Cal-Adapt and the Usability of Climate Adaptation Tools

By

Melissa Deas
BA in Sociology
Harvard University
Cambridge, MA (2010)

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Signature redacted

Department of Urban Studies and Planning
(May 21, 2015)

Certified by

Signature redacted

Professor Frank Ackerman
Department of Urban Studies and Planning
Thesis Supervisor

Accepted by

Signature redacted

Professor Dennis Frenchman
Chair, MCP Committee
Department of Urban Studies and Planning
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Abstract

Communities around the globe have already begun to feel the impacts of climate change. Looking forward, the impact will only become more pronounced. As such, an increasing number of municipalities, counties, and states are asking how they can prepare. Various non-profits, public entities, and even the private sector are trying to facilitate smart preparedness policies by providing tools that forecast expected changes and provide guidance for vulnerability assessments. Many of these tools take the form of map-based visualizations showing downscaled climate data. This thesis explores whether communities are actually able to use this downscaled data to inform decisions and consider policy options that will increase their resilience.

I specifically focus on a tool produced by the State of California called Cal-Adapt. Based on interviews with local officials and climate professionals across California, I find that climate tools like Cal-Adapt do provide value. They deliver information needed by local officials to think through future conditions and lobby for the resources they need. Despite this, Cal-Adapt is not reaching its full potential. Local action is impaired by an ambiguous policy objective at the state level regarding what local officials ought to be doing to respond to climate change. This lack of guidance is reflected in Cal-Adapt, which fails to support specific decisions. As a contrast to Cal-Adapt, I look at two other web-based tools, and one case study of a county that applied climate data quite heavily in its vulnerability assessment. In all three examples, the data developers employed a collaborative approach that brought decision-makers, stakeholders, and scientists together. All three tools gained power through this collaborative process, making their data more usable when compared to Cal-Adapt. However, even in places with access to collaboratively built tools, the state’s failure to mandate action on climate preparedness continued to impair action.
Acknowledgments

This thesis would not have been possible without the team of people who supported me. My thesis advisor, Frank Ackerman worked with me every step of the way, providing thoughtful feedback and reading drafts, no matter how rough they were. His feedback allowed me to improve the depth of my analysis and final written product. Additionally, I would like to thank my reader Larry Susskind who constantly pushed me to be more assertive in my findings and pointing out gaps and questions I had not thought of.

I would also like to thank Susan Wilhelm and Guido Franco at the Energy Commission. When I came to the Energy Commission I never imagined that it would be such an empowering work environment. They supported all of my research, did not shy away from critical feedback, and embraced opportunities to improve Cal-Adapt. Susan and Guido give me confidence that California is in good hands.

Additionally, I need to thank the many people who spoke with me during my research. This thesis is built on their feedback and I would like to thank everyone who took time to speak with me despite their busy schedules. It was great to learn about the work happening throughout California and meet so many passionate people working on this important topic.

I must also thank the many students within my department that spent long hours in coffee shops and libraries writing by my side, reflecting when necessary, and reminding me that we were all working on this together. Finally, I want to thank my parents Bruce Deas and Suzel Bozada-Deas and my fiancé Jep Johnson. They listened to my moments of exasperation and celebrated my breakthroughs. I am so grateful I have such a wonderful support system.
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Chapter 1: Introduction

Resilience, climate adaptation, climate preparedness—these words are becoming increasingly common in urban and regional planning dialogues. More and more, communities are recognizing that climate change is real and is already having a tangible impact on the built environment, natural systems, and the socio-cultural relationships to the spaces in which we live (Bierbaum et al., 2012; Flood and Schechtman, 2014; Rickards, et. al, 2014). In August 2014, I was one of 800 attendees at the first California Adaptation Forum. Here, elected officials, researchers, non-profits, and public and private sector representatives came together to discuss how to better prepare California for the real impacts of climate change. All of us were concerned with how changing climatic conditions would impact important systems in California including water, energy, public health, biodiversity, agriculture, public safety, and vulnerable populations.

At this time, I was wrapping up a ten weeks summer internship with the California Energy Commission (CEC). During this, I collected end-user feedback on the CEC’s web-based climate adaptation resource: Cal-Adapt. Cal-Adapt is an online tool that features climate projections on: temperature and extreme heat, precipitation forecasts, wildfire risk, sea level rise, and snowpack melt, downscaled to a 12 by 12 kilometer grid for the entire state of California. Over the summer, I interviewed city planners, county officials, consultants, and academics across California regarding their experience using Cal-Adapt and their progress on climate adaptation. These interviews left me surprised at how behind many of these Californians felt. Despite California’s reputation for being progressive on climate issues, many leaders commented that they were still trying to figure out where to start. Even those who had made significant progress, and were described by their

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1 Cal-Adapt can be accessed at [http://cal-adapt.org](http://cal-adapt.org).
colleagues as success stories, spoke of their accomplishments humbly. They noted how much more remained to be done. Most reported continued frustrations including limited capacity, a lack of adequate funding, and uncertainty about what to do next. Many of these same people attended the California Adaptation Forum to figure out how to move forward in their own sectors and communities. Did they need more information and better online resources like Cal-Adapt? How should they conduct a vulnerability assessment? How should they move from simply talking about risks to addressing them? How should they measure progress?

This problem is not unique to California. Recently, a group of graduate students at the University of Michigan tried to untangle what support climate adaptation planners needed and if resources existed to fulfill their needs. They surveyed 89 organizations nationwide that are working on climate adaptation to assess the current state of adaptation resources. They found a vast number of resources already in existence. These 89 organizations relied on over 3,400 distinct climate adaptation resources or services (websites, guidebooks, maps, etc). Describing this research in a webinar, Melissa Stults (2014) stated, “Many of you have probably heard before that the landscape feels overwhelming, and perhaps a little muddled. I can tell you as someone who works in this space, and has for the last decade, 50% of the resources that we came across and were coding were things I had never even heard of before. So the landscape is enormous. And again this is only 89 organizations.” Many of those I interviewed explained that there were too many resources out there, leaving them confused on how to evaluate which were most relevant or correct. Even more, many of the resources do not address their primary questions and hurdles. Clearly, these 3,400 resources (including Cal-Adapt) need to be assessed critically.

In part, my interviewee’s confusion relates to the complexity of climate adaptation and the number of other challenges faced by decision makers; tools and resources cannot solve many of the problems these practitioners face. If city officials are overworked and stretched too thin to
even think about climate adaptation, then websites, guidebooks, and tools like Cal-Adapt will fall on deaf ears. Perhaps more tools, or even better tools, are not the ultimate solution. Rather, the state should be providing assistance or increased funding to build local capacity.

However, what currently exists in Cal-Adapt, a state sanctioned, readily available, downscaled set of climate data, is certainly worth evaluating. It takes time and political will to build capacity and create more funding sources. In contrast there is already a team of developers working on Cal-Adapt. Additionally, the CEC spent two full years developing the tool using public funding (Koy et. al, 2011). Any investment such as this must be tested and evaluated. Even more, during my conversations with adaptation specialists I learned that Cal-Adapt is a tool that some see as a potential model for new adaptation resources. For example, I spoke with one member of a White House Task Force on Climate Preparedness and Resilience who had visions of integrating aspects of Cal-Adapt into the U.S. Climate Resilience Toolkit. He wanted similar downscaled information available nationwide (McCormick, 2014). Another individual at the Urban Sustainability Directors Network explained that other states envy resources like Cal-Adapt:

Cal-Adapt is something that other people really wish they had outside of California…. They see a lot of value in someone externally providing a really sleek visual interface that anyone could access that brings together information about what is projected to happen. They value that it has credibility behind it; the state government’s role is a really big deal…They are hungry for stuff that they can use (Fitzgerald, 2014).

Finally, one of the original tool developers within the state commented that California has received international recognition for this tool. Officials in Korea, Australia, and some island nations have reached out to learn what it took to make the tool, to see if they could replicate it domestically (Malchow, 2015).

Despite these successes, the website has significant limitations, which I quickly uncovered through conversations with California decision makers. Many recognized the tool’s potential, but
felt that it needed additional work to be fully successful. While some adaptation practitioners had applied Cal-Adapt to their work, many did not seem to understand what to do with the information within the tool (Deas, 2014). A look inside Cal-Adapt shows that it contains interesting local information, but little or no guidance regarding how to use it.

What is Cal-Adapt?

Cal-Adapt.org is a website developed by UC Berkeley's Geospatial Innovation Facility (GIF) and the CEC. The primary feature of the website are maps showing downscaled climate data. Additionally, the website also features publications from California researchers on climate change, short articles on climate change impacts, and background information on climate scenarios and modeling. Figure 1 shows the homepage for Cal-Adapt, which directs users through the content of the site.

Figure 1. Cal-Adapt's home page. Screenshot from Nov. 11, 2014

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2 On August 27, 2014, I published an informal internal memorandum outlining potential updates on Cal-Adapt to the CEC based on my interviews. This paper includes some of the same suggestions and builds off of these ideas within a theoretical framework.
The easiest way to understand what Cal-Adapt does is to go on the website and explore the maps themselves. Many of them are dynamic and include visual animations that cannot be captured through static pictures. Figures 1.2-1.6 show a select number of screenshots, which give a sense of the website's content. Cal-Adapt’s maps show climate change projections for temperature, wildfire risk, snowpack, precipitation, and sea level rise under high emissions (A2) and low emissions (B2) scenarios. The charts show changing conditions over time through the end of the century. Information is presented on the website at either the county-level or at a 12 kilometer by 12 kilometer grid. This downscaling of information to the local level allows users to explore data tailored to where they live or work.

**Figure 1.2**: Projected average temperature by decade from 1950 through the end of the century under a high emission scenario for the Bay Park Area of San Diego County. Screenshot from Nov. 11, 2014.
Figure 1.3: Projected average precipitation by decade from 1950 through the end of the century for San Diego County under a high-emission scenario. Screenshot from Nov. 11, 2014.

Figure 1.4: Projected areas threatened by sea level rise and storm surge risk for San Mateo County. Screenshot from Dec. 8, 2014.
Figure 1.5: Projected wild fire risk for Sierra County under a low emission scenario. Screenshot from Nov. 11, 2014.

Figure 1.6: Projected decadal average snowpack at the end of the century for Sierra County under a low emission scenario. Screenshot from Nov. 11, 2014.
The information provided around temperature is the most detailed. For each grid cell, Cal-Adapt shows the expected changes to the average, low, and high temperatures annually or by month. Cal-Adapt also provides detailed information regarding extreme heat, including projections on number of extreme heat days by year, timing of extreme heat days, duration of heat waves, and number of warm nights. Figures 1.7-1.8 show a selection of these temperature maps.

Figure 1.7: Number of extreme heat days by years for San Diego Region under a high emission scenario. Screenshot from Nov. 11, 2014.
The Question

This thesis asks what can tool-developers and the state of California learn from Cal-Adapt about the usability of downscaled climate projections presented on a web-based mapping platform for local decision-making? This question is answered by: 1) analyzing end-user feedback on Cal-Adapt, and 2) comparing Cal-Adapt to other tools and efforts to help communities use downscaled climate forecasts.

Cal-Adapt was chosen because I have extensive experience with it through an opportunity over the past summer to collect end-user feedback to share with the CEC. The purpose of this research is to build on the academic literature regarding climate tools, drawing on information from Cal-Adapt and the other tools I reviewed. However, I also aim to provide the CEC and other state agencies with practical suggestions about how to better serve Californians as they work to improve Cal-Adapt.
Methods

I conducted over 50 semi-structured interviews with a diverse set of actors across the state of California. This research was supported by MIT, and was approved by MIT’s Committee on the Use of Humans as Experimental Subjects. The interviews were conducted in two phases. The first phase took place primarily in the summer of 2014 and focused on the end-user experience with Cal-Adapt. The second phase, conducted between October 2014 and February 2015, sought to fill in gaps and build on the data collected during the first phase. I aimed to better understand the history of Cal-Adapt in order to more accurately assess the success of the tool vis-à-vis its original intent. I also explored two similar tools and one case study. These were used to better understand Cal-Adapt’s strengths and weaknesses by comparing it to other climate adaptation resources.

Selecting A Scope and Population:

During the first phase, I worked directly with the CEC. At this point they were preparing to do a series of updates on Cal-Adapt that would be released in the spring of 2015. As such, the CEC team behind Cal-Adapt actively sought end-user feedback that could inform revisions to the tool. Given this practical need, I worked closely with the CEC to identify a series of questions that they wanted answered, including: Who is using Cal-Adapt? What are they using Cal-Adapt for? What issues or problems have users encountered? If people are not using Cal-Adapt, why not?

Potential users of Cal-Adapt include individual residents, farmers, business owners, researchers, land developers, utility providers, and a diverse set of public officials. The CEC recognized that it would be overly ambitious to try to speak with all of these potential users during one summer, and expressed interest in my focusing on local level public officials and staff engaged in climate change planning. Even with this narrower population, the potential pool remained quite

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3 As I am writing this thesis many of these updates are going into effect. Unfortunately, the timing of the updates was too late for me to explore whether the changes have improved the usability of the tool.
large. Scholars and practitioners alike argue that for adaptation work to be successful it must break down traditional silos between governmental agencies and departments because climate change’s impacts will be felt across jurisdictional lines. Therefore, efforts should include contacts with officials from public health, emergency services, economic development, land use planning, and other departments (Archie, et. al., 2014; Brunner and Nordgren, 2012; Moser and Ekstrom, 2010).

Some communities were taking an integrative approach. For example, adaptation work in the County of San Diego involves officials from the Port of San Diego, each of the city governments in the county, emergency services, the Airport Authority, the Tijuana River National Estuarine Research Reserve, ICLEI Local Governments for Sustainability, and various foundations and university research centers (Hedge, 2014; Climate Collaborative, 2014). In other cities, adaptation is being addressed most proactively by a smaller subset of officials. For example, in Benicia, climate adaptation falls primarily on the shoulders of one specific climate action coordinator (Porteshawver, 2014). I found that the person or people most active in thinking about climate adaption varied significantly city to city, making systematic sampling incredibly difficult. I used a snowball sampling technique, finding most of my sample through other interviewees or contacts. During this process I also found that much of the actual technical work of adaptation planning remains in the hands of academics, consultants, and non-profits. Even though these are not public officials, I realized that any feedback on Cal-Adapt would be thin unless I contacted technical experts.

In the second phase of my research I was interested in addressing the questions that were not well answered by my first round of research. First, what is the history of Cal-Adapt and the state’s intentions for this tool? To answer this I conducted a series of interviews with state officials and developers who were involved in the original design of the tool.
Second, if local adaptation planners did not find Cal-Adapt to be as useful as they hoped, are there other tools and resources that are helping communities be successful? How are these resources different from Cal-Adapt? To answer this question I interviewed developers involved in making other spatial analysis tools. Specifically, I spoke with tool designers behind Coastal Resilience Tool produced by the Nature Conservancy; Our Coast, Our Future produced through a partnership of various scientific organizations focusing on sea level rise risk in the Bay Area; and the data produced by the Terrestrial Biodiversity and Climate Change Collaborative (TBC3) in Sonoma County.

The Population

During the first phase, I conducted 40 interviews. Many of these interviewees could not be easily categorized into one group (for example non-profits that function in the public interest or academics working as consultants). However, as an over-simplification I categorized each to the best of my abilities based on the perspective most prevalent in the feedback I heard from them (See full list in Appendix, Table A.1). 10 participants represent the municipal level, 10 represent the county level, 6 represent regional bodies or organizations, 3 are state organizations, and 15 are technical experts from non-profits, academia, and private consultant firms active in climate change related work. Importantly, this sample is highly biased towards those already active in climate change related work because I was specifically looking for people who likely had some experience using Cal-Adapt and might have feedback to offer. I did try to include a diverse geographic range of places, including coastal and non-coastal communities, as well as rural, suburban, and urban communities. To fill geographic gaps, I did my own Internet research to identify additional people to contact.
Out of the 44 people I spoke with for phase I, 10 had never heard of Cal-Adapt prior to my contacting them, 9 had heard of it but never tried using it, 8 had visited the website but had not used it for official business, 4 had used it for basic tasks such as finding a graphic to insert into presentations they were preparing, and 13 had used it more extensively, often citing it directly in reports or materials they were preparing. Of the people who had used Cal-Adapt the most extensively, 6 were technical experts such as academics or consultants and 7 were local officials working at the city or county level.

Table 1.1: Summary of Phase 1 Interviews
Number of Interviewees by Category and Experience with Cal-Adapt

<table>
<thead>
<tr>
<th>Experience with Cal-Adapt</th>
<th>City</th>
<th>County/Regional</th>
<th>Academic/Consultant/Non-Profit</th>
<th>State</th>
<th>Total</th>
<th>Percent of Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never heard of</td>
<td>4</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>22.73%</td>
</tr>
<tr>
<td>Cal-Adapt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heard of Cal-Adapt,</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>9</td>
<td>20.45%</td>
</tr>
<tr>
<td>but never used it</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dabbled around on Cal-Adapt</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>8</td>
<td>18.18%</td>
</tr>
<tr>
<td>Used Cal-Adapt for</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>9.09%</td>
</tr>
<tr>
<td>basic tasks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Used Cal-Adapt more</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>0</td>
<td>13</td>
<td>29.55%</td>
</tr>
<tr>
<td>extensively</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>16</td>
<td>15</td>
<td>3</td>
<td>44</td>
<td>100.00%</td>
</tr>
</tbody>
</table>
During the second phase, I interviewed another dozen people (see Appendix, Table A.2). This batch of interviews was much more focused on technical developers and included 1 county employee, 2 county level natural resources experts, 4 state employees, 6 tool developers and 3 consultants or technical experts (some overlap between the groups).

