themselves with adaptation and this held true for the results I observed. Mitigation strategies are more quantifiable via emissions inventories and GHG reduction calculations, while adaptation benefits have fewer measurable outcomes. Completing an emissions inventory and setting a clear emissions reduction target tends to focus the CAP more closely on methods of mitigation than adaptation since the emissions savings can be calculated with specific metrics (Wheeler 2008). Outcomes of adaptation, on the other hand, are not as easily measured (Portney 2013). In addition, practices that produce immediate results may also be favored over ones that incur benefits over the long-term. Adaptation's effects tend to accrue over a longer time period than with mitigation, so it may receive less current attention in a city's CAP (Bassett and Shandas 2010).

Many cities did not identify their climate vulnerabilities on a local scale in their CAPs, suggesting that they may not have been equipped with the resources to do so. They might not have been able to secure effective partnerships or resources to conduct research to identify, analyze, and prioritize the city's immediate climate risks. Instead, plans assessed climate change impacts more superficially, drawing data from generalized scientific studies or state government websites. The California Adaptation Planning Guide and Cal-Adapt were among the referenced statewide resources that can help local California governments review some of their climate threats and solutions, but not in truly in-depth or specific ways. Moreover, some CAPs were adopted before many of these guides or websites were published, so they lacked access to state guidance on local adaptive planning. Other cities, like San Francisco, worked with local planning consultants or research universities to clearly identify and articulate their largest climate risks and which adaptation strategies to prioritize and implement. Even so, cities that have identified local climate risks may not perceive all of them as immediate threats or currently harmful, so they choose not to adapt (Dow et al. 2015). Therefore, for threats considered minor, the city does not include

strategies for adaptation in the CAP, but in future revisions, the climate risks may be reevaluated and potential solutions revisited.

Efforts involving collaboration with and assistance from outside interest groups may be pursued because cities are able to solicit help from others with specific knowledge and expertise. Some jurisdictions may not consider adaptation their responsibility, and the unclear divisions of roles in setting the goals and tasks of adaptive planning can make a city reluctant or unwilling to write adaptation into their CAPs (Nalau et al. 2015). However, by [#2.INFO] establishing partnerships with local groups, cities may reconcile the adaptation deficit and understand the climate change risks they face without spending excessive time and resources conducting local research, while also not bearing the full responsibility for adaptation (Tang et al. 2010; Burton and Mustelin 2013). All plans referenced working with local consultants, think tanks, universities, or other organizations to develop the CAP or deliver results on specific action strategies. The Oakland Climate Action Coalition is an example of how collaboration between different stakeholder groups allowed the city to balance social equity concerns in the Energy and Climate Action Plan (Garzón et al. 2012). Public participation is equally crucial—a community-based governance model of planning that seeks input from local citizens can create a CAP more thoroughly addressing residents' concerns (Baker et al. 2012; Wiseman et al. 2010). In Oakland, where many disadvantaged, underrepresented, low-income, and minority populations live, this process was especially important. However, not all partnerships focused on adaptation. For example, Benicia and Antioch sought help from city planning researchers at local universities to develop ideas for the CAP and organize workshops to engage the public, but not for researching adaptive planning strategies. While these partnerships may not have contributed to their adaptation score, such collaborations allow cities to begin learning to understand and adapt to climate change.

Cities along the San Francisco Bay shoreline had higher average adaptation scores than non-coastal cities. Places more susceptible to sea level rise may feel the risks of climate change more urgently than inland cities and respond accordingly. However, this may have been heavily biased by several other factors—based on the Bay Area's geography, coastal cities are also sites of higher population density and economic development. These larger and more urban places typically have more complex and developed CAPs than smaller towns.

Cities are more likely to implement adaptation methods that have already been proven successful. These "low-hanging fruit" strategies usually take less effort to implement and deliver

quick and near-term results (National Academy of Sciences 2010). The matrix categories where cities scored the highest on average were [#2.INFO] climate change research and partnerships; and [#5.EDUC] community engagement and public education. These low-cost and not time-intensive methods are relatively easy for the city to initiate. Strategies that are highly visible and allow an opportunity for the city to engage with the public are also more likely to be selected (Bassett and Shandas 2010), which may explain the high presence of efforts like tree planting, LEED building, and public education projects across all CAPs. From a public relations standpoint, these actions help the city's image by signaling to citizens several ways that local government is helping the city become more sustainable.