This research was combined with a review of key adaptation documents produced by the state, including support documents for local officials, regulatory documents from various agencies, and strategy documents that explain the states overall adaptation mission.

**Questions beyond the scope of this thesis:**

This thesis does not focus on what makes one climate model, scenario, or projection scientifically more accurate than another. There is a strong argument that downscaled climate data are inherently problematic, meaning that users must be careful when using such forecasts. This is part of an important debate, just not a concern in this thesis. For my purposes, I will consider the underlying information in all of the tools I review to be reasonably “correct.” The only challenges I will put to these data are the ones expressed by the potential users I interviewed.

Additionally, I do not answer the questions of what climate science should be used to do or what successful climate adaptation looks like. Instead, I consider any “use” to be a sign of progress. I was originally tempted to define use as “actively considering future climate risks when making typical planning decisions such as where to allow future development, how much water to keep in reserve, and where to invest in flood protection efforts.” However, given that most of the users I spoke with were in early stages of considering climate change risks and were not yet at the stage of proposing risk management strategies, if I were to define “use” this way no one would be succeeding. Instead, I consider “use” to be any attempt by decision makers to actively engage with
climate projections and assess their community's risk with the intention of considering policy changes.

**Summary of Main Findings:**

Cal-Adapt provides interesting information, but falls short of being a useful decision support tool. This is largely because decision support is not what the website was designed to do. Cal-Adapt remains too broadly focused to guide specific risk management decisions. As such, it is currently only used as a basic “information source” by highly motivated local officials who often have access to experts (such as academics, scientists, or climate consultants) that can help them apply the data within Cal-Adapt. Even so, these users are only using Cal-Adapt for basic vulnerability studies that fall short of informing on-the-ground-decisions. I find that local actors do not necessarily need more information, but rather action-oriented information and more prescription from the state. Once the state knows what decisions local actors should be making they should build a new version of Cal-Adapt that specifically aims to provide the information local officials need to fulfill state mandates.

In Chapter 2, I review prior scholarly work on the subject of downscaled climate forecasts. This chapter grounds my discussions of Cal-Adapt and climate science tools within the context of adaptation planning in general and current understandings regarding best practices. I will introduce a framework that I subsequently apply to assess the usability of climate forecasting tools. Finally, this chapter introduces the idea that the process by which tools are built has a large impact on their ultimate usability.

In Chapter 3, I argue that that many of Cal-Adapt’s flaws are rooted in the fact that California’s state government failed to formulate an adaptation strategy that envisions the types of decisions local actors should be making with climate projections in mind. This ambivalence and
lack of leadership is ultimately reflected in a tool that does not provide direction to users. Without more clarity regarding what the state expects localities to do about managing climate risks, Cal-Adapt will never be a true decision support tool.

In Chapter 4, I present three alternatives to Cal-Adapt. In each situation, decision makers and scientists worked together to figure out what information they needed and how best to collect and communicate it. This may be difficult for the producers of Cal-Adapt to do in a consistent fashion for the entire state. Regardless, these alternative efforts provide important insights into how communities actually come to understand climate information.

In Chapter 5, I review the key lessons from my research and make recommendations for addition research. Overall, I find that tools gain usability from either a clear mandate from above dictating their use, or from a collaborative process that allows end-users to determine how they intend to use the tool. Without one or the other, tools are likely to sit on a shelf.

A Word of Thanks to the California Energy Commission

Although this thesis discusses a number of shortcomings of Cal-Adapt, I don’t mean to be overly critical of the CEC or GIF. In fact, I am in awe of what the fantastic team behind Cal-Adapt accomplished with very limited resources. The California Energy Commission realized that one of their key information gaps was their inability to assess how and whether people were using Cal-Adapt. This is the very reason they hired me. Throughout my work over the summer, the team did not shy away from frank discussions of the tool’s limitations. They were incredibly receptive to suggestions about how the tool could be improved.

Based on my initial findings they are already pursuing some important changes. In March 2015 they added a new section to the website that provides more examples of successful climate change work, links to other decision support resources, and updates on recent news regarding
climate change. They are also in the process of incorporating improved data layers for sea level rise so that the website reflects the more dynamic and downscaled modeling. They are working with the Office of Planning and Research to allow Cal-Adapt to be used in an online planning guidance portal. All of this goes a long way toward responding to the feedback from users I collected over the summer of 2014. Despite this progress, if California decides that Cal-Adapt should be a true decision support tool, the website will likely need to be completely rethought and rebuilt to serve that purpose.
Climate change is already affecting California. Sea levels have risen by as much as seven inches along the California coast over the last century, increasing erosion and pressure on the state's infrastructure, water supplies, and natural resources. The state has also seen increased average temperatures, more extreme hot days, fewer cold nights, a lengthening of the growing season, shifts in the water cycle with less winter precipitation falling as snow, and both snowmelt and rainwater running off sooner in the year... If the state were to take no action to reduce or minimize expected impacts from future climate change, the costs could be severe. (California Natural Resources Agency, 2009, p. 3)

This statement opens the 2009 California Climate Adaptation Strategy. The report calculates that trillions of dollars worth of assets are at risk to sea level rise, wildfire, and extreme weather. Even without considering the less tangible costs (health, social, environmental, and indirect economic impacts), the situation is frightening. California must take concrete steps to adapt to changing circumstances and protect itself against these risks. Cal-Adapt is a tool that aims to locate and measure the severity of these risks so that California can more intelligently respond. How can climate adaptation tools like Cal-Adapt be useful to planners and decision makers in responding to climate change? What does successful adaptation planning even look like? How can a tool possibly improve planning without a clear image of how the tool should be used? These turns out to be an incredibly difficult question to answer.

Before delving into how Cal-Adapt performs these functions and how well it communicates critical information to potential users, this chapter takes a few steps back. I present an analysis of scholarly work that contextualizes Cal-Adapt within a general understanding of climate adaptation processes and best practices. This foundation allows me to better assess Cal-Adapt's role in helping decision makers protect California against climate risks and to identify how this research contributes to the previous scholarly work on climate adaptation.
What is Climate Adaptation?

The basic premise behind adaptation planning is that, even if the world cuts back on greenhouse gas emissions significantly today, it will be impossible to completely avoid the impacts of climate change. In fact, many places around the world are already experiencing climate related risks. Given this, communities should think critically and take actions that will either protect current systems against changing risks or adapt them to be more resilient under new climatic conditions. This might involve raising buildings to protect against sea level rise, improving insulation to adapt to higher temperatures, or building in better drainage to account for increased precipitation (Berkhout et al., 2006; Bierbaum et al., 2012; Palutikof et al., 2013).

While there is no one methodology for climate adaptation planning, most scholars agree on a basic cycle for decision-making. This cycle involving understanding risks and vulnerabilities, assessing options, implementing those options, monitoring the policies effectiveness, and revising strategies as needed (Baker, et al, 2012; Bierbaum et al., 2012; Carmin et al. 2012; Moser and Ekstrom, 2010a; Tribbia and Moser, 2008). This is a fairly open ended process and leaves much of the details to be figured out by the individual practitioners. Many state governments and non-profits have tried to provide more direction, publishing guidelines suggesting best practices. In California, the Natural Resources Agency, in partnership with California Polytechnic State University, and California Emergency Management Agency (now the Office of Emergency Services) published an Adaptation Planning Guide in 2012. It outlines a 9-step process that follows the understanding—assessing—implementing—evaluating process (see figure 1). The 68-page guide provides a detailed description of the types of actions that local planners could take within each step. However, even this long document remains at a relatively high level. For example, the guide suggests that decision makers first assess their exposure to climate change by using “the best available” data for their region. It points users to Cal-Adapt, but otherwise
provides little direction on where practitioners can locate the “best available” data or how they can evaluate climate data resources. Many of those I interviewed explained that it was difficult for them, as novices, to determine which resources would best serve their region or sector, suggesting that more guidance is needed at this step.

Using this information, a city or region can move on to step two: systematically brainstorming what “community structures, functions, and populations” (20) will be affected. The guide provides a checklist of potential systems to consider. This is useful for guiding decision makers into thinking about an expansive set of systems. Next, the guide recommends that the planning team conceptualize the impact climate change will have on those systems. Here the guide remains vague, recognizing that experts within particular sectors will have a better sense of how to evaluate specific systems. This makes sense, but means that success hinges on the ability of these experts to fashion a functional methodology for identifying potential impacts and assessing the likelihood of these impacts. Here, there is a real risk that communities may not pay enough attention to less obvious risks or may not weigh risks in a way that is sensitive to vulnerable populations.

Overall, these guides provide a starting point. They do not, however, describe a well-paved or easily followed roadmap. Even more, so few communities have made progress on climate adaptation, that is it hard to evaluate how well this process actually works.

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Bierbaum et al. (2012) in a comprehensive review of adaptation efforts surveyed 298 municipalities throughout the United States. Of these, only 13% had done a vulnerability assessment. Only a handful had begun assessing or choosing responses. Without on the ground action or response, there is only so much researchers can do to evaluate success.

**Making Good Decisions, Generally**

Stepping back from adaptation, one could make an argument that good adaptation planning simply looks like good planning. In fact, the framework for making adaptation decisions could be applied to most any decision. Identifying risks or needs, selecting options, implementation, monitoring, and revising based on feedback is generally good policy advice. Climate change seems like a particularly daunting challenge because one cannot rely on historic information to inform future decisions. Climate science and modeling is complicated and hard for novices to fully understand. Even more, people have a tendency to be reactive rather than proactive when pursuing risk related policy, which is especially dangerous with a slow moving crisis like climate change (Pearce, 2003). On the other hand, planners have been dealing with uncertainty for as long as the profession has existed. It is hard to predict how much a city will grow or shrink in fifty years, what technology will arise, or how the economy will change. El Niño systems, earthquakes, hurricanes, and other natural disasters bring many unknowns regarding timing, severity, and degree of impact. Planners already have strategies for planning for all of these events.

*The Successive Limited Comparison Approach*

If adaptation planning is simply good planning, what does a good policy framework look like? It would be impossible and impractical to cover the full history of this debate. As a starting point, Lindblom (1959) famously argued that complex problem solving is less about making one
single good evidence-based decision, but rather is a process of “muddling through.” He argues that rational policy analysis is impossible because policymakers lack the capacity, time, or information to know all the potential impacts of a policy or to consider all the possible alternatives to that policy. Instead, rational policy formulation should be discarded for a more practical methodology. He calls this the “successive limited comparison” approach in which policy-makers look at a small set of options that differ only slightly from current policies. This makes the scope more manageable for analysis. It also narrows the field to what is politically feasible. Change is achieved over time by making incremental tweaks to existing policies, mirroring evolution rather than transformational policy revolution.

Perhaps, when it comes to climate change, however, transformational policy revolutions are necessary. If the future will see drastic changes, must we respond with drastic policies? When it comes to mitigation, there is a strong argument for large-scale and radical change. Without severe reductions in greenhouse gas emissions, the global implications are quite possibly catastrophic. When it comes to adaptation, radical policy may not always be the best option. Kates et al. (2012) argue that transformational change (defined as either novel changes, changes that involve rethinking settlement patterns, or large-scale interventions) may be needed in extraordinarily vulnerable regions such as islands. Dramatic policy change may also be called for where incremental safety measures encourage people to build and settle in ultimately dangerous locations. Additionally, if climate change becomes more severe than projected, or mitigation efforts fail, then transformative change might become necessary. Despite this, for many adaptation projects incremental change may be sufficient, efficient, and more politically feasible. For example, flood protection barriers can be built to be intentionally flexible and robust. Engineers can build temporary structures that are cheap to replace when more information becomes available. They can also build in mechanisms to tweak, expand, or reduce the barrier as researchers and planners.
learn more about the severity and likelihood of flood risk. This flexibility also allows policy makers to respond to previously unrealized externalities associated with the chosen barrier method such as its impact on neighboring communities or ecosystems. This “fail-cheap” method may ultimately be more effective than pursuing expensive and drastic projects to protect against a large, but uncertain risk.

Technical and Local Knowledge

Good decision-making is obviously more complicated than simply determining the degree of change needed. Reflecting the planning ethos of his time, Lindblom operates under the assumption that policy is made by professionals using rational thought. Today, much of the planning literature criticizes this reliance on professional and scientific approaches in favor of local and community knowledge (Forester, 1988; Innes and Booher, 2004; Sandercock and Forsyth, 1992). Corburn (2003) finds that planners must negotiate demands from policy makers above them, technical experts, and a vocal public. While negotiation can be difficult, he argues, it is actually beneficial compared to a top-down approach. Specifically, local knowledge brings four distinct values: 1) it can provide key information expanding the overall knowledge base; 2) it creates more democratic decision-making systems and adds legitimacy to decisions; 3) it can improve effectiveness by helping to identify low-cost solutions and spreading the burden of implementation to involved community members; and 4) when done well, local involvement can identify distributive justice and social equity concerns. Despite this increasing acceptance of local knowledge, Krizek et al. (2009) point out that rational models continue to be favored when decisions are viewed as highly technical such as those regarding hydrology and transportation.

This debate about how to balance technical information with local knowledge to create informed evidence based decisions plays out heavily in climate adaption. The combination of
novelty, scientific complexity of projecting climate change, and the technical nature of the many systems that are vulnerable (power, transit, water), often creates a natural impulse to rely on more technical approaches. The guidelines around adaptation describe the adaptation process as based on “a rational decision-making” framework (Moser and Eckstrom, 2010, 22027). This rational process, however, does not preclude widespread and diverse community involvement. Rather, celebrated adaptation efforts acknowledge that information must both be bottom-up and top-down (Mastrandrea et al., 2010).

**Climate Adaptation and Scale**

With adaptation, an important policy question is what level of government should be responsible for which decisions. Adaptation planning looks different depending on the scale at which it is happening. Within the United States, federal and state governments have primarily facilitated, supported, and assisted with adaptation efforts. Most innovation and actual work has happened at the local level (Bierbaum et al., 2012; Rickards, et al., 2014). This is based on an argument that local governments know their community best and control many of the local resources that are at risk.

Recently many scholars are pushing back against the assumption that adaptation is a local issue. Rickards et al. (2014), argue that the decentralization of adaptation planning to the smallest scales necessitates a huge amount of learning by a large number of people, which may be inefficient. Even more, local level adaptation is not required by higher levels of government forcing local decision makers to prioritize it against a number of other pressing local concerns that can easily overshadow it. Baker, et al., (2012) argue that it is quite possible that the demands of adaptation planning exceed the capabilities of local governments. They point out that this lack of capacity extends beyond financial, information, political, and technical capacity, but has more to
do with a lack of clear responsibility or statutory obligation to address change. They argue that state and federal governments must clarify what adaptation looks like and create regulations that mandate which actors should be involved and how. Without this direction, only places with political will or champions for change will opt to participate. Additionally, state governments and federal governments own and control large tracts of land and therefore must also be involved in the application of adaptation efforts. Without all levels of government (and the private sector) working towards adaptation, each individual branch can only influence what is within their own jurisdiction (Bierbaum et al., 2012).

**Information Barriers to Adaptation Planning**

In California, I found that even those local planners widely regarded as leaders felt that they still had a long road ahead of them. They knew they were just scratching the surface of a complicated problem that would take a coordinated and expensive response. Scholarly works similarly describe the vast difficulties these individuals face. Moser and Ekstrom (2010) found that in every stage of adaptation efforts (spanning understanding risks, planning for risks, and implementation of potential solutions), many barriers exist. They categorized these barriers into three categories: 1) Leadership, finding that without top-down mandates for adaptation planning, “leaders are required to initiate the process” and may “vary in quality of guidance, motivation, and vision they provide” (22029); 2) Resources, finding that communities lack both financial means to support adaptation and technical/informational means to understand the risk; and 3) Values and beliefs, finding that people’s belief in climate change or willingness to discount future risks in favor of current needs can be a significant barrier to progress. More recently, Bierbaum et al., (2012) conducted a comprehensive review of climate adaptation efforts by federal, tribal, state, local governments and the private sector and found that “barriers to implementation still impede
action in all sectors and across scales. The most significant barriers include lack of funding, policy and institutional constraints, and difficulty in anticipating climate change given the current state of information on change” (362).

Climate adaptation tools aim to break down the barriers that decision makers face. Cal-Adapt primarily speaks to the information barrier. It provides highly accessible and minimally technical downscaled climate data that aims to allow decision makers to better understand the likely changes their communities will face. It also seeks to help with funding gaps by providing this information free of charge. If used as part of a public education or public outreach process, Cal-Adapt may even help create the political will for climate adaptation. Despite these values, Cal-Adapt can only do so much. The tool is limited. It cannot fill in for overworked staff. It cannot make up for overstretched budgets. It certainly cannot overcome institutional constraints regarding who has jurisdiction to affect what change.