Some methods also pose financial or other limitations for a city and might not provide the best return on investment, so they are avoided or delayed. Many cities received low scores for [#6.BIO] natural habitat and biodiversity conservation and [#4.RISK] emergency risk management. Implementing these adaptation measures requires considerable more funding, time, and effort. A lack of financial support, supervision, and overall encouragement can prevent cities from committing to more serious adaptive planning efforts such as aiding native wildlife and restoring local habitat (Ekstrom and Moser 2014; Salon et al. 2014). Cities that understood adaptation well were more likely to include such intensive strategies of adaptive planning in their CAPs. It should also be noted that adaptation is a relatively recent practice in locally-based climate action planning, such that fewer CAPs might have the capacity to implement difficult adaptation strategies (Broto and Bulkeley 2013). Innovative practices in adaptive planning are slow to be adopted and cities may hesitate to be leaders of new and untested adaptation practices (Bassett and Shandas 2010).

Co-benefits

Strategies with co-benefits between mitigation and adaptation can provide opportunities for cities to start implementing adaptation and reducing climate change effects. They benefit the city's long-term adaptation efforts, and boost adaptation scores. For example, [#5.EDUC] community engagement and public education programs that focus on climate change and adaptation scored well because they can be integrated with efforts to educate the public about reducing greenhouse gases. [#8.DEVL] Social and economic development of city infrastructure,

which includes transit-oriented development and environmental justice considerations, also scored highly because these types of solutions have the ability to reduce emissions while maintaining economic viability or benefiting citizen well-being. Cities may not be aware of mitigation strategy benefits in terms of enhancing climate resilience. Thus, adaptation strategies with mitigation co-benefits are more likely to be pursued because they can reduce greenhouse gases and help cities reach emissions reduction targets. Urban forest management is another example of a strategy cities promoted because of its carbon capture benefits, yet it also contributes to community health and aesthetics by making urban areas more inhabitable and enjoyable (Ordóñez et al. 2010). Some CAPs that I studied acknowledged this co-benefit, describing the cooling effect that planting trees has to reduce the urban heat island effect. CAPs are still generally written for cities to track mitigation goals and activities, so mitigation strategies in CAPs feature more prominently than adaptation strategies do. Cities that recognize co-benefits may feel that these strategies are worth pursuing. Cities unaware of co-benefits may end up addressing adaptation indirectly, so they may receive a lot of benefits that they did not account for. However, some climate actions are also favorable for mitigation, but harmful for adaptation efforts, and vice versa (Bedsworth and Hanak 2008). I did not attempt to quantify or observe these effects, so a deeper investigation into the outcome of these co-benefit strategies is a possible direction for future research.

Some CAPs, such as San Jose's or San Francisco's, embraced specific visions of sustainability by centering on large-scale goals for the city to reach instead of setting an emissions reduction target like many other CAPs did. However, CAPs that have a specialized format or goal may also be too focused on those goals, and therefore may lack the capacity or scope to include adaptation goals or co-benefits. Despite being large urban centers with highly visionary CAPs, neither San Francisco nor San Jose received a notably higher adaptation score than other cities studied. Taking a thematic and broadly visionary approach to writing a CAP may make the city less aware of the ways adaptation can help reduce climate change effects and this would reflect in a weaker adaptation score for the CAP.

Local responses to regional and state policy

State and regional climate action planning policies appear to have had mixed effects on the inclusion of adaptation in CAPs. In the cities studied, CAPs that referenced statewide laws on

climate change and emissions reduction commended the state's pioneering efforts. While AB32 and SB375 set clear goals for mitigating emissions, there is less guidance from the state concerning adaptation. The overall lack of a standardized format or guidelines to follow may disadvantage cities by not requiring them to consider adaptation strategies very closely. Without a strict mandate requiring CAPs from cities, climate action is ultimately left to the discretion of local governments. This was reflected in the CAPs reviewed. While some CAPs referenced the California Adaptation Planning Guide and Cal-Adapt, most did not. The lack of emphasis on adaptation by the state may lead cities that rely heavily on instructions from higher levels of governance to neglect adaptive planning as well.

All of the CAPs that I studied were adopted or revised after the passage of AB32, so they mentioned how the law stresses the importance of reducing emissions statewide. It is possible that AB32's GHG emissions inventory and target helped encourage cities to take on climate action planning themselves. SB375 and the mandate for the San Francisco Bay Area MTC to cut regional transportation emissions by 7% by 2020 may also inspire cities to begin climate action planning. Supportive regional policies encourage climate action planning in cities, even when similar climate policies are lacking or have stalled on a statewide or national level (Salon et al. 2014). Plan Bay Area, the Sustainable Communities Strategy required by SB375, has significant impacts for the emissions activities of cities. Developing a CAP can help individual cities identify ways to support and meet Plan Bay Area's requirements. Unlike with AB32, not all CAPs mentioned Plan Bay Area, which was formally adopted in July 2013, after most of the CAPs studied (12 out of 15) had already been adopted by their local governments. This suggests that, in the Bay Area, the influence of state legislature may have been stronger than any regional impetus in prompting cities to pursue climate action planning.

Since ICLEI's Cities for Climate Protection program focuses primarily on mitigation, support from the program had little effect on adaptation scores. The presence of ICLEI and similar environmental planning groups may contribute to increased overall sustainability in the Bay Area (Betsill 2001; Betsill and Bulkeley 2004). However, while ICLEI's Bay Area presence is strong and certainly helpful in mitigating emissions in local cities, the failure to incorporate adaptation methods in the process may also be consequential in the long run.

The strong correlation in scoring between registered percentages of Democratic and Republican voters and the overall adaptation score is an indication of residents' political attitudes

and viewpoints on climate change and adaptation, which are widely regarded as being of greater concern to liberals. Implementing adaptation requires collaboration and consensus on climate change and its mechanisms, which is not always strongly supported by conservative ideologies (Dunlap and McCright 2008). Cities with a higher percentage of Democratic voters may find more local support and enthusiasm for implementing actions in their CAPs. In contrast, CAPs from more conservative areas may focus more on economic savings generated by environmental actions to encourage citizens to adapt (Frick 2014). This suggests that the political leanings of local voters can influence the importance a city places on the CAP, the urgency with which measures are carried out, and the funding and support for sustainability projects.

Study limitations

I used a small but representative sample of fifteen Bay Area local jurisdictions to apply to my adaptation scoring matrix. While the information is explanatory of local climate action planning trends in the Bay Area, my findings have a limited inference and I am unable to extrapolate any information that can be applicable to regions beyond the San Francisco Bay Area. Therefore, the data does not indicate that all cities in all metropolitan areas may experience the same results for adaptive planning. Additionally, the sample size was small so trends on correlation are inconclusive. As mentioned in the discussion on co-benefits, the scoring matrix did not take into account and adjust for co-benefits between mitigation and adaptation. Finally, studies using a scoring matrix methodology often use averaged scoring data from several scorers, in order to obtain more fair and unbiased numbers. However, as the sole user of the adaptation scoring matrix on the sampled CAPs, my results likely reflect some amount of scoring bias and subjectivity.

Future Directions

Continued research on this topic can investigate other facets of adaptation through the scoring matrix model, which helped me quantify the large amounts of qualitative information I encountered in my research. New and innovative sustainability and adaptation practices are emerging (Bassett and Shandas 2010), so the scoring model can be continuously revised to

incorporate such changes. It is also important to balance the effects of co-benefits in the model and determine how much they can influence and change adaptation scores. While this study examined fifteen jurisdictions in the Bay Area, future studies can expand upon my work by examining adaptation in CAPs from other metropolitan regions and comparing results. For example, it may be valuable to examine links between California's policy mandates on climate change and themes in local CAPs across the state. This would investigate the institutional capacity for cities to implement climate change solutions in California, compared with other jurisdictional levels. Further research can also explore connections between the extent of adaptation and factors like funding or political attitudes, which were found to be influential drivers of the adaptation process. Interviewing city officials and planners from the cities I sampled could provide a greater level of understanding of the climate action planning process in different cities and possibly confirm some of the trends I observed in my study.

Currently, cities have yet to reach the monitoring and evaluation phase for measures from the CAP, but as a city's sustainability efforts mature, this is essential to maintaining the CAP as a reliable and effective planning document. Finally, it is evident that a local government's envisioning of a city's future is possibly critical towards its understanding of the functions and roles of a climate action plan and this would be an interesting path to explore in continuing research.

Best Practices for Future CAPs

My findings suggest that cities need a stronger focus on adaptation in their CAPs in order to make their physical, economic, and social structures more resilient to impending climate change impacts. Moving forward in climate action planning, cities need to consider the best practices befitting their local environment. Some suggested efforts for enhancing adaptation in future revisions of climate action plans include:

- *Adaptation focus*: Cities should focus on the direct adaptation of local infrastructure and populations in CAPs, in addition to mitigating greenhouse gas emissions. In particular, understanding the local impacts of climate change is important to designing actions that maximize environmental benefits. A clear grasp of adaptation and commitment to include it in CAPs can improve the city's adaptive planning elements in the CAP overall.