**Barriers to Using Climate Projection Tools**

As mentioned earlier, nearly all climate adaptation guidelines recommend beginning with an analysis of how the climate is expected to change and what that means for the community or system (Füssel and Klein, 2006; Kelly and Adger, 2000; Weaver et al., 2013). Without educated forecasts about what the future risks are, planning for risks is impossible. Rickards et al., (2014) point out that national and state level governments see it as their role to provide information regarding climate risks in order to address the gap between what municipal governments are expected to do and their limited resources. Cal-Adapt is an example of this drive to provide information.

Recently, scholars have begun to look critically at the “usability” of these future climate projections. Weaver et al., (2013) found that, despite their importance, there is “a severe
underutilization of climate models as tools to support decision-making” (40). From the literature, it is clear that there are two main reasons why this might be the case: 1) Substantive issues in which the projections are inherently fraught with uncertainty or cannot provide the specificity necessary for robust decision-making; and 2) usability issues in which decision makers lack the capacity or knowledge to put the projections to productive use.

**Substantive Issues**

Unfortunately, the substantive issues are numerous and unlikely to be resolved by the time action must be taken (Stainforth et. al, 2007). Inherent in current climate data is significant uncertainty about what to expect in the future due to the high numbers of assumptions that feed into projections and models (Hayhoe et al., 2013). Moreover, there are many unknowns about how society will react in coming years (Weaver et al., 2013). Additionally, the scale at which information is produced often does not match the scale at which decision makers must operate. For example, in a study on climate adaptation and water utility planning Barsugli et al. (2012) writes:

One of the major concerns water utilities have had with climate model output is the coarse resolution from the models. Climate models typically divide the world into grid cells or grid boxes that are 100 to 200 kilometers wide; this resolution is too coarse to account for local climate conditions. This necessitates the use of a downscaling method to translate the GCM output to a finer scale. Downscaling introduces additional complexity and uncertainty to the process, and the implications of the choice of downscaling method—the use of various statistical methods or the choice of a regional climate model (RCM)—are not always clear. (390)

This huge level of uncertainty should leave any well-versed decision maker questioning how much they can rely on these models to inform the choices they make. Cal-Adapt is a model that downscales climate information to a 12 by 12 kilometer grid. Downscaling to a higher resolution may make data appear more usable to planners working on a similarly small scale, but it also introduces more uncertainty. Even though the developers of the site at Cal-Adapt are proud of the
scientific rigor that went into their downscaling method, they will readily admit that the data are surrounded by uncertainty (Guido, 2014).

To make matters more complicated, Enserink et al. (2013) find that policy advocates and scientists have different perceptions of both uncertainty and the goals of climate scenarios that complicate how the two groups react to data. As they write, decision makers’ “perception of uncertainty is often static and rather crude. Uncertainty is something that makes decision-making difficult, and therefore it is in their interest to see it reduced to probabilities and cost benefit ratios” (10). In contrast, scientists are not driven by the same policy pressures and often have a deeper understanding of uncertainty. Additionally, scientists producing “scenarios value them primarily as learning processes” (9) that can show how systems respond to various inputs. In other words, while decision makers typically rely on the outputs of models to form policy objectives, data-producers use the inputs to determine what might be driving changes. Therefore, the applicability of the data to each of these tasks may be very different.

Usability Issues

The substantive issues with climate data cannot all be solved. Uncertainty will continue to exist in efforts to forecast the future in complex systems. Encouragingly, researchers are finding that there are clear ways to move forward with adaptation models that factor in uncertainty. For example, Hallegatte (2009) argues that in the face of uncertainty, decisions should not be based on optimizing climate models, but by simply making decisions more “robust” to changing climatic conditions given the existing information In other words, projections such as Cal-Adapt should not be used to determine thresholds such as the exact temperature or precipitation that a building should withstand. Instead, the models yield important information about the potential range of
likely conditions. A building should be designed to succeed at all points within that range or across
the various scenarios regarding future conditions.

If climate adaptation is possible using uncertain models, what does it take to get decision
makers to actually make the hard decisions? Scholars increasingly recognize that the barriers
preventing the applicability of climate data go beyond these issues of uncertainty. Weaver et al.
(2013) point out that this takes knowing how much information decision makers need and how to
package it in a way they can digest; not an easy task. Moser and Luers (2008) found that unless
climate information fits seamlessly into existing procedures, planners are reluctant to use it. This is
especially true if there is no mandate to do this extra work.

Cash et al. (2006), analyzing El Nino/Southern Oscillation forecasting, note that science
and technology will only be used by stakeholders if it seen as “not only scientifically credible, but
also salient and legitimate” (468). By this they mean that decision makers will only use data if they
believe that it is relevant to the problem they are trying to solve and if they can defend their choice
to use the information.

While salience and legitimacy are clearly important, usability is more complex. Users must
also know how to access the data and have the capacity to use it. Likewise, local planners must feel
that climate adaptation is worth their time. In Chapter 3 I will look at Cal-Adapt using a more
nuanced framework that will touch on each of these issues.

Co-Production of Climate Science

A number of scholars contend that the key to delivering “usable” scientific information
that is meaningful to decision makers is the process by which it is produced. (Cash et al., 2006;
Dilling and Lemos, 2011; Jasanoff, 2004; Tribbia and Moser, 2008). If decision makers work with
scientists to determine which scenarios to use to project future risks, which variables to downscale,
and how to present that information, the final result will be more effective. It certainly seems that if climate modelers and decision makers worked more closely together, then misunderstandings of what data is needed, and the potential misuses of uncertain data could be avoided.

While this deep understanding of knowledge is certainly desirable, it is not a quick or easy process. Specifically, Dilling and Lemos (2011) recommend that it involve a series of iterations to truly lead to robust decision-making processes and added value:

First, iteration allows for better customization of knowledge to meet specific needs. Second, through iteration producers and users may uncover new uses for climate knowledge that might not have been identified before. And while many constraints and opportunities for knowledge use may be beyond the control of the science production enterprise, a better understanding of users’ decision context may critically influence the ability of producers to meet users’ expectation of climate knowledge as decision support information.” (684)

In other words, co-produced information that is generated iteratively will not only better align research to what is needed by users, but can also push the field forward in potentially innovative ways. Importantly, participatory scenario planning for climate adaptation achieves more than improvement in the quality and resonance of the final product; it allows for participants, who are often novices in climate science, to gain expertise through the exercise of thinking through the various scenarios and data. This gradual learning process is particularly important given the complexities and potential misapplication of modeled data. (Chermack, 2004; Rickards et al., 2014; Van Drunen et al., 2011).

However, not every decision maker has access to scientists with the skillsets to create customizable climate data for their needs (Dilling and Lemos, 2011). Even more, scientists are often driven by the need to get published in peer-reviewed journals that have little use to decision makers and may not see value in entering drawn-out participatory processes (Archie et al., 2014). Finally, Aron et al. (2001) point out that the co-production of science for policy runs the risk of choosing inputs for pragmatic reasons or to create consensus, rather than more scientifically
defensible reasons. Given this, how can sustained, productive, and academically rigorous relationships between users and producers be created?

Clark et al. (2010) suggest that the solution lies in facilitating this interaction through a third party. This will prevent the boundary between scientists and policymakers from being dissolved completely and reduce the risk that science will be overly politicized or that policy makers will over-rationalize decisions. They label this third-party facilitation “boundary-work.” Tribbia and Moser (2008) also call for third party “boundary organizations” that can enable “scientists and decision makers to increase mutual understanding of capacities and needs while remaining within their professional boundaries” (317). Dilling and Lemos echo this conclusion, writing that “information brokers” who are literate in both science and policy are key. Yet identifying information brokers may not always be easy. They write, “one of the key challenges to producing usable science may therefore be to determine who or what organization needs to take on the process of connecting science to decision-making” (685). Practically speaking this void continues to be pervasive in many local decision-making contexts. Sometimes consultants or university connections can fill this gap by serving as technical mediators between the decision makers and the data producers.

In my interviews I found that locations that have successfully integrated Cal-Adapt into their adaptation planning, for example Santa Cruz and Santa Barbara, drew on local experts through the university system. However, not every town has the capacity to form these necessary partnerships. If information brokers who are fluent in both science and policy are necessary, what can California do to fill this void?
How This Thesis Adds to the Literature

In their comprehensive review of adaptation, Bierbaum et al. (2012) specifically comment that more research needs to be done on delivering usable climate change information. They write “research should address the types of information that need to be made available, as well as the methods for transmitting such information in a way that can best support understanding of climate change risks and opportunities and facilitate decision-making” (394). This thesis cannot break down all of the barriers that local governments face. It cannot answer who should be doing climate change work or how they should be doing it. However, it can discuss issues and best practices for transmitting climate information. Cal-Adapt was expensive to build and will be costly to maintain if the state continues to utilize and update it. Looking at it critically will allow the state to better understand what is working well about the tool and what is not working. Additionally, by comparing it to similar tools, I can assess if it is following best practices in tool development as they emerge.
Chapter 3: The Usability Of Cal-Adapt

A Story

On February 14, 2014 President Obama landed in Fresno, California and pledged $183 million in federal funds for drought relief efforts in California. Karla, a volunteer city planner in a smaller city in the Central Valley had seen the impacts of the drought—fallow fields, signs along the highway warning residents to save water, cracked earth. Raised by conservative parents in a conservative town, Karla knew that climate change policy would be an uphill battle. Despite this, she watched the President’s press conference because it was a rare occurrence for the Central Valley to have such important visitors. She heard the President not only promise drought support, but also argue that the drought is a reflection of climate change. He said:

We have to be clear: A changing climate means that weather-related disasters like droughts, wildfires, storms, floods are potentially going to be costlier and they’re going to be harsher. Droughts have obviously been a part of life out here in the West since before any of us were around and water politics in California have always been complicated, but scientific evidence shows that a changing climate is going to make them more intense. Scientists will debate whether a particular storm or drought reflects patterns of climate change. But one thing that is undeniable is that changing temperatures influence drought. (Obama, 2014)

Many of Karla’s friends and neighbors were skeptical of climate change and she knew they would easily dismiss the President’s claims. But more recently, Karla was starting to agree with arguments that climate change is a real concern. On some level, the President’s words made sense. That night, she got on the Internet to better understand what climate change would mean for her family and hometown of Turlock.

4 Karla is a fictional character. The description of President Obama’s visit and speech is accurate.
Using the California Climate Portal she found a website called Cal-Adapt.org that featured interactive maps and charts. She typed in her zip code and the first map zoomed into a grid cell encompassing Turlock, CA.

![LOCAL CLIMATE SNAPSHOTS](image)

**LOCAL CLIMATE SNAPSHOTS**

**Temperature**

Projected changes in annual average temperatures for the low emissions scenario

- **Historical Average**: 60.2 °F
- **Low-Emissions Scenario**: 64.3 °F (+4.1 °F)
- **High-Emissions Scenario**: 66.9 °F (+6.7 °F)

The information in the chart below corresponds to the selected area on the map (outlined in orange).

**Figure 3.1**: Changes in annual average temperatures for a low emission scenario in Turlock, CA. Screenshot from March 31, 2015.

Next to the graphic she found a chart showing that under a “low-emission” scenario her city could expect to get 4.1°F warmer, but under a “high-emission” scenario the city could expect to get 6.7°F warmer. She thought to herself, what are a few more degrees? She saw maps for snowpack melt and sea level rise, but Turlock did not have snow or coastlines so she moved past those quickly. Based on a map showing wildfire risk, she found that Turlock also seemed to mostly be spared from significant change.
Figure 3.2: Projected increase in area burned in 2085 under a low emission scenario. Screenshot from March 31, 2015.

Maybe climate change would not be as bad as she originally expected. Finally, she looked at her biggest concern, precipitation. Here the map played a video showing small changes to the annual precipitation over a one hundred year period, but Karla had a hard time identifying trends. To the right of the map she found a chart. It suggested there would be a small decline, but nothing that appeared dramatic. How sensitive was her hometown to small changes in precipitation?

Figure 3.3: Changes in precipitation under a high emission scenario. Screenshot from March 31, 2015.
She dug a little deeper into temperature, since that seemed to be the most extreme change. She looked at what the average change in temperatures would be for both average high temperatures and average low temperatures. The most troubling information she found using what this website called the “extreme heat tool.” Here she found that for Turlock an extreme heat day was defined as 100°F and that historically her community had 4 extreme heat days a year. This model predicted that the number would ratchet up over the years, predicting about 12-35 annually by 2050 under a high-emission scenario.

Figure 3.4: Number of extreme heat days under a high emission scenario. Screenshot from March 31, 2015

The number of warm nights (defined as above 69°F) would increase similarly. Here she could imagine the impacts. Warm days and night meant it would be harder to keep crops watered and livestock cool.
This was all interesting information, but Karla did not know what to do with it. What was the likelihood of a low or high emission scenario? How much should she really care about a few degrees temperature change? What did the precipitation change mean? How much could she rely on this information? She was primarily concerned about drought, but was not sure what all this information meant for drought. What, if anything could she do to protect her community?

Karla’s fictional questions mirror many of those I heard during interviews. The maps and graphs in Cal-Adapt are visually attractive and provide an impressive amount of information. They are clear, easy to understand, and widely accessible. Yet, if the people accessing Cal-Adapt do not understand how to apply the data and information presented on the site to their work, is the tool missing its mark?

The History of Cal-Adapt

As introduced in chapter 1, Cal-Adapt is a web-based tool that is just one of many initiatives from the State of California to address climate adaptation. In November 2008, former Governor Schwarzenegger signed executive order S-13-08 calling for state agencies to develop a strategy to prepare for the impacts of climate change. This culminated in the publication of the 2009 California Climate Adaptation Strategy (CCAS). The CCAS recommended that the state dedicate itself to the advancement of climate change impact research. The CCAS also recognized that this research would need to be compiled and published in a format that would allow decision makers to access and leverage it. One author of the CCAS explained that the state worried about recommending that a broad range of actors engage in climate adaptation work without this tool. They felt it would be unfair to ask them to respond without providing the resources to understand the extent of changes at a regional or local scale (Malchow, 2015). Therefore, the CCAS recommended the creation of a website with the express purpose of synthesizing “the latest
climate information into useable information for local needs” (California Natural Resources Agency, 2009, p. 9). Based on this mandate, Cal-Adapt was developed.

The California Energy Commission (CEC) and their partners at the Berkeley Geospatial Innovation Facility (GIF) spent the next two years building and developing Cal-Adapt before it was formally launched in June 2011 (Koy et al., 2011). The CEC was selected to be the lead state agency because they administered the Public Interest Energy Research (PIER) program. At that time, PIER funded most state-supported climate change research and was a natural choice to support Cal-Adapt as well.

The CEC and GIF worked with climate scientists across the state to collect an enormous amount of information and think critically about how to display it so that non-experts could understand it. Therefore, much of the early stakeholder engagement was not with users, but with scientists who authored the data. The small team of spatial analysts at GIF applied many creative and complex algorithms to reconfigure the information, optimize it, and display it for a wider audience. GIF and the CEC maintained a commitment to only publishing credible, peer reviewed data, out of a belief that this was essential for both accuracy and legitimacy. They made sure that Cal-Adapt provided clear citations to the original research supporting the visualizations with links to papers describing the research in more detail.

Who is Cal-Adapt For?

Kurt Malchow, the California Adaptation Coordinator at the California Natural Resources Agency felt that Cal-Adapt was created for a broad range of users. The state hoped that anyone thinking about development, land management, infrastructure, or other potentially relevant decisions could use Cal-Adapt to understand the location and severity of climate change in more geographic detail compared to the coarse grid (often limited to 100-300 km resolution) used in
general circulation models of the global climate. Various state agencies such as CalFire or the Department of Forestry could use Cal-Adapt to better understand local and regional vulnerabilities. However, as he explained: “It was really for regional and local jurisdictions, because that is where the action is happening.” Malchow adopted the mainstream view that local governments are better equipped to assess local needs and work with their community to identify responses. Additionally, he pointed out that the state controls only a small minority of California land. The rest is federally, privately and locally owned. This means that, in the absence of state regulation, collaboration with local entities will be necessary to achieve change.

Given this intended user population, the state prioritized “convenience, usability, accessibility, and direct lineage to the research” (Malchow). Kevin Koy from GIF explained that they did not want to overwhelm users with too much information or text. Instead, Cal-Adapt’s interface is simple and relies heavily on colorful graphics. GIF wanted to ensure that users could easily query the site to find their hometown and that information would be presented with little scientific jargon. Impacts such as wildfire, sea level rise, precipitation, and temperature change are front and center and easy to access from the home page. GIF and the CEC also wanted to ensure that the site would be usable by more advanced users. Therefore, they included more detailed information such as warm nights, timing of heat waves, and monthly temperature predictions for users willing to spend more than a few minutes exploring the maps. They also made the underlying data downloadable, in case users want to manipulate the raw data.

After the initial release in 2011, Cal-Adapt actively sought feedback to improve the website’s design from various community groups and NGOs (mostly in the Bay Area). Koy estimated that he gave 20-40 lectures to various different audiences regarding Cal-Adapt focusing on how it was developed and how to use it. Based on early feedback, the team changed how the website conveyed uncertainty for their temperature data in their “degrees of change” and “decadal
average maps” (see below) to include bands of uncertainty. These bands of uncertainty are not included for all impacts, but are a step in the right direction.