- *Benchmarking*: Adaptation efforts must be tracked with adequate metrics as rigorously as mitigation strategies are, to ensure that implementation conforms to stated goals in CAPs and that effective outcomes may be delivered and monitored over time.
- *Collaborative and democratic planning*: Local alliances can help cities collect information on local climate vulnerabilities and balance citizen concerns. Adaptation can also be achieved through collaboration with stakeholders outside of governmental jurisdiction—particularly with local advocacy groups, research institutions, environmental non-profits, and private firms. Climate action planning should also consider environmental justice and equity concerns, as some climate solutions could disproportionately benefit high-income residents, and may increase inequality and poverty levels in a city. Working with representatives for affected populations ensures that diverse needs are fairly addressed in the CAP.
- *Low-hanging fruit and long-term planning*: Simpler fixes for the city and climate—the low-hanging fruit—provide an entry point into adaptation, but cities also need to prepare long-term resources in their CAPs for more intensive climate resilience strategies. For example, public education programs are achievable for cities on all scales and scopes, while conservation requires more effort. However, cities must address both strategies in their CAPs in order to create a resilient and sustainable city. Issues of finances and human resources, especially for more costly measures, need to be discussed in preparing the CAP.
- *Building political alliances*: Political support for climate action can expedite and benefit the climate action planning and adaptation process. On the other hand, a lack of support from city officials or local voters will hinder a CAP's progress. Planners hoping to develop CAPs need to understand how to navigate local political values, whether they are supportive of or oppose sustainable development practices.
- *Co-benefits:* Co-benefits are helpful in allowing cities to achieve multiple benefits through climate action and they need to be researched and included more thoroughly while developing CAPs.

Adaptive planning remains an innovative idea and process, but a city implementing adaptation strategies may induce surrounding cities to follow their lead, once they realize adaptation's legitimacy and benefits (Tolbert and Zucker 1983). Policy innovations from leading local governments can prompt surrounding cities to be similarly inventive (Berry and Berry 1999).

Smart and carefully planned implementation of adaptation strategies allows cities to achieve their vision for a sustainable city and reduce their total impact on the environment.

Broader Implications

Results of this study show how to better inform the development and revision of local adaptation planning policy, especially pertaining to CAPs in the Bay Area. Local CAPs are written for many purposes, and encompass many formats and strategies, as there is no standard method of creating a CAP. The CAP may take on different roles and meanings for cities that pursue them. For some cities, the CAP simply exists as a document required by a larger jurisdictional authority. For other cities, it is a roadmap for a sustainable and livable city. Well-planned CAPs can provide the framework and mechanisms through which effective climate action and adaptation can occur. Regardless of their ultimate purpose, CAPs are increasingly being developed and adopted on a local level, so it is important to understand the best ways to encourage effective adaptation at that scale.

Business-as-usual growth without a CAP is unsustainable, as city resources are strained by growing populations and climate change. As climate change risks and impacts manifest on a local scale, evaluating climate action plans for their breadth, depth, and effectiveness becomes increasingly important. The adaptation scoring model allows cities to identify strengths or weaknesses in current plans and understand effective adaptation planning strategies. It also helps cities review CAPs and how adaptation strategies can lead to a sustainable future. This can help them create and implement policies to significantly improve local resilience. In the long-term, adapting cities to withstand climate change not only reduces environmental damages, but also creates safer and healthier communities to live in.

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APPENDIX

Appendix A. Characteristics of city climate action plans.

	Year CAP was adopted	Emissions Reduction Goal	Coastal?	CCP at time of CAP adoption?	Link to CAP website
San Rafael	2009	25% reduction of 2005 levels by 2020	yes	yes	Website
Santa Rosa	2012	25% reduction of 2005 levels by 2015	no	yes	Website
Novato	2009	15% reduction of 2005 levels by 2020	yes	yes	CAP
Oakland	2012	26% reduction of 2005 levels by 2020	yes	yes	Website
Walnut Creek	2012	15% reduction of 2005 levels by 2020	no	no	Website
Antioch	2011	25% reduction of 2005 levels by 2020	no	yes	Website
San Jose	2014	35% reduction of 1990 levels by 2020*	yes	yes	Website
Sunnyvale	2014	15% reduction of 2008 levels by 2020	yes	no	Website
Mountain View	2012	15-20% reduction of 2005 levels by 2020	yes	yes	Website
San Francisco	2013	25% reduction of 1990 levels by 2017	yes	yes	Website
Redwood City	2013	15% reduction of 2005 levels by 2020	yes	yes	CAP
San Carlos	2009	15% reduction of 2005 levels by 2020	yes	no	Website
Vallejo	2012	15% reduction of 2008 levels by 2020	yes	no	Website
Benicia	2009	10% reduction of 2000 levels by 2020	yes	yes	Website
Dixon	2012	15% reduction of 2005 levels by 2020	no	no	CAP