![Figure 3.5: Monthly temperature over time for Oakland, CA: (a) best guess estimates, and (b) including bands of uncertainty. Source: (Koy, et al., 2012)](image)

They also added county boundaries in addition to the 12-kilometer pixels. This was based on feedback that users understand their communities in terms of accepted jurisdictional boundaries, not randomized uniform pixels (Koy et al., 2012)

**What is Cal-Adapt for?**

While the 2009 CCAS was clear that Cal-Adapt should help local decision makers think through climate change, this remains a broad mandate. Koy commented that Cal-Adapt was not designed to be a decision support tool for any specific kinds of planning decisions. The CEC and GIF did not think they were the right actors to imagine or dictate how users should put the information in Cal-Adapt to use. Instead, they planned to create what is called an Application Program Interface (API). This allows other tool developers to use the information and maps within Cal-Adapt to develop their own tools that could be more decision oriented.

Malchow equally expressed ambiguity about how Cal-Adapt should be used. He felt that the state could never require that local governments use Cal-Adapt, because certain jurisdictions such as Los Angeles already have access to more detailed and location-relevant climate
information. Additionally, he did not have a specific vision for how Cal-Adapt would be used. He commented that the state does not mandate that local governments address climate adaptation. He hoped that seeing the devastation that climate change might wreak on California—the airports under water, the extremely warm temperatures—would be enough to prompt local action.

Importantly, the Natural Resources Agency recognized that Cal-Adapt's applicability was nebulous. Therefore, they sponsored the development of a 2012 Adaptation Planning Guide. One of the prime authors, Adrienne Greve at California Polytechnic State University commented that the Adaptation Guide specifically wanted to answer the question: “how the heck do you use this Cal-Adapt thing in terms of data vulnerability assessment.” Her team focused on adaptation efforts in small towns with few other climate change data resources. While Cal-Adapt is already relatively user friendly, the Adaptation Guide aimed to contextualize it within the context of on-the-ground planning. As mentioned in the previous chapter, this guide is a good first step, but is relatively high level and unspecific.

**My Feedback**

In the summer of 2014, I was brought on by the CEC to answer outstanding questions they had about user's experience of the tool. Specifically, the CEC was interested in finding out more regarding: 1) who was using Cal-Adapt; 2) how they were using the tool; and 3) what issues or problems they encountered when using the tool. This feedback did not aim to repeat the usability analysis that GIF had conducted looking at website design (though I did happen upon some of this feedback). I aimed to delve deeper into the question of Cal-Adapt's utility for actual on-the-ground planning. My work also varied significantly from the work that the team behind the Adaptation Planning Guide did. They sought to answer how Cal-Adapt, as an existing tool, could be put to use by planners. Instead, I researched if Cal-Adapt was actually being put to use and if
not, why not. Through the course of my work I found that a select group of relatively sophisticated users had found an application for the tool, but many others did not know that Cal-Adapt even existed or were unsure about how to apply the information on Cal-Adapt to their own work.

**The Five Components of Usability in Cal-Adapt**

In chapter 2, I discuss the theory that for climate science to be useful, it must be salient and legitimate to decision makers (Cash et al., 2006). While both these attributes are clearly important, there is value in breaking down usability beyond these two criteria to identify more specific issues. Borrowing from sociology, Schudson (2002) identifies five characteristics that make something culturally potent, which can also be applied to usability. He argues that for something to be meaningful, it must

1. **Be accessible:** people must be able to obtain information in the first place;

2. **Have rhetorical force:** people must recognize the information’s importance or power and feel that it is trustworthy, which is similar to credibility and legitimacy;

3. **Resonate:** people must understand how the information applies to their own needs, which is similar to salience;

4. **Be institutionalized:** it must become part of persistent processes, for example decision makers must find mechanisms to integrate climate projections into long-term decisions; and

5. **Be actionable:** meaning that people must understand what specific responses are appropriate given the information.

While each element of Schudson’s framework for potency may appear intuitive and elementary, breaking Cal-Adapt into these component parts showcases where usability breaks down and
therefore potential areas for improvement. In this section I will delve into each of Schudson’s five categories. I will define each of the components in more detail. Then I will assess Cal-Adapt’s successes or failures pertaining to each. Collectively, I will argue that the failure of the California state government to define a narrow enough set of policies or goals for Cal-Adapt (the action component) is linked to its failures to deliver in each of the other four components of Schudson’s framework (accessibility, rhetorical force, resonance, and institutionalization).

**Action**

To repurpose Schudson’s framework to evaluate usability, I start with his last component: “action.” Action can be thought of as the end-goal of the product. It is this goal that drives how the tool is designed, how it is perceived, and ultimately whether it is evaluated as successful or not. A phone is only useful if it can successfully make calls. A car is only useful as a mode of transportation, if it can be driven. While Schudson treats action as just one of the five components, it is distinct from the others. Accessibility, rhetorical force, resonance, and institutionalization drive the ability of the tool to be put to action. In this sense, the first four components can be understood as inputs into this last component. However, this is not unidirectional. The strength and clarity of the intended goal, action, has important implications for the success of the other four.
Looking specifically at Cal-Adapt, I see a failure to define its decision-making purpose as one of its greatest flaws. The 2009 *California Climate Adaptation Strategy* states the mission of Cal-Adapt as the following:

To show state supported research (and other research) in a way most relevant and useful to policy makers and local communities as a public outreach tool for the California climate adaptation strategy. The tool will show basic climate impact information at a scale that allows local communities to develop their own climate adaptation strategies based on this information (148).

In other words, the goal for Cal-Adapt is to: 1) provide a platform for climate research to be published; 2) to be used by policy makers and communities to promote adaptation planning in the state; and 3) to be used for local adaptation strategies. If Cal-Adapt is to be judged exclusively within the confines of this statement, then it can be viewed as a partial success. Cal-Adapt is a repository of state climate research. It includes hundreds of academic articles on climate change, and showcases the state’s efforts to downscale larger climate projections. Also, based on comments from my interviewees it can be used as a source of graphics and charts for public outreach efforts. Finally, it also did provide information at a more local scale that has allowed
communities such as Santa Cruz, Santa Barbara, and Berkeley to profile their climate related risk and input data directly into their climate action and adaptation plans.

However, Cal-Adapt falls short in defining its actionable purpose and usability for actual decisions. It fails to provide recommendations about the type of climate change analysis or adaptation strategies that local areas can pursue using the downscaled information on the site. Currently, Cal-Adapt provides no guidance within the tool itself about who should be using the tool, or how those users should leverage or apply the information. Instead, it operates under the assumption that if Cal-Adapt publishes information, users will come to the website with pre-formed questions or will find reasons to use the information that exists.

Table 3.1: Potential Uses for Climate Data and Cal-Adapt

<table>
<thead>
<tr>
<th>Planning Documents</th>
<th>Standards, Ordinance, and Programs</th>
<th>Other Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• General Plans</td>
<td>• Capital improvement programs</td>
<td>• Budgeting</td>
</tr>
<tr>
<td>• Climate Action Plan</td>
<td>• Zoning code</td>
<td>• Public education of climate related risks</td>
</tr>
<tr>
<td>• Climate Adaptation Plan</td>
<td>• Building code</td>
<td>• Agency/departmental presentations to elected officials</td>
</tr>
<tr>
<td>• Area and Specific Plans</td>
<td>• Fire code</td>
<td></td>
</tr>
<tr>
<td>• Local Hazard Mitigation Plans</td>
<td>• Tree ordinance</td>
<td></td>
</tr>
<tr>
<td>• Local Coastal Plans</td>
<td>• Floodplain ordinance</td>
<td></td>
</tr>
<tr>
<td>• Urban Water Management Plan</td>
<td>• Storm water Management program</td>
<td></td>
</tr>
<tr>
<td>• Downtown Plan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Sustainable Community Plans</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Regional Transportation Plans</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Integrated Regional Water Management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Local Coastal Programs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cal-Adapt reflects the CEC and GIF's determinations that it should be a data resource rather than a decision support tool. This determination is out of line with actions and perspectives of many state leaders I spoke with. These people wanted more than information for information's sake. They wanted local governments to pursue measures that would protect communities and increase resilience. The very fact that the CEC hired me to evaluate the tool from local planners' perspectives suggests that they hoped the information was usable by this group. The Natural Resources Agency commissioning of the Adaptation Planning Guide in 2012 suggests that they wanted local governments to use Cal-Adapt for vulnerability assessments and local planning. Additionally many state agencies wanted to use Cal-Adapt for their own work: The Office of Emergency Services expressed interest in integrating Cal-Adapt into their hazard-modeling tool. The Office of Environmental Health Hazard Assessment wanted to integrate their social vulnerability analysis with Cal-Adapt to help planners analyze the intersections of climate change and vulnerable populations. The Department of Health is also actively thinking about how the temperature information can allow communities to prepare for extreme heat events. While all of these are solid starting places to refine and define the "actionability" of Cal-Adapt, these wishes were not integrated into the initial development of the tool and continue to remain nebulous.

Problematically, defining the purpose of a tool after it is built makes it difficult to ensure the information is "relevant and useful" to local users. Only after the tools was fully developed, did the authors of the Adaptation Planning Guide try to answer how local planners could use the information in Cal-Adapt for vulnerability assessments. They had to work with what Cal-Adapt offered, rather than building a tool that provided what users needed. As one California climate consultant and academic stated:

If I were to rebuild it, I would start not from the data but from the decision. That is the number one rule that you pursue in all analytic approaches. Anything we have learned
from science technology tells you that you do not start from the science side (the supply of the data). What do people want to do? What is the decision they are up for? And to what extent is it sensitive to climate related changes? (Moser, 2014)

In a rush to deliver information quickly, the developers of Cal-Adapt missed a key step that is instrumental for usability. This choice was not unreasonable at the time. The state has yet to define the “decisions” they want made. If the developers had waited, Cal-Adapt very likely would not exist today. Is it better to build an only minimally usable tool compared to no tool at all? The answer depends on how narrowly the state defines the target audience. Open data may prove useful to academics or other scientists. It may also play a public relations role, symbolically showcasing California’s commitment to research, science, and climate policy. However, if the target audience is truly local officials, skipping this step is detrimental and can render the tool unusable to most.

**Table 3.2: Strengths and Weaknesses of Cal-Adapt Related to Action**

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>State can use Cal-Adapt to share climate data and research</td>
<td>Users are unsure of what kinds of decisions they can use the information in Cal-Adapt to inform.</td>
</tr>
<tr>
<td>Planners can use Cal-Adapt charts, graphics, and values in reports, vulnerability assessments, grant application, presentations, and public engagement efforts.</td>
<td>Cal-Adapt is not part of a clear policy framework that dictates who should be making which types of decisions using climate forecasts.</td>
</tr>
</tbody>
</table>

**Accessibility**

In Schudson’s discussion of accessibility he argues that for something to be retrievable potential users must know that a concept or product exists and where to find it. I believe that a third component must be added to this definition: users must have the capacity to gain access to the product. This is one of the essential points in the definition of accessibility as it pertains to people with disabilities. If one is in a wheelchair, a store that involves walking up a flight of stairs is not
accessible, even if that person knows it exists and where it is located. Similarly, if the products a store sells are too expensive for the purchaser, it fails to be accessible for that purchaser.

Most of Cal-Adapt failures in accessibility pertain to the fact that potential users do not know the tool exists. In my sample of potential users 22% of interviewees had never heard of Cal-Adapt prior to me contacting them (4 city planners, 3 county officials, and 3 regional entities). As mentioned before, this sample is in no way representative, but if anything it skews towards those more familiar with climate adaptation. This suggests that in the wider California planning population many potential users are simply unaware of Cal-Adapt. Interestingly, two of the people who had never heard of Cal-Adapt were in the active stages of climate adaptation planning, suggesting even those engaged in the topic may not know that Cal-Adapt is a resource available to them.

Once a user knows that Cal-Adapt exists, there are few barriers to access. It is free to use and available to anyone with an Internet connection. In fact, the CEC is so committed to accessibility that they opted not to require user registration for access. The downside of this choice is that it makes it harder to monitor who their users are, or contact people when the site is updated. This also makes it harder for the CEC to collaborate with or collect feedback from these users. Despite this, the CEC wanted users to have instant access to the information without having to share potentially sensitive personal information such as their email or job title.

Additionally, the website aims to be intuitive, even for those lacking a background in climate science or mapping software. While power users with technical capacity can download the information into Excel or ArcGIS and further manipulate the files, Cal-Adapt allows the typical and less-savvy user to explore the information directly within the web interface (Koy et al., 2011). All a user has to do is click on the data category they want to review, input the location they are interested in, and the relevant images and charts appear. Many of the people I spoke with this
summer lauded the modern and streamlined dashboard type layout. For example, one planner from the city of Benicia commented:

I don't even know if people know all of the components of a vulnerability assessment. Before you asked me which data layers to use, I just don't know. I have no idea what I am supposed to be doing. …The cool thing about Cal-Adapt is that you type in your city and poof all of this information pops up (Porteshawver, 2014).

The website also aims to increase its accessibility through its reliance on graphics. The creators understood that in today’s world of information, it is easy to overwhelm people. My interviewees recognized this. For example, a planner from San Luis Obispo commented, “having too much text is a drawback, and this doesn’t do that. This is its major strength” (David, 2014) From my interviews it was clear that a clean interface, modern graphics, and intuitive design made the website much more accessible to the typical planner.

Table 3.3: Strengths and Weaknesses of Cal-Adapt Related to Accessibility

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free and available to anyone with internet access</td>
<td>Potential users do not know that Cal-Adapt exists</td>
</tr>
<tr>
<td>Minimal use of jargon and reliance on graphics allowing non-experts to explore data</td>
<td></td>
</tr>
<tr>
<td>Available for the whole state of California</td>
<td></td>
</tr>
</tbody>
</table>

Accessibility and Action

Accessibility is incredibly important for action. Unless users know that Cal-Adapt exists, where to find it, and have the capacity to use it, there is very little chance that Cal-Adapt will be utilized. It is clear from my analysis that the CEC must reach out more actively to potential planners. Cal-Adapt cannot operate under the assumption of “if you build it, they will come.” To be fair, when the tool was first released Koy did a number of presentations to a wide range of users. However, staff turnover and the proliferation of other climate change tools necessitate ongoing publicity.
Defining the intended action is also important for accessibility. If the CEC is clear about who they want to use the tool and for what, then the CEC can do more targeted outreach to those populations. For example, if the CEC decides that all municipal planning departments ought to be using Cal-Adapt for their local hazard mitigation plans, there is a clear subset of the planning population that the tool should be marketed towards. Even more, this can guide the CEC to partner with the Office of Emergency Services. Together they can work with local hazard planners to ensure that the internal presentation is clear and effective to that group given their capacity and training.

**Rhetorical Force**

According to Schudson, rhetorical force is the idea that a concept or product must be memorable or powerful to potential users for it to have potency. Schudson makes a distinction between rhetorical force and resonance, noting that someone can understand the power of an idea or product without feeling any personal connection to it. As a personal example, I understand the importance of having an aquarium in one’s community. It provides a way for the community to interact with aquatic life and learn information that may encourage them later to support the protection of marine species. It also provides a venue for academic research and is a potential economic driver, bringing in visitors, tourism dollars, and prestige to a city. Despite all of this, I would be fine living in a city without an aquarium because I personally find fish unappealing. As a consumer, while aquariums have rhetorical force for me, they fail to resonate.

Looking at Cal-Adapt, most of the people I spoke with understood the rhetorical force of the tool. My particular research population believes that climate change is real and important. Therefore they saw value in the state of California investing in climate related research. Those who had done more work in climate adaptation, and were cognizant of the incredible expense of
downscaling, had an even deeper appreciation of the tool. They knew that for many cash-strapped communities, it would be impossible to fund a local risk assessment similar to Cal-Adapt without significant outside financial support.

Another aspect of rhetorical force is trustworthiness. People valued the fact that Cal-Adapt is a state product giving it credibility. Many commented that a prime difficulty in climate adaptation is choosing between all of the resources that exist, and justifying that choice. They commented that just getting started is difficult when they are instead debating which models to use, which projections to rely on, which dates to plan for, and under which emission scenarios. Pointing to the state makes that justification piece easier, since the state has perceived authority and legitimacy to vet information. Many of these practitioners commented that they would welcome even more direct prescription from the state, feeling that planning would be easier if they were just told that they must plan for 2050 and 2100, using the A1 and B2 emission scenarios available on Cal-Adapt.

One large issue that decreases the rhetorical force of the tool is that, despite the state’s legitimacy, many users worried it was outdated information (which hurt its trustworthiness). Most state guidance documents, such as the sea level rise analysis document from the California Coastal Commission (2013), recommends that planners use “the best available science” (3). Coastal communities active in planning for sea level rise were quick to identify that the sea level rise data available in Cal-Adapt were not “the best available” given that the projections were old (2009). They pointed out that they do not incorporate more advanced modeling techniques, such as the Coastal Storm Modeling System data available in Southern California and the Bay Area (Barnard, 2014). Their doubt about this aspect of the tool challenged the legitimacy of the rest of the

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5 Many of the people I spoke with were much more focused on sea level rise compared to any other climate related impact. This might be because relatively liberal coastal communities are more likely to be active in climate change.
website. This is only made worse by the fact that Cal-Adapt does not make it easy to determine when the various data-layers were last updated. This makes it hard for users to determine if Cal-Adapt offers the “best available” for the other layers.

Finally, when it came to the actual application of Cal-Adapt to policy-decisions, users also became very concerned about the question of confidence and usability. They appreciated that the information was more downscaled to their region, but remained unsure about how much they should rely on the numbers within Cal-Adapt. This is a sensible question since, as discussed earlier, projections are inherently uncertain. While Cal-Adapt provides bands of uncertainty in two of their temperature maps, this information is not available for other impacts. Cal-Adapt also does not provide guidance on handling uncertainty in the decision-making context. This leaves it up to users to figure out what kinds of decisions they can responsibly make based on Cal-Adapt data—a determination that most local officials do not have the expertise or comfort with climate adaptation to make themselves.

Table 3.3: Strengths and Weaknesses of Cal-Adapt Related to Rhetorical Force

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Decreases cost of climate analysis</td>
<td>• Sea level data clearly outdated</td>
</tr>
<tr>
<td>• Carries state’s stamp of approval.</td>
<td>• Unclear how much confidence users can have in the data</td>
</tr>
<tr>
<td>• Decreases procedural decisions regarding climate analysis users must make</td>
<td>• Hard to verbalize role of Cal-Adapt in decision-making context</td>
</tr>
</tbody>
</table>

related work compared to conservative inland communities. It might also be because the Coastal Commission is one of the few agencies to financially support local adaptation analysis through their Local Coastal Programs.
Rhetorical Force and Action

Even though the information on Cal-Adapt was not necessarily adopted or used by my interviewees, many of these same people support continued development and investment in Cal-Adapt because they believe downscaled climate information is an important endeavor. However, the failure to specify a narrow enough set of “actions” that Cal-Adapt can be used for has important implications for rhetorical force. Many users had a hard time expressing the “importance” of the tool in the context of local policy. Some felt that the tool might serve well as a source for images to use during public outreach in a presentation, but had a hard time imagining much beyond that. In fact, a number of people asked me who Cal-Adapt was intended to serve and for what purpose. Based on these questions, it is clear that the website itself fails to make a clear case about why it is important and decision relevant, and for whom.

Resonance

Resonance is the idea that a concept or product cannot only have importance in the abstract, but rather that the consumer must understand how the product applies to his or her own needs.

Cal-Adapt was designed to resonate. The 2009 CCAS specifically states that Cal-Adapt “will show basic climate impact information at a scale that allows local communities to develop their own climate adaptation strategies” (28). The basic concept was that other models or projections were at too large a scale to be locally relevant, and that through downscaling, Cal-Adapt would resonate more strongly with local users. Users could find their town on the map and see the risks that climate change will bring to their community. How could Cal-Adapt possibly make a stronger case for resonance?
Ironically, based on my interviews, resonance was one of Cal-Adapt’s weakest points. Half of the users who had heard of Cal-Adapt prior to me contacting had not bothered to actually use it or had only dabbled around on the site. They enjoyed using the site for their own personal curiosity, but failed to see a professional use for the tool. For the tool to truly resonate with water planners, public health officials, land-use planners, emergency services, etc. it needs to provide information that someone sitting in those jobs could use in the daily decisions they need to make (how many private wells should a county allow), or the long-term planning needs of their departments (does the fire department need to invest in a third fire truck). For example, a public health official might use Cal-Adapt to understand how intense future heat waves are likely to be in their jurisdiction and how proactively they should work to ensure people have cooling options. Currently, Cal-Adapt does not explicitly suggest this. Nor does it provide information about how a public health agency would make that determination.

A final issue with resonance is that much of the information practitioners actually wanted is not present in Cal-Adapt. For example, if one wants to plan for flood risks, Cal-Adapt is not sufficient. It provides information on average annual precipitation increases, but no information on the potential for extreme rain events that a flood manager would need. It provides information on coastal storm surge in addition to sea level rise, but provides no information on inland or riverine flooding or the likelihood of saltwater intrusion. While the information is downscaled, it is not refined enough to be used for land use planning which is done at the parcel level. Arguably local decision makers could use Cal-Adapt as a jumping off point. Problematically, however, the very people who are most likely to use Cal-Adapt have the fewest resources to support additional research or analysis.
Table 3.4: Strengths and Weaknesses of Cal-Adapt Related to Resonance

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Can find information tailored to one’s own community</td>
<td>• Does not connect changes to impacts, meaning users must do additional analysis.</td>
</tr>
<tr>
<td></td>
<td>• Does not connect impact to actions, meaning that the user must figure out how to apply the information themselves</td>
</tr>
</tbody>
</table>

Resonance and Action

Once again, all of these problems are tied to the failure to define the decisions Cal-Adapt should be used for or to narrow the target audience to specific users. If Cal-Adapt listed the types of decisions that could be made using its projections, and what next steps could be taken to get there, then the tool would be much more likely to resonate with the individuals in charge of making those decisions. For example, a planner concerned about water supply could be told that they should use Cal-Adapt to understand how snowpack reductions might impact their water supply. The tool might suggest that they 1) identify where their water comes from; and 2) use the snowpack and annual precipitation information in those regions to estimate future water resources. Cal-Adapt can suggest that communities able and willing to do more in-depth analysis pair this information with their own analysis of groundwater recharge and stream flow. It could also suggest that these planners think critically about working regionally or at the watershed scale in recognition that their neighbor’s actions will impact their community’s water supply⁶. Suggestions like this would guide users to begin asking the critical questions. As it stands, individuals in San Diego County and Los Angeles told me that the snow pack melt map was not relevant to them, even though they import much of their water from other regions that do rely on snowpack (Water Education Foundation, 2014). In reality, this will not be as easy as listing broad

⁶ Please note that this is a strictly hypothetical example, not necessarily reasonable advice for a specific water planning problem.
kinds of decisions that Cal-Adapt might inform. Once the state determines which kinds of
problems local officials should address using the tool, Cal-Adapt will need to be rebuilt to actually
answer the questions relevant to those problems. For example, if Cal-Adapt is to help answer
questions regarding future water supply needs, Cal-Adapt will need to rethink which impacts it
projects, the scale at which this information is provided, and the kind of background information
potential users will need to consider. This product may look so different from Cal-Adapt that it is
an entirely different tool altogether.

Institutionalization

Schudson writes that institutionalization discriminates between something that is culturally
important and something that is merely a fad. In order for something to have sticking power, there
must be institutional consequences for its use. One elects to consume an institutionalized concept
or product not only because it has potential personal benefits, but also because there are
meaningful sanctions if one chooses not to do so. For example, cars are ingrained into the
institutional fabric of the United States. In many parts of the country, the highway system, zoning
ordinances that prevent high density and mixed-use neighborhoods, and the lack of public transit
options mean that driving is imperative for buying fresh food, traveling to and from work, and
getting other needed services such as health care.

Cal-Adapt is institutionalized only in a limited sense. The advisory board for the tool
includes officials at the Department of Transportation, Department of Water Resources, Natural
Resources Agency, the Coastal Commission, Public Health, and the Office of Planning and
Research. Theoretically this means that these various agencies can better understand what is
available on Cal-Adapt, find ways to integrate it into their own agenda, and provide advice about
how the tool could be more useful for their agency. Despite this, I learned from conversations
within the CEC that their funding stream limits their ability to collaborate effectively with other agencies.

Even more, except for promotion of Cal-Adapt in the Adaptation Planning Guide, state agencies are not actively suggesting that the local planners they interact with use Cal-Adapt. The Coastal Commission, for example, is one of the few agencies that provide grants for adaptation planning within California. However, given that the sea level rise information in Cal-Adapt is old, they do not suggest that local planners use Cal-Adapt in their analysis (California Coastal Commission, 2013). Additionally, the Department of Public Health has expressed interest in using Cal-Adapt for public health planning, but has not yet determined how they would suggest that local health departments use it (Wilhelm, 2014). Similarly, when I spoke to officials at the Office of Emergency Services, they had limited knowledge of Cal-Adapt but did not include it in the portfolio of tools they recommended cities use as they prepare hazard mitigation plans (Norris, 2014).

Finally, I learned through my interviews that there are no requirements from the state that local governments pursue adaptation. If communities are not interested in pursuing this work themselves, it is very easy for them to choose not to. Currently, there are only weak incentives, such as the Coastal Commission grants, or potential funding through FEMA for local hazard mitigation planning (California Natural Resources Agency et al., 2012). This means that there are no negative repercussions, and only a few positive ones for adaptation planning (not including the larger moral imperative to protect one’s community from harm and economic loss). If there were more institutional requirements, people might be hungrier for tools such as Cal-Adapt that can make the process easier and cheaper.
Table 3.5: Strengths and Weaknesses of Cal-Adapt Related to Institutionalization

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Cal-Adapt’s advisory team brings many state agencies and experts together, creating opportunity for broad adoption.</td>
<td>• State agencies are not actively incorporating Cal-Adapt into their agenda or promoting its use.</td>
</tr>
<tr>
<td>• Cal-Adapt has the state’s seal of approval.</td>
<td>• Climate adaptation is not required in California.</td>
</tr>
</tbody>
</table>

Institutionalization and Action

As Schudson points out, institutionalization is not an imperative for action, but certainly helps. For example, the city of Santa Cruz decided that climate change is an important enough issue to their residents to hire a “climate action coordinator” on staff in their city government. This individual came in with scientific training to understand climate models and had the time to research and use tools including Cal-Adapt to do local analysis. In Santa Cruz, incentives from the state were not required for action (R. Clark, 2014). However, institutionalization is key if the state hopes that the imperative to address climate risks will be felt by cities without discretionary funding, champions for climate change, or political will to pursue climate adaptation on their own. Communities like Santa Cruz, Berkeley and Chula Vista were the outliers. Most places, even those with staff interested in climate adaptation, were focused on mitigation or other issues and had placed adaptation on the back burner.

Certainly, those places without capacity or political will are unlikely to make any progress without mandates or compelling incentives. Adaptation Planning Guide author Adrienne Greve hoped that the Central Valley would use Cal-Adapt and the planning guide to conduct high-level vulnerability assessments. She pointed out that these communities will be profoundly impacted by drought and heat. They have limited funding to hire consultants or technical experts, much less large city staff to do a vulnerability assessment. Despite this, even when she offered her own
services free of charge, she found that most of the central valley cities were not interested. Tools like Cal-Adapt will only be used by these cities if they are incentivized either positively or negatively to take on climate adaptation.

**How Can Cal-Adapt Improve?**

Cal-Adapt would benefit from more thought into accessibility, rhetorical force, resonance, institutionalization and action aimed towards a specific decision-making context. To do this, California should first address its larger climate adaptation agenda. As one of the regional facilitators I interviewed pointed out: “The first thing the state needs to do is figure out if every city and county needs to have their own adaptation plan. No one has an answer to that” (Seville, 2014). This comment brings up a couple of important issues. First, are comprehensive adaptation planning efforts even necessary? Would it be better to figure out how each agency (natural resources agencies, emergency management, public health, etc.) can integrate climate adaptation into the work they are already doing? The reality is that there is likely some benefit to both processes. Comprehensive planning can provide direction while agency efforts can actually apply the climate adaptation agenda to real decisions. The second issue is the question of scale. Should every city do comprehensive adaptation planning? For many places in California it might make more sense to work at a county or regional scale. This will allow cities to pool resource, coordinate decisions across municipal boundaries, and think through interventions that have impacts beyond city boundaries. If the state were to determine that the county level was the best scale, they could create incentives or requirements for county-level climate adaptation plans and critically assess how Cal-Adapt can be part of that effort.

Even more, based on my conversations with state officials in planning and at the CEC, it is clear that there is still uncertainty about which local decision-making processes should take
climate projections into consideration. In the fall of 2014, I worked with contacts at the state to find a potential case study that would have allowed me to observe Cal-Adapt’s application within a decision-making context. I was sent to various departments including emergency services, public health, and transportation, and none of them had a clear image of what they wanted the local officials they oversee to do with Cal-Adapt or even what they thought local governments should be doing to respond to climate risks. Until there is consensus on who needs to be doing adaptation planning in the first place, what risks needs to be considered, and how these local planning efforts can support larger regional and state agendas, progress is likely to be haphazard.

The counterargument to this is that the onus of figuring out what to do should fall on the shoulders of local governments who are more aware of local needs. As mentioned at the beginning of this paper, there are thousands of climate adaptation resources out there and more are being built every day. Cal-Adapt should not have to answer all questions (though hopefully it should answer some). A proactive public official could easily find a guidebook that provides step-by-step information on how to do a vulnerability assessment. They then could turn to Cal-Adapt only to obtain basic information about broad trends based on projections. These officials could then draw on the knowledge of local people and past memories of weather events to draw a picture of their climate-related risk. Is it just laziness that is preventing action? In some cases the people I spoke with could be more proactive and creative. However, more often the officials were incredibly busy and did not have time to do extensive research. For many of them, considering climate change related risks was not their primary responsibility. Even more, many of these people did not even know which questions they should be asking, and could not possibly know where to start with their research. For example one planner in a coastal community asked me to define climate adaptation at the beginning of my interview because he was unfamiliar with the concept in the first place.
Cal-Adapt was not designed to be a decision-support tool because tool developers did not see it as their place to determine what kinds of decisions local actors should be making. In an ideal world, the state would not be solely in charge of dictating which decision local actors must make. Instead, these mandates would be based on a process that brought together state and local officials, as well as the scientific community. I hope that California is ready for this to be a long iterative process. In the interim, there is a strong argument for leadership from the state. As one of the consultants I interviewed stated:

I think we could make this a lot easier if the state provided guidance on what to do. This would makes it easier for plans to cross jurisdictional lines...Through guidance, the state can build capacity at the local level on how to make robust decisions, how to think in terms of climate change impacts as well as vulnerability, and how to deal with uncertainty. This would lift all boats. (Moser, 2014)

As this individual pointed out, California state agencies can facilitate action by synthesizing and suggesting best practices. The state can and should improve the tool's accessibility, rhetorical force, resonance, and institutionalization. They likely could do this more deliberately if they first determine the desired use of the tool.
Chapter 4: Other Approaches to Developing and Using Climate Adaptation Tools

Chapter 2 presented a scholarly debate positing that the usability of the science communicated through tools such as Cal-Adapt depends on the process by which it is built. A strong process creates opportunities for collaboration by bringing together decision makers and scientists to build and apply models and forecasts. This ensures that the science is tailored to the decision makers’ needs and that the decision makers better understand the application and limitations of the science. To facilitate this conversation, scholars recommend finding someone who is literate in both science and policy and who can act as an interpreter between the two groups (Clark et al., 2011; Dilling and Lemos, 2011; Tribbia and Moser, 2008). From this perspective, many of Cal-Adapt’s limitations may stem from the process through which it was built. The layers were largely chosen based on the availability of data, not on the demands of a user population. Moreover, the user population was left too nebulous for systematic polling or meaningful engagement. Some community outreach did occur, but was focused on “the look and feel” of the tool more so than the content. Even more, as I argued in the last chapter, it was designed before a policy framework was developed (the Climate Adaptation Guide), and therefore could not use that framework to inform how it presented information.

What does an alternative approach that is grounded in collaboration or stakeholder engagement actually look like? Is it more effective? In this chapter I will present three alternative approaches to climate science development that use bottom-up methodologies. First, I will look at two web-based spatial-analysis tools that specifically aim to bridge the divide between tool developers and users. The two tools I will analyze are: 1) Our Coast, Our Future— a model developed to show sea level rise and storm surge risks in the California Bay Area; and 2) The

7 Can be accessed at: http://data.prbo.org/apps/ocof/
Coastal Resilience Tool\(^8\) – a resource which also shows sea level rise risk but is focused on impacts to natural systems.

Finally, I will present a case study that shows an even more extreme version of a collaborative approach for understanding and applying climate science. For this, I will look at Sonoma County in Northern California, which provides an example of concerted collaboration between climate scientists and local decision makers. The county relied heavily on climate science provided as part of a pilot study conducted by The Terrestrial Biodiversity and Climate Change Collaborative (TBC3) and the North Bay Climate Adaptation Initiative (NBCAI). These groups analyzed complex hydrology projections for Sonoma County using a collaborative process. I will discuss how this method allows for a very different application of climate science than what is possible through Cal-Adapt or even the other two tools.

Taken as a whole, these three examples demonstrate an alternative to the type of design utilized in Cal-Adapt (see Appendix, Table A.3). They support scholarly work arguing that processes inclusive of both scientists and decision makers produce a more usable tool. However, they also speak to the difficulty of doing this well. The increased usability of these tools must be balanced with the fact that they are more time intensive to build and less broadly useful outside of their original design community.

**Web-Based Tools**

Our Coast, Our Future and the Coastal Resilience Tool are both web-based tools similar to Cal-Adapt, but with a narrower focus on sea level rise. Like Cal-Adapt, both feature map-based interfaces that allow a user to zoom in on their own community and visually see areas at risk of storm surge and flooding under various scenarios. However, they were developed using distinctly

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\(^8\) Can be accessed at: coastalresilience.org
different processes. For background and the history of these tools, I spoke with one of the primary developers behind each tool. Each of these individuals shared lessons learned, their perspectives on the relative strengths and weaknesses of the tools, and an evaluation of the tool’s usability. These interviews only provide one perspective on the tool and ideally should be supplemented by additional research. Despite this, both cases make a strong case for intentional stakeholder engagement that begins before the tool is conceptualized.