*municipal emissions only

Appendix B. Demographic and physical characteristics of cities.

	Region	**Population**	**Area** (square miles)	**Density** (persons per square mile)	**Median Income** (USD)	**Median Home Value** (USD)	**% Registered Voters - Democrat**	**% Registered Voters - Republican**	**% Registered Voters – No party preference**
San Rafael	North Bay	57,713	16.47	3,504.1	$73,953	$695,800	55.1	17.4	23.1
Santa Rosa	North Bay	167,815	41.29	4063.9	$60,354	$360,800	52.3	20.9	21.5
Novato	North Bay	51,904	27.44	1,891.5	$77,702	$560,300	49.5	22.7	22.7
Oakland	East Bay	390,724	55.79	7,004	$52,583	$428,900	65.7	5.6	18.3
Walnut Creek	East Bay	64,173	19.76	3,428.1	$81,593	$585,000	44.8	29.4	21.8
Antioch	East Bay	103,372	28.35	3,611.1	$65,254	$233,600	38.5	37.4	22.1
San Jose	South Bay	945,942	176.53	5,358.7	$81,829	$560,400	45.2	21.4	29.6
Sunnyvale	South Bay	140,081	21.99	6,371.1	$100,043	$710,700	44.5	19.8	32.3
Mountain View	South Bay	74,006	12	6,174.7	$97,338	$788,700	48.9	16	31.5
San Francisco	SF/Peninsula	805,235	46.87	17,179.1	$75,604	$744,600	55.8	8.4	31
Redwood City	SF/Peninsula	76,815	19.42	3,955.5	$79,415	$765,400	50.3	20	25.8
San Carlos	SF/Peninsula	28,406	5.54	5,129.3	$118,021	$918,800	48.1	23.44	24.5
Vallejo	Outer Bay	115,942	30.67	3,780.2	$58,371	$218,300	58.8	14	23.1
Benicia	Outer Bay	26,997	12.93	2,088.1	$88,502	$422,700	47.6	24.8	22.3
Dixon	Outer Bay	18,351	7	2623.1	$72,522	$278,600	38.5	37.4	22.1
Source		U.S. Census	U.S. Census	U.S. Census	U.S. Census	U.S. Census	California Secretary of State	California Secretary of State	California Secretary of State
Source Year		2010	2010	2010	2010	2010	2014	2014	2014

Appendix C. Regression analysis of the adaptation score and city characteristics.

	(1) Score All Factors	**(2) Score Population Factors**	**(3) Score Political Factors**	**(4) Score Financial Factors**	**(5) Score Democrats**	**(6) Score Republicans**
Population	$-5.65E^{-5}$	$-6.30E^{-5}$				
	$(4.42E^{-5})$	$(4.67E^{-5})$				
Area	0.25	0.26				
	(0.23)	(0.24)				
Density	$3.25E^{-3}$	$3.61E^{-3}$				
	$(2.11E^{-3})$	$(1.97E^{-4})$				
Median Income	$1.02E^{-4}$			$-2.50E^{-4}$		
	$(1.72E^{-4})$			$(-1.46E^{-4})$		
Median Home Value	$3.40E^{-6}$			$2.72E^{-5}$		
	$(1.21E^{-5})$			$(1.14E^{-5})$		
% Democrats	1.78		1.75		0.69**	
	(1.72)		(1.67)		(0.19)	
% Republicans	1.00		0.85			-0.55**
	(1.42)		(1.37)			(0.16)
% No Party Preference	0.35		1.05			
	(1.20)		(1.27)			
Constant	-122.85	3.85	-112.47	23.32	-16.02	30.23
	(147.18)	(9.06)	(142.35)	(8.19)	(9.41)	(3.57)
R^2	0.81	0.43	0.56	0.32	0.51	0.50
N	15	15	15	15	15	15

*p < 0.05, **p < 0.01, ***p < 0.001