**Our Coast, Our Future**

![Our Coast, Our Future](image)

**Figure 4. 1: Home page for Our Coast Our Future**

Our Coast, Our Future (OCOF) is a tool that provides land use managers and planners sea level rise information for the California Bay Area. OCOF is the product of a collaborative effort between the Gulf of the Farallones National Marine Sanctuary, U.S. Geological Survey (USGS), the San Francisco Bay National Estuarine Research Reserve, Pont Blue Conservation Science,
National Oceanic and Atmospheric Administration (NOAA), Coravaï, the National Parks Service, and the Bay Area Ecosystem Change Consortium. The diverse team behind the tool brings together experts in ecology, bioinformatics, geology, biology, hydrodynamics, climatology, spatial data, technology communications/marketing, and website design. The tool draws on a modeling approach developed by USGS called Coastal Storm Modeling System (CoSMoS), which estimates sea level rise and storm surge. CoSMoS data is widely regarded as more specific and accurate compared to the information originally used in Cal-Adapt (Cal-Adapt is currently in the process of updating its sea level rise layers to include CoSMoS data).

Figure 4.2: Flood potential for San Francisco near AT&T Park using 75cm of expected sea level rise. OCOF 2015.

For background on this tool, I spoke with Grant Ballard from Point Blue Conservation. He explained that OCOF aimed to provide more detailed and dynamic sea level rise information for the Bay Area compared to what was available elsewhere. They also wanted to create a tool that

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9 Coravaï is a web-based tool and application developer.
relied on direct user feedback. Ballard commented that he had seen too many other tools go unused. OCOF believed that robust stakeholder engagement, beginning early on during the design phase, could correct problems suffered by similar web-based resources.

Therefore, OCOF hired specific individuals to identify and reach out to an array of stakeholders including the Coastal Conservancy, the Coastal Commission, the San Francisco Bay Conservation and Development Commission, Caltrans, various permitting agencies, municipal and county government officials, and major landowners. OCOF met with 140 individuals over the course of three scoping meetings. These meetings identified the types of questions users wanted OCOF to answer. OCOF also created an advisory committee of volunteers who beta-tested the tool and provided periodic feedback on the usability of the site. Additionally, OCOF collected expert feedback from an invitation-only technical advisory committee. These stakeholders were knowledgeable about climate adaptation and modeling and could provide feedback on how to portray climate science honestly and accurately.

Ballard explained that when they originally imagined OCOF they hoped that it could promote coastal planning aimed at protecting natural habitats and encouraging natural flood protection techniques. However, the stakeholder driven process made it clear that most people were much more concerned about development and human infrastructure. Even though this did not reflect the missions of many of the collaborating organizations, OCOF chose to respect the stakeholder feedback. Ballard continues to be disappointed that OCOF does not have much to say about natural resources, but notes that this is a trade off that they made to ensure users actually saw value from the tool.
The Benefits of Collaboration

One of the primary benefits of this collaborative approach was that it allowed OCOF to clearly identify and understand their target audience. This had important implications for the accessibility, rhetorical force, and resonance of the tool. Collaboration also allowed them to identify key partners who helped promote OCOF’s importance in institutional processes.

Accessibility

Like Cal-Adapt, OCOF is online and free to the public. Additionally, the tool developers were similarly concerned with ensuring that average planners and land use managers would have the technical capacity to use the tool. In fact, OCOF goes much further than Cal-Adapt in this respect. Rather than simply minimizing jargon, the tool actively aims to teach users how to think about climate risks. They provide extensive background on their model and literature for anyone interested in the theory behind climate modeling. They have detailed information that guides a user through choosing which sea level rise projections to consider (see figure 4.2) and interpreting the data portrayed in their maps. They include a glossary of key scientific terms that planners and others users may not know off-hand. OCOF also includes an extensive “frequently asked question” section. In this section OCOF explain how the tool is different from similar products such as the NOAA Sea Level Rise Viewer. It also provides details on specific questions, including: “why don’t marshes appear flooded under the selected scenario?” By addressing these questions the tool can preempt and address the concerns that users might have as they engage with the data in a more meaningful way.

\footnote{OCOF provides much more detailed sea level rise data compared to Cal-Adapt, and for that reason also requires much more explanation. This accounts for some of the differences in the need to “educate” the user for the data to be accessible.}
Importantly, OCOF would not have been able to identify which questions they needed to confront without targeted stakeholder engagement. Ballard explained that his team learned a great deal through this process. He stated:

People are really strapped for time and capacity. They're afraid of the learning curve. They basically don't have time to do much other than what they're already doing. So we have to make sure that we're really getting what it is they need and listening, and not just telling them that they should be doing something.

OCOF aimed to use this process to ensure that they could identify what those core questions were and that they could communicate answers in a way that made sense. This process allowed them to strategically be responsive to feedback. Ballard ultimately felt that OCOF ended up being a tool that most anyone could use if they invested the time to explore the site.

Comparing Sea Level Rise projections

**Introduction**

Your planning efforts for estimating sea level rise impacts appropriately should be derived from reputable sources of information. The graphs below provide a comparative look at some of the most commonly cited reports so you can evaluate the landscape of best projections and make more intelligent choices about which scenarios to look at more closely.

**What projections are likely to occur in a given year?**

Move the slider control below the graph left and right to see how different climate experts projections of sea level rise compare to one another. Hold your mouse over each bar for details.

![Graph of Sea Level Rise Projections](Image)

**Figure 4.3: Guidance on choosing sea level rise projection from OCOF (2015)**

Rhetorical Force

In Chapter 3, I explained that Cal-Adapt scores pretty well on rhetorical force. Most people can identify why Cal-Adapt might be useful for an abstract audience. Most people also believed that the data was credible because it had the state’s seal of approval. Without speaking...
directly to users it is hard for me to fully assess if OCOF scores as well on rhetorical force, but my guess would be that it does. Sea level rise is a salient enough issue that the public is likely to understand that models showing related risks are important. Additionally, the many experts behind the tool also give OCOF credibility.

The rhetorical force issues within Cal-Adapt stems from the fact that people had questions about the ultimate usability of the data. They questioned if Cal-Adapt was up-to-date and wondered how much uncertainty plagued the outputs. OCOF addresses the first issue by explaining that CoSMoS is the most up-to-date modeling technique available. More interestingly, however, they also explicitly confront uncertainty. OCOF recognizes the data’s limitations, and did in-depth analysis to better understand where their data succeeds and where it fails. They provide place-by-place reasons why their maps might be misleading or incorrect. For instance, for Point Reyes Beach, OCOF explains: “consequential flooding extents in scenarios up to [sea level rise of] 150 cm are not accurately predicted and projected in these areas. The magnitude of velocity is over-predicted along this shoreline for all scenarios.” By noting where the data is unreliable, the tool developer signals to the user that they vigorously examined their data and are willing to be honest about its shortcomings. This ensures that users do not apply data that is knowingly incorrect. It also makes the developers appear more credible.

Resonance

OCOF is able to be more responsive to users’ needs because it knows who their users are and worked with them long enough to know what their questions are. In this way accessibility (the technical ability to actually use the tool) is tightly linked to defining the intended purpose of the tool. A section titled “How can OCOF help you?” explains that OCOF was designed for planners, managers, and scientists that want to use sea level rise and storm data to inform decisions. It
specifically lists twelve job titles of people that the tool might help, including land use planners, coastal resource managers, restoration managers, hazard mitigation planners, and floodplain managers. It suggests that the tool can be used for purposes such as habitat conservation plans, climate action plans, and infrastructure maintenance. It encourages users to draw on OCOF for graphics, data, and authoritative citations in grant proposals, presentations, websites, and public communication. Even more, OCOF explains how the tool fits into a general climate adaptation planning effort. OCOF explains that adaptation planning normally involves an assessment of risks, the identification of potential responses, and implementation/evaluation of those responses. OCOF, they suggest, can help with the first stage “by providing the science needed to understand and evaluate how sea level rise could impact your community.”

This is fundamentally different from Cal-Adapt, which neither defines its target audience nor explains how the website can be used by any specific groups for climate adaptation. Even though this is a fairly easy addition, it helps move OCOF from merely having rhetorical force (people understand that the tool could be helpful) to having stronger resonance (those within the target audience are explicitly told how the tool is helpful to them).

**Institutionalization**

OCOF also garnered institutionalization through the stakeholder process. Ballard explained that members representing the Coastal Commission were involved from the early days of the process and by the end were quite excited about putting the tool to use. The Coastal Commission now specifically recommends that local planners in the Bay Area use OCOF when submitting Local Coastal Programs. In this way, OCOF is institutionalized, thus increasing its likelihood for uptake.
Is OCOF being used?

OCOF is being used by a select group of people. In addition to recommending that local governments use OCOF, The Coastal Commission uses it internally to evaluate permitting applications to determine if developments would be at high risk of inundation or flooding. This is a particularly interesting use because it means the tool is being used by an agency in their normal decision-making process rather than in specific adaptation planning efforts. Additionally, in my research on Sonoma County I learned that the Sonoma County used OCOF for their sea level rise analysis.

Despite these examples, Ballard actually had mixed feelings about its use, stating:

I hope it keeps going and we’re committed to making sure people are using it...There’s always this temptation to build another one—a newer, fancier, better one, and spend more money on that...It’s kind of sobering that probably only 600 people have even registered to really use it, which is way better than we’ve had for some of our other tools. We spent I don’t know, probably in total $750,000 building the tool. 600 people, it depends on what day it is. I sometimes feel like that’s a lot, and sometimes I feel like that’s not enough.

Since Cal-Adapt does not track users and covers a different jurisdiction (California compared to the Bay Area) it is impossible to compare its uptake to OCOF’s 600 registered users. Despite this, Ballard comment speaks to how, even with stakeholder engagement and very intentional tool design, larger barriers continue to exist. Ballard noted that people are incredibly strapped for time and capacity. Given this, he thinks that only people who are already passionate about climate change have taken the time to learn how to use the tool. As I argued in Chapter 3, without state regulations requiring adaptation, use of tools like OCOF may always be limited.
Coastal Resilience Tool

The Coastal Resilience Tool (CRT), developed by The Nature Conservancy (TNC), is a mapping portal that provides a select group of practitioners access to downscaled sea level rise information. To build the tool, TNC worked with partners at the Natural Capital Project, NOAA, USGS, the Center for Integrated Spatial Research at the University of California, Santa Cruz, Azavea, The University of Southern Mississippi, and the Association of State Floodplain Managers. The tool provides data-layers and assistance in select locations including Ventura and Monterey Bay in California, the New Jersey coastline, the Gulf of Mexico, and the U.S. Virgin Islands. The tool is aimed at planners, climate advocates, and other decision makers who are preparing planning documents.

The goal of the CRT is to promote more nature based solutions to climate change. Like OCOF and Cal-Adapt, CRT helps decision makers understand their vulnerability to coastal hazards through maps that show sea level rise and storm surge. Additionally, CRT allows users to

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11 Azavea is a geospatial technology firm that assists with mapping technology.
look at social and economic vulnerability using U.S. Census information available at the block-level. It also tries to assess a community’s economic exposure to flooding by estimating the potential damages to housing, transportation and infrastructure based on inputs from the US Multi-Hazards Tool developed by the Federal Emergency Management Agency. Finally, the tool allows users to look at certain ecological features including models of habitat migration and ecosystem changes based on sea level rise. Importantly the tool is more than a mapping tool, it is also a network. The Coastal Resilience Tool connects participants in each of the TNC’s project areas. It also gives users access to TNC staff and advice on cost-effective ecosystem based approaches to climate adaptation.

Figure 4.5: CRT Mapping Portal showing Combined Hazards in Ventura
For background on this tool, I spoke with Sarah Newkirk at TNC. Newkirk was involved with earlier versions of the CRT when she was working on the East Coast and more recent updates to the CRT through her work with Ventura, CA.

Interestingly, CRT’s early history is quite similar to Cal-Adapt’s. Back in the early 2000s, Newkirk and her team worried that the existing climate resources scared people about future risks, but provided little information that was locally relevant. Newkirk explains:

The information on sea level rise wasn’t useful because decision makers didn’t understand it. Even if they were inclined to believe that sea level rise was happening and that it was human-induced, they didn’t really have a very clear sense of how it was going to play out in their landscape.

To respond to this, in 2006 TNC built the CRT. The first iteration did not rely on an extensive stakeholder engagement process. In partnership with NOAA’s Coastal Services Center and NASA Goddard Institute they downscaled climate models and visually mapped sea level rise using an interactive GIS-based platform. At the time the tool was the only one of its kind.

In the years after the CRT was released, TNC did a number of usability tests and found that, by and large, people were not using it. After a number of workshops and conversations with users they realized:

It wasn’t actually designed to meet users’ specific and articulated needs… There was too much land use data in there. Additionally, there wasn’t a policy framework for doing any of the work, so it wasn’t like they could do anything with it specifically.

The TNC had been operating under the assumption that if they designed a tool drawing on scientific information, users would respond by creating a policy framework for adaptation planning. Newkirk and her team quickly realized that this was unrealistic.

Therefore, TNC decided to explore a new approach that included a more robust stakeholder engagement process in which they worked directly with the City of Ventura as they designed the tool. Additionally, TNC found that it was important to allow users to ask questions
whenever they got stuck or were confused. In Ventura, stakeholders worked directly with consultants and scientists to figure out what information they needed and to troubleshoot any of their problems.

TNC continues to test if the tool is user friendly to a wide range of groups. One of the important features of the TNC’s tool is periodic usability testing throughout the process. As Newkirk explains:

What [our analyst] does is ask the user to do a series of tasks. She times them and she’ll tell us what kind of clicks they do. If there is a way of getting from one thing to another thing with one click and it takes them six clicks to actually get there, you know that’s a problem. I don’t think a lot of other people do that.

Through this usability analysis, TNC can ensure that the tool is intuitive to users who are not well versed in spatial analysis or GIS.

The Benefits of Collaboration

CRT has seen benefits from the more collaborative approach they used more recently compared to the top-down approach they originally used. Compared to OCOF, this collaborative approach helped them hone in on how to make a tool that was accessible, filled a need, resonated with users, and could be institutionalized. Interestingly, however, TNC used an approach aimed at specific “actions” rather than a bottom up process that focused on these elements first. Newkirk explains the theory stating, “The short answer is that you want your tool to be built to serve a particular policy.” Knowing this policy purpose can inform the tool’s design.

Newkirk’s team actively identified potential opportunities for climate adaptation policy. They determined that they did not want to create new processes (climate adaptation plans), but wanted CRT to serve existing planning efforts. For example, TNC determined that local coastal programs, local hazard mitigation plans, and comprehensive planning documents were all existing planning processes that could benefit from sea level rise risk analysis. Like OCOF, CRT
specifically focused on building a tool that would support the local coastal programs required by the Coastal Commission. Newkirk explains:

We started to design ours to serve local coastal program plans. We were aware that the Coastal Commission was going to be writing sea level rise policy guidance and wanted to fit the tool to fit the policy instrument that most local governments will follow.

Knowing this information helped Newkirk and her team determine what kinds of questions the tool should be able to answer. For example, Newkirk explained that the science behind the models is incredibly complicated and provides more information than users needed. Therefore, TNC found that it made more sense to provide a limited amount of information that would not be as overwhelming. This was not a one-time process, but reflected the iterative nature that Dilling and Lemos (2011) endorse. For example, Newkirk explains that they first designed the tool focusing on solely on planners involved in coastal programs, but realized that this design did not incorporate the needs of elected officials who ultimately would be making important decisions. Therefore, they went back and revised the tool.

**Accessibility**

Through an iterative process that was highly focused on the tool’s application to policy, TNC slowly built a tool that hits on all other aspects of Schudson’s framework. They carefully designed a tool that would be accessible to the very stakeholders that need to be involved in local adaptation planning by working directly with them as they worked through the tool. During the design phase these users had frequent interaction with scientists to assist them when they needed more information or got stuck. Newkirk explains that they learned during this process and no longer need this same handholding. Additionally, the tool developers improved CRT based on user feedback making the tool more intuitive.
Rhetorical Force

In 2011, Ventura became California’s first community to experiment with managed retreat (Barboza, 2011). Due to Ventura’s well-documented vulnerability to sea level rise, TNC did not have to actively convince people of the theoretical value of a tool that shows sea level rise risk. Additionally, they were also able to build credibility based on the reputation of TNC and the collaborative process by which it was built. Since stakeholders were engaged from the early days, they developed trust for the tool over time.

Resonance

TNC was also able to build direct resonance with users through their stakeholder engagement process. Stakeholder engagement proves to be a good marketing technique; those asked to offer feedback must invest in the tool by thinking critically about how it could serve their purposes and what they need from it. As such, planners and climate advocates had to connect the dots between the information the tool provides and their specific jobs. Additionally, TNC critically considered who would need to use the tool. As evidenced by the decision to modify the tool to resonate more with elected officials, TNC took active steps to ensure that the right stakeholders (those necessary for policy change) bought into the tool.

Institutionalization

Finally, by focusing on pre-existing planning processes, and specifically the local coastal programs, TNC did not have to create an institutional necessity for the tool. Instead, they plugged into pre-existing institutional needs.
Is CRT being used?

Newkirk reported that advocates and public officials are actively using CRT in Ventura. For example, one group used the tool to argue that the coastal power plant needed to be moved or upgraded to be flood resistant. Also citing data from CRT, the city of Oxnard put a moratorium on construction of coastal based power plants. The U.S. Navy used CRT to think through their base management plan for their property in Ventura.

Newkirk admitted that the tool is successful in Ventura because stakeholders had access to the scientists that developed the tool and had direct influence over the tool’s content. The question remains how much the information will be used now that TNC has finished developing the tool. Newkirk remains hopeful, stating:

We’re now at the point where the information is out there and people are using it. Do they still need to be able to ask questions? I don’t think so. It needs to be something that the community owns…. I don’t find myself fielding a lot of questions at all. This suggests that a robust stakeholder engagement process during tool development can create longer-term value even after the tool developer pulls back.\textsuperscript{12} Could TNC build the same tool based on what they learned in Ventura for another part of California and expect similar results without doing a stakeholder process? Or was the collaborative process key to creating value? If the latter is the case, TNC and would have a hard time replicating CRT statewide in a short period of time.

Conclusions for Cal-Adapt from These Web-Based Tools

Without additional research I cannot conclusively argue that either CRT or OCOF are more usable than Cal-Adapt. Despite this, these tools do provide an alternative narrative for tool development that could address some of the shortcomings identified in Chapter 3. It certainly seems that if Cal-Adapt had been designed to support specific planning processes or had involved

\textsuperscript{12} Future research might want to verify if Ventura decision makers agree with this assessment.
potential users in determining its design, then the tool might be more usable. Those communities and agencies that influenced the tool design became natural users and champions for the tool’s promotion. They also narrowed the scope regarding what information to present, and identified areas that created widespread confusion.

**Climate Adaptation in Sonoma County – A Collaborative Approach**

In recent years Sonoma County has become one of California’s leaders in climate adaptation. Time and time again, interviewees elsewhere in the state recommended that I speak with Sonoma County climate advocates because of their unique regional and collaborative approach. As with CRT and OCOF, Sonoma County actively sought to bring diverse participants together. Even more, they explicitly used information brokers to bridge the gap between science and policy. It would be unfair to say that Sonoma County and Cal-Adapt fall on complete opposite ends of the spectrum in terms of top-down versus bottom-up approaches. However, they do fall far enough apart that I can analyze the advantages and limitations of a highly iterative and collaborative method for understanding climate science as it plays out in the real world.

For this research I spoke with four people who represented an even larger subset of organizations. Misty Mersich works for the county on climate mitigation and adaptation. As such she speaks from the perspective of decision makers and policy. Caitlin Cornwall is a trained biologist and works for the Sonoma Ecology Center, a non-profit focused on sustaining the county’s ecological health. Cornwall is also one of the founding members of the North Bay Climate Adaptation Initiative. Lisa Micheli is the executive director of the Pepperwood Institute, a researcher involved in the Terrestrial Biodiversity and Climate Change Collaborative, and another founding member of the North Bay Climate Adaptation Initiative. Finally, I spoke with Sara Moore who is a private consultant specializing in climate adoptions. She assisted the county in
their vulnerability assessment. These people provided a number of perspectives from which to assess Sonoma County’s process.

*An Introduction to Sonoma County*

Sonoma County, located in Northern California, is home to approximately 495,000 people. The county has a varied landscape including 55 miles of rugged coastline, historic redwood and oak forests, marshlands, the Russian River and its various tributaries, pasture and agricultural land, and nine incorporated municipalities. Beginning in the 1990s, the wine industry expanded rapidly as farmers realized that the Mediterranean climate and volcanic soil makes it ideal for growing high quality grapes for wine (Alkon & Traugot, 2008). The county estimates that wine production alone generates nearly $14 billion annually. Given the social and economic importance of this industry, the county embraces its country-chic charm, local food movement, and growing tourism industry. In addition to wine, the county is a leading producer of milk, livestock and poultry, other fruits and nuts, and nursery plants (Sonoma County Agricultural Commissioner, 2014). This agricultural identity drives policy. Over time, voters and cities actively chose to limit growth to maintain the “small-town in the country” vibe. Six of the nine cities have official urban growth boundaries, and the county as a whole limits development between cities and between neighboring counties (Sonoma County Transportation Authority, n.d.).

Politically, Sonoma County is heavily Democratic. In 2012, 71% of voters voted for Barack Obama and 25% voted for Mitt Romney (County of Sonoma, 2012). The county also has a long history of environmentalism. Alkon and Traugot (2008) comment that Sonoma County’s agricultural and wine industry views itself as aligned with, rather than at odds with, the environmental movement. Natural resources, open rangelands, and parks are widely viewed as important assets worth protecting. Moore similarly commented that Sonoma County residents are
willing to pay more and sacrifice more to protect their parks and natural lands than anywhere else she has worked.

**Progress Prior to Climate Adaptation Efforts – Building the Foundation for Regional Work**

Sonoma County’s recent successes in adaptation build on a long history of climate change policy that created the necessary networks for a collaborative approach. In 2005 the mayors of the nine cities and the board of supervisors for the county agreed to a mutual greenhouse gas reduction target of 25% below 1990 levels by 2015. At that time this was the most aggressive commitment to reductions in California. The county soon realized that achieving this target would take significant coordination. Therefore, in 2009 Sonoma County established the Regional Climate Protection Authority (RCPA) using community development block grant funds (Mersich, 2014).

Having a dedicated countywide agency committed to climate change is a real advantage for Sonoma. Rather than having already busy city or county employees take on the added burden of thinking through climate change, Sonoma County has full time staff who can coordinate mitigation and adaptation strategies and then share this information with the necessary decision makers at each municipality and county agency. In addition to the efficiency, working at the county level allows more cohesive responses. RCPA can envision strategies that align with natural boundaries such as watersheds, rather than artificial political boundaries. It can also more efficiently determine who can shoulder the burden of various mitigation strategies.

**The Rise of Adaptation**

Importantly, RCPA was founded with the mission of achieving greenhouse gas reductions, and has only begun to think about climate adaptation more recently. As such, climate adaptation continues to lag behind their mitigation work. However, now that adaptation is increasingly recognized as a priority, RCPA is proving to be the right organization to analyze the County’s
needs and raise these issues to elected decision makers. Most recently they sponsored a countywide vulnerability assessment that will be used to inform the county’s climate action plan.

RCPA is not the only, or perhaps even the most important participant. Many of the people I spoke with identify 2009 as the year that climate adaptation gained momentum in Sonoma County. That year, a few scientists and researchers already concerned about climate change convened a three-day conference on watershed ecosystems that brought together 150 scientists, conservationists, natural resource managers, and government officials from the Northern Bay Area (Feifel, 2010). This group discussed how climate change would impact the region and the work they were currently doing. Cornwall, an attendee, explained that many people had an “aha” moment at this conference. They realized that 1) climate change will have a profound impact on natural resources agencies, and 2) climate change could be a powerful argument to address the environmental issues these individuals already cared about. At the end of the conference, attendees decided that much more work was needed. To do this, they formed the North Bay Climate Adaptation Initiative (NBCAI), a coalition of natural resource managers, scientists, and public officials dedicated to identifying “positive solutions to the problem of climate adaptation for the ecosystems and watersheds of Sonoma County” (NBCAI, n.d.).

Today NBCAI is a powerful partnership between research groups including the Sonoma Ecology Center, Point Blue Conservation Science, the Pepperwood Preserve, the Community Foundation for Sonoma County, and the Gold Ridge Resource Conservation District. This core group of organizations collaborates with local natural resources agencies including RCPA, Sonoma County Water Agency, the Sonoma Land Trust, and the Sonoma County Agricultural Preservation and Open Space. As stated on their website, NBCAI’s main goal is “to foster an open conversation between technical experts, land managers and policymakers in support of effective local scale climate adaptation strategies that preserve natural resources, biodiversity, and ecosystem
services” and to provide adaptation methods that can be extended beyond Sonoma County to the entire North Bay. NBCAI embodies the very argument that effective climate adaptation must involve individuals that can work with both science and policy iteratively to allow people in both camps to work productively together.

*Science and Policy Working Together: TBC3 + NBCAI + County Officials*

Shortly after creating NBCAI, one of the organization’s founders, Dr. Lisa Micheli, became involved in groundbreaking climate research in what is now called The Terrestrial Biodiversity and Climate Change Collaborative (TBC3). TBC3 has a mission similar to NBCAI’s, which is to bring together scientists to support and enhance land management in the face of climate change (Terrestrial Biodiversity and Climate Change Collaborative, 2015). TBC3 has produced a number of products, but the one that has made the most headlines is their set of high-resolution climate hydrology scenarios (Hannibal, 2014). Micheli, who is also the director of Sonoma County’s Pepperwood Preserve and Dwight Center for Conservation Science where much of the research for TBC3 is conducted, explained that Sonoma County greatly benefitted from this:

“We really got the world’s experts on the bay area’s natural resources from hydrology, climate, plant, wildlife point of view. This effort, which was funded by the Gordon and Betty Moore Foundation, is actually where all the data is coming from that we’re using in Sonoma County. To a certain extent, Sonoma County is the pilot of where we’re taking this massive knowledge base. We have 100 years of historical climate and hydrology models for the entire region as well as maps and time series. We selected 18 climate scenarios and generated these 270 meter projections that have both climate and hydrology.”

Through this relationship, Sonoma County had access to world-class scientific information without a large price tag. Soon after TBC3 was launched they began working closely with the
Sonoma County Water Agency to use their modeling to look at the long term impacts of climate change on Sonoma County’s water supply and potential changes in future demands.

Importantly, access to scientific information is only one piece of the puzzle. In fact, access to this information is no longer what makes Sonoma County unique. TBC3 has put all of their data online at no cost to anyone interested in it. However, without the support of the scientists at TBC3 and NBCAI, it is unclear how well other groups can put the information to use. Micheli specifically commented: “It is my impression that you cannot just make a dataset, put it on the web and expect people will figure out how to use it. I think we’re in this period where people benefit from a high level of hand holding.” Cornwall of the Sonoma Ecology Center and NBCAI echoed this. She describes herself as the “decision support tool,” or what climate adaptation scholars call an information broker. She sees it as her job to help the various decision makers figure out what their questions even are regarding climate change. Then she works with those on the science side to figure out how to deliver the necessary information.

The countywide vulnerability assessment that RCPA sponsored and NBCAI authored after two years of research illustrates what this iterative and collaborative process looks like. For this, the TBC3 team identified eighteen different climate change scenarios based on the IPCC recommendation. As a first step, NBCAI convened a meeting to evaluate the scenarios. During this, spatial analysts, academic researchers, and technically savvy individuals from various resource agencies in Sonoma County chose six scenarios to use for the vulnerability assessment. They specifically rejected any scenarios that assumed an aggressive global mitigation effort because they thought these were unrealistic. However, they did select some that included moderate mitigation and could be used to as ammunition to defend the need for local mitigation policies. The other scenarios were chosen specifically to show a variety of extreme potentials—wetter, hotter, and drier outcomes. This group reasoned that it did not make sense to apply scenarios as one-size-fits-
all inputs into climate projections. Instead, they argued that if an organization is concerned about preparing for drought conditions, they should use a climate scenario that projects a world that is hotter and drier. On the other hand, if an agency is concerned about flood risks, they should look at a scenario that predicts increased rainfall. This will allow planners to respond to worst-case scenarios. Given the high levels of uncertainty about what will actually transpire, they reasoned this was the most responsible choice.

After the scenarios were selected, NBCAI interviewed resource managers, emergency service providers, and other public officials about their work. Cornwall asked: What do you manage? What does a worrisome climate related event look like to you? Can you tell us about a time when a weather related problems occurred in the past? NBCAI and the TBC3 used these “bad events” as a starting point to better understand their data. Using historical records they identified the quantitative patterns during these bad events. They used these patterns to better understand how climate projections translated to real risks. This proved to be an important step since many risks are not well understood. For example, Cornwall’s team quickly learned that no one had a quantitative definition of drought that they could operationalize using their data. Only by going back and looking at times when drought conditions negatively impacted the county could NBCAI and TBC3 start to unpack what quantitative indicators to look for.

Through this process, NBCAI identified a few key indicators they believed would be instructive for resource managers. For example, they realized that soil moisture, rather than heat, provided better information regarding drought conditions. Sonoma County is highly dependent on groundwater for irrigation and water supply. Given this, they are primarily interested in determining what will impact ground water recharge. Additionally, NBCAI and TBC3 identified an indicator they call the climatic water deficit (CWD), which is a “numeric measure of drought stress which quantifies plant’s need for water that exceeds the moisture available in the soil” (Cornwall et
al., 2014). If the CWD increases (as it is projected to do in three of the four scenarios NBCAI looked at for this impact\textsuperscript{13}), then there will be less water available for groundwater recharge and runoff. With more arid conditions, wildfire risk will increase, crop suitability will change, and natural habitats will experience new stresses. All of this suggests that Sonoma County might need to change its plant diversity to protect groundwater.

Ultimately this research was incorporated into the Sonoma County Vulnerability Assessment titled *Climate Ready Sonoma County: Climate Hazards and Vulnerabilities*. This document catalogues the various risks facing the county. Compared to other vulnerability assessments I reviewed in the course of this research, Sonoma County's is much more detailed and quantitative. Sonoma County can also more confidently say that the risks they looked at mirror the issues their resource managers are concerned about. As a result, the public health officer in the county is expanding her heat response team. Additionally the Basin Advisory Panel has already concluded that groundwater is a far more resilient water resource compared to surface water and has increased the priority of actions that recharge aquifers. However, by and large, much more needs to be done. Representatives from NBCAI and RCPA admitted that this is their next challenge. As Misty Mersich at RCPA explains:

\begin{quote}
You'll notice that document doesn't have a lot of what we're going to do and strategies on how to get there. That is the next stage of that document. There have been a lot of reviewers and a really coordinated effort to put that document together. Yet there still has not been as much outreach as we'd like. The next step is to bring this to officials in organization outside of natural resources such as transportation and Public Works to start a dialog and conversation about how it applies to their jobs.
\end{quote}

It took a full two years to get to this point, and RCPA guesses that it will be another couple of years before these results are translated into policy. RCPA and NBCAI understand that this next

\textsuperscript{13} While Sonoma County identified 6 scenarios, they only applied the ones that created the largest risk to specific impacts. For example, for drought risk, they did not look at scenarios that predicted wet conditions.
phase is going to be a harder sell. These less sophisticated users may have more difficulty connecting the dots between the work they are doing and climate vulnerability. Additionally, these other groups may be more resistant to change. Moore, who has helped during the first phases of stakeholder engagement, commented that despite the progressive atmosphere in Sonoma County, agriculture is a hard group to convince to change, saying:

These are people who are skeptical and they are looking at the bottom line and they don’t want to waste their time and money on anything that’s not going to be contributing to their bottom line. If you can talk to them about needing to plan longer than one crop rotation ahead, even if that’s financially hard, then that’s going to save Sonoma County’s main economic sector in the long run.

Moore commented that Sonoma County would need to be strategic about reaching these groups through sources that they already trust. As a start RCPA has developed an outreach plan, which includes a Sonoma County Adaptation mini-conference on the subject. Still, it remains to be seen how successful this model will be and how soon these impacts will actually make their way into the county’s climate action plan.

**Lessons for Cal-Adapt from Sonoma County**

Why look at Sonoma County? What can it teach us about the usability of climate projections and climate science for decision-making? What can it tell us about the utility of Cal-Adapt? Overall, this collaborative process created an opportunity for joint learning, which led to the innovative application of a new data resource. Sonoma County still may not be able to turn their analysis into action, but they also were able to address all five of Schudson’s components. The process increased the number of people that had access to a complicated data set by using NBCAI to facilitate conversations between science and policy that otherwise would have been tremendously difficult. Sonoma County increased rhetorical force by ensuring that people from both the policy world and science world agreed to and trusted the scientific methodology used for the
vulnerability study. Sonoma County increased *resonance* by choosing variables that actually mattered to the natural resource agencies and looking at a politically salient issue in the community: water supply. Sonoma County addressed *institutionalization* by involving RCPA and the many agencies that actually need to amend their policy frameworks to respond to climate change. As a result, Sonoma County has seen the beginning stages of *action* as Public Health and the Basin Advisory Panel have already responded. Hopefully more action will continue.

**Additional Lessons from These Alternative Approaches**

Beyond Schudson’s five vulnerability steps, these other tools suggest some other important key lessons for tool design. In this section I will briefly discuss some of the primary lessons from Sonoma County, OCOF, and CRT:

*Knowing what the community cares about provides real value*

The TBC3 data turned out to be powerful in Sonoma County because it allowed many of the people already excited about climate change to explore the very hydrological issues they were already interested in. Given the agricultural identity of the county and fear of drought conditions, the TBC3 data resonated strongly. Additionally, due to the progressive atmosphere in the county it also made sense to couch this discussion in the language of environmentalism and habitat protection. As RCPA branches out to less environmentally friendly sectors of the county, this choice may need to shift. Similarly, CRT and OCOF gained power by supporting planning processes (local coastal programs) that are required by the state. The tools succeeded because they provided a means for people to perform an analysis that they already wanted to do.

Depending on the place and audience, data producers need to find ways to present the right information using the right political framing. In the conservative Central Valley, an argument about the economic cost-savings behind climate adaptation might be more persuasive than an
environmental argument. In a more urban community like San Francisco or Los Angeles, soil moisture might not be the indicator that gets a wide range of people excited about climate adaptation. Instead, it might be the urban heat island effect. This speaks to the difficulty of creating a tool that will resonate throughout a state as diverse as California. It is hard to predict what impacts and issues are going to be persuasive or relevant for all people.

*Scale may be more about resonance than resolution*

Sonoma County, CRT, OCOF and Cal-Adapt all made a similar assumption that downscaling is a worthwhile exercise. For sea level rise the argument for downscaling is clearest. If one is using storm surge data to determine how much to elevate buildings or where to put flood protection infrastructure, parcel level data is ideal. For other issues like temperature, the value of downscaling is more ambiguous.

The people I spoke with at RCPA and NBCAI all believed that finer resolution data is superior to coarse data. Cornwall commented that many planners are working at the parcel or sub-watershed scale, making Cal-Adapt too coarse to be helpful. While downscaled data might resonate more strongly with certain users, it also creates new problems. Micheli commented that TBC3 scientists do not want people to choose one 18-acre-pixel and think that the projections are reliable. Instead, she believes that TBC3 data's superiority stems from the fact that it is presents data at the watershed level, which corresponds to meaningful natural boundaries. Even more, it can be re-aggregated by users into the boundary of their choice. The value of downscaled data, therefore, is not in its ability to help a user determine where exactly to build a wall or plant a crop. The value is in that it allows data to be more flexible and more easily organized into buckets that match user's mental models.
More Information Necessitates More Handholding

TBC3's dataset is vast and therefore incredibly powerful. Sonoma County was able to look at a huge set of inputs and variables and determine what information they found most useful. On the hand, the size of the TBC3 dataset required the willingness of experts to take the time to work with Sonoma County officials. These experts patiently worked with the county to decide which of the six scenarios should be used for projections. They also diligently dug through the data to find the indicators that would meaningfully demonstrate future risks. Sonoma County accepted that this process would take years, necessitating multiple meetings and time-consuming collaborative efforts. In contrast, Cal-Adapt sacrifices power for a simple and streamlined interface. Cal-Adapt shows a limited set of impacts and scenarios. Non-climate experts can interpret these outputs with limited assistance. Yet, the data only shows a few variables, ones that may not resonate with all users.

Another problem with this model is that it is resource intensive, making it difficult to replicate in other places. CRT for example provided more detailed information regarding data infrastructure assets. Collecting this for the entire state would be tremendously difficult. Similarly OCOF provided detailed information about where their data was less reliable. This type of analysis is much easier to do at a county or regional scale compared to at the state scale.

Information brokers are a key element

In Sonoma County, NBCAI stepped in as the decision support resource working between science and policy. It brought talented people who are comfortable in both policy and science in to translate information between the two groups. They ensured that data was both communicated in such a way that it would be meaningful to decision makers and that decision makers would not
misuse the data. Members who were involved in the process felt that NBCAI’s information broker role was essential to the county’s success. Mersich, explaining Cornwall’s role, stated:

Caitlin had to make decisions on certain things, and then interpret it to us. Sometimes we would say, “No, that makes no sense.” Interpreting the science data and then listening to us, the policy people, and trying to make it something that worked for both put Caitlin in a pretty difficult position sometimes.

Even though it was difficult, Mersich expressed gratitude towards Caitlin and NBCAI. She recognized that her team would not have been able to understand the science without NBCAI.

Similarly in OCOF and CRT, the tool developers convened meetings that brought together technical experts with decision makers. In Ventura, Newkirk worked closely with the community to facilitate this interaction. In the Bay Area, OCOF hired a specialized consulting firm to facilitate their stakeholder engagement.

In contrast, the state cannot work with each community to produce information through a collaborative process like what was seen in Sonoma County. It would be even difficult to do the less intensive versions used by OCOF or CRT. They also cannot assign or pay for an information broker to each community to help them interpret and apply the data in Cal-Adapt. While the information on Cal-Adapt is less complex and therefore less reliant on translation, information brokers do more than translate. They facilitate joint learning regarding how climate will impact a community.

_Climate Science is Valuable_

As mentioned in Chapter 2, there is some disagreement about how much detailed quantitative data is necessary for progress. Many climate change risks could be identified through qualitative analysis using the broad trends that are shown in Cal-Adapt. One only needs to look at current drought conditions in California to know that planning for hotter and drier scenarios is
necessary. Planners can ask residents about prior floods, fires, or dry times to better understand local risks. Despite this, those I spoke with in Sonoma County saw real value in more complex quantitative analysis. While the fire department may already know that they need to increase resources to combat a growing fire risk, without data they do not have the ammunition to make this argument to people who control their funding. Data allows these agencies to answer questions from people who do not have a full grasp of the problem.

For some communities large scientific reports may not be convincing or necessary. In Chula Vista a broad qualitative climate vulnerability study proved to be effective and persuasive for their stakeholders. In these cases, Cal-Adapt might be enough to get started.

Even communities that are making progress still have a long way to go.

Sonoma County has access to world-class climate research. The vast majority of residents believe in climate change and there is a strong environmental movement support climate change access. RCPA and NBCAI have been able to find grant money and foundation support for their studies and the upcoming climate action plan. Despite all of these strengths, they still have more work to do to get from a document that merely discusses the vulnerabilities faced by the county to one that outlines a plan to respond to those vulnerabilities. Once that is done, the county will face even more hurdles to actually get those ideas implemented.

In chapter 2, I mentioned that climate adaptation “success” is very hard to measure and evaluate. Is Sonoma County successful despite all of the work they still have to do? I believe that it is. They are building a strong foundation for future climate work through their collaborative approach. While slow, they are doing the hard work that will allow continued progress.

What is the lesson for Cal-Adapt? Perhaps it is not a problem that Cal-Adapt cannot easily be used for specific decisions like land use decisions, or what types of crops farmers should grow
in future years. Perhaps it is okay if Cal-Adapt simply allows people to do a first-level analysis of the threats in their communities. Afterward, these communities can build the coalitions necessary to do more rigorous analysis. The question that remains is how can Cal-Adapt communicate that purpose to local municipal and county officials in such a way that they know where to go with the tool. Even more, how can the state get the necessary agents to meaningfully engage in climate adaptation policy discussions if the political will does not already exist?
Chapter 5: Conclusion

On March 12, 2009, the San Francisco Chronicle published a story reporting that oceans were expected to rise 5 feet by the end of the century, impacting nearly “half a million people and $100 billion in property.” This was based on a recently published study from the Pacific Institute. Along with this headline they posted the map shown in figure 5.1, which points out that much of the Bay Area, including its airports, was at risk of being underwater.

![Map of Bay Area at risk of flooding](image)

**Figure 5.1: Areas at risk of flooding in the Bay Area with sea level rise of 4.6 feet**

*Source: SF Chronicle, March 12, 2009*
Sara Moore, a consultant specializing in climate adaptation and stakeholder engagement, remembers when this story came out. She stated: “I’m grateful to the Chronicle for putting those maps on the front page because it inspired so much good research; you couldn’t ignore it.” Moore proposed that this story is one of the reasons why the Bay Area is currently making progress on its plans to address sea level rise. For her, the maps have value. However, the value is not in their usability. She stated: the maps got people to “panic about sea level rise at a community level. It forces people to realize that climate change is not only going to happen, but it is going to happen to me.” Moore recognized that this is an important first step to creating the political will necessary for climate adaptation.

However, scaring people provides only limited value. Moore went on to explain: “If I am getting together my neighbors to talk about climate change, I don’t really want to scare them. In fact, I need to stop myself from scaring them.” People who are overwhelmed by fear are not going to come up with productive solutions. At some point the conversation about the risks of inaction must transition to one about the benefits of action. Can maps do this? Cornwall, commenting on Cal-Adapt, lodged a similar complaint, stating “Cal-Adapt is enough to make people lose sleep at night, but not enough to know what to do about it. I think that the scale of Cal-Adapt produces worry, but paralyzed worry.”

If accepted as valid, this criticism could be interpreted in one of two ways. The pessimist will argue that Cal-Adapt is failing to achieve what California needs – actual decision support that encourages people on the ground to use climate data when making important choices that can protect against future risk. The data might allow local officials to identify broad trends and concerns for their community. However, the scale does not match the scale at which decisions are being made and the information is out of sync with what potential users feel they need to make informed choices.
The optimist, on the other hand, might point out that there are places in California that have not yet come to terms with their climate related risks. For places outside of California’s progressive coastal communities, it is not a given that residents or local officials will consider climate change scary enough to invest limited resources in analysis or interventions. For these communities, Cal-Adapt is a potentially powerful community engagement tool. Cal-Adapt might create more questions than answers, but if no one is asking the questions then Cal-Adapt still provides a real value.

During the course of my research, I waivered between optimism and pessimism. I believe that Cal-Adapt is a worthwhile resource for public outreach and qualitative vulnerability assessments, but feel that it must communicate this purpose more intentionally. Additionally, Cal-Adapt can and does fill in gaps for communities that are already integrating climate data in their work, but cannot assess every impact. However, Cal-Adapt is not a decision support tool, limiting its utility. To meet this need, Cal-Adapt must be transformed based on a collaborative process focused on meeting the demands of specific decisions. To do this, state government officials must accept that they need to take a more active role in encouraging or even requiring climate adaptation. If they do this, Cal-Adapt (or other California adaptation tools) can be an integral support for that top-down push.

In its imperfections Cal-Adapt provides a tremendous learning opportunity for researchers analyzing best practices in climate adaptation. It is the first statewide tool that shows so many different climate related risks at a relatively small scale. It would be ridiculous to think that the first time at bat would be a home run. This allows researchers to better understand the hurdles and barriers that real people face as they try to think through climate related risks. In Chapter 2, I mentioned that more research is needed on delivering usable climate change information
(Bierbaum et al., 2012). Cal-Adapt and other similar tools are ideal forums to better understand just that.

**Summary of Main Findings**

Cash et al., (2006) argue that for climate data to be usable it must be legitimate and salient. My research supported this, but additionally found that it was important that users had the technical capacity to use data, a clear understanding of what kinds of decisions could be made using the data, and felt the political pressure to actually take the time or allocate resources to climate analysis. Even though Schudson’s (2002) work did not discuss climate change or online tools specifically, I found that applying his framework as a usability test provided a detailed and telling lens for identifying strengths and weaknesses of climate tools. Looking at accessibility, I asked if users knew the resource existed and had the necessary skills to use it. Regarding rhetorical force I asked if users saw the data as credible and important. Addressing resonance, I asked if users understood how the tool’s data applied to their particular decision-making needs. Agreeing with Schudson’s theory that for something to have lasting power it must be part of an institutionalized process, I asked if the tool supported regulations or requirements for incentive programs. Finally, I argued that defining the specific action that the data should inform was key to building a tool wisely.

In my analysis of Cal-Adapt, I identified how weaknesses in each of these components hurt the ultimate usability of the data. In particular, the failure to define a narrow enough “action” component led the tool developers to build a tool that simply provided information rather than supporting specific decisions. In many ways, the tool usability was thwarted from the very beginning. As soon as developers recognized that they did not have a clear enough direction to build a decision support tool and instead chose to build an information resource, they
compromised the essence of what Cal-Adapt was supposed to be. The audience remained too broadly defined for targeted stakeholder engagement or marketing. Likewise, the ultimate goal remained too nebulous to identify what data users would actually need to meet that goal. This suggests that a key feature in creating usable climate science planning tool is building a policy framework that creates clear mandates for using climate data. This is a problem that extends beyond tools and is felt by all people struggling to define what climate adaptation success looks like.

This hypothesis is supported not only by Cal-Adapt’s usability issues, but also by the relative progress being made in climate mitigation. Interviewees in cities and counties across California commented that because of state regulations requiring climate mitigation, climate adaptation is currently on the back burner. Even in Sonoma County where adaptation has been popular, RCPA is prioritizing climate mitigation rather than adaptation because they need to meet state and local targets. Similarly, Ballard commented that OCOF is getting less use than he would like, because most cities in the Bay Area are preoccupied by mitigation work. This tension speaks to the importance of state regulations. California’s climate mitigation policy, the Global Warming Solutions Act of 2006 (AB-32), calls for local governments to reduce GHG emissions by 15% by 2020 in support of the statewide limit. The California Air Resources Board developed support tools for municipalities to prepare local inventories and determine possible interventions to meet this goal. Planners in many communities I spoke with were actively using these tools because there was increased pressure to do so. If there were similar concrete objectives and pressures for adaptation, there would be more demand for Cal-Adapt and more action on the ground. Until then, adaptation efforts are likely to be uneven, occurring only in places where adaptation champions already exist.
In Chapter 4, I support the argument made by many scholars that to create usable climate information, it is helpful to use a collaborative process that brings decision makers and scientists together (Cash et al., 2006; Dilling and Lemos, 2011; Jasanoff, 2004; Tribbia and Moser, 2008). I find that stakeholder engagement provides direction in the absence of top-down mandates. For example, in Sonoma County, NBCAI and the TBC3 relied on the natural resource officials to guide the adaptation process. They identified their major climate concerns and contributed memories of past weather events, allowing scientists to determine the best variables to analyze. They also helped determine which scenarios the county should use for projections, which helped scientists determine which assumptions these users were comfortable making. This also ensured that the community understood and trusted the data. Overall, my case studies and interviews show how a bottom-up process increases the amount of information that tool developers and scientist have, allowing them to make smarter decisions and create more relevant, more usable products for their target audience. It also allows for the community to gradually learn how to use climate data and think through potential interventions.

This engagement may also be key to creating the local capacity necessary to move forward. As Cornwall points out “you cannot put planning documents too far ahead of what people are willing to do” and expect results. Ultimately, communities that that take the time to build coalition and local knowledge may be more effective at adaptation in the long run. This process allows them to gain a deeper understanding of the risks they face and create the inter-agency connectivity to respond. Perhaps what is equally or even more important than the final tool is the joint learning about climate change that happens while the tool is being developed.

Still, building tools based on widespread collaboration is a time consuming process. Sonoma County and NBCAI specifically hoped that their method would be a pilot for similar communities. This is a great goal, but many of the people I spoke with admitted that the process is
likely going to be difficult to replicate elsewhere because of its reliance on smart, well-educated researchers and scientists located in Sonoma County. This supports Dilling and Lemos’s (2011) observation that co-produced data is useful, but often expensive and difficult to produce.

**Additional Findings Worth Further Investigation**

In this thesis, I was only able to examine a limited number of tools and more research is needed to verify my findings. Researchers may want to examine a larger range of climate adaptation tools, including additional map visualization platforms as well as other common resources including guidebooks and decision matrices. An experimental design may also be particularly illustrative. For example, researchers may want to identify specific decisions that should take climate related risks into account. They then could work directly with communities to see what information they need to actually make these decisions. Developers could experiment with various tool designs and observe how well these work on the ground. Luckily, tool developers like TNC and the many groups behind OCOF are already doing much of this work.

Additionally, during the course of my research I uncovered a number of questions that warrant more analysis. First, what role should various jurisdictions (city, county, regional, state) play in creating climate data and responding to climate change? Second, is downscaling actually helpful and why? Finally, who should be the main audience for climate change tools?

*Who should create climate information?*

In chapter 2, I introduced an ongoing debate regarding the scale at which climate adaptation efforts should be taking place. Traditionally, federal and state governments have facilitated, supported, and assisted with adaptation efforts while actual decisions happen at the local level. State and federal officials point out that local officials are more in touch with local needs and are more knowledgeable about how changes will impact their community (Bierbaum et
al., 2012; Rickards, et al., 2014). However, this creates inefficiencies, since it means that many people have to learn how to think about climate related risks (Rickards et al., 2014). It also creates friction when local governments lack the clear responsibility to respond to changes (Baker et al., 2012).

When it comes to the more specific question regarding who should produce climate information, does it make sense for this to be at the state or federal level? My research identified three successful examples of data producers working at the county or regional scale: CRT focused on Ventura County, OCOF focused on the Bay Area, and TBC3 worked within Sonoma County. This scale provided a number of benefits. For example, in Sonoma County, municipalities were able to pool resources and do more in-depth analysis than they could on their own. This also allowed for analysis that crossed smaller jurisdictional boundaries, such as on watershed risks. This supports the traditional wisdom that data production should take place at a larger jurisdiction than the municipal scale.

However, it also suggests that the state might be too large a jurisdiction for data production. The diversity of California communities’ means that the information needs in one community might not be transferrable to others. Sea level rise is a major risk for the Bay Area, but is not salient in the Central Valley. The size of the state also makes a highly collaborative process unwieldy and hard to manage; state officials cannot possibly work with every city and resource manager to determine the data that they need. Perhaps, it would be more efficient for the state to fund climate portals and tool development at the regional level? While I think this would be an interesting option, I also see potential downsides. Communities with no interest or political will to address climate change may choose not to create tools even if offered state funding. Additionally, certain areas of the state do not have the density of researchers, scientists, or non-profits with the capacity to develop climate information. Finally, doing this work regionally is inefficient. Multiple
regions may spend large quantities of money and time producing the same information. Future work should assess the best scale for producing climate tools. My guess is that it will make most sense to provide broad information at the state or federal level, but that more detailed information should be produced regionally.

If this is the answer researchers will need to determine how tools can best interact with one another. In the introduction I mentioned that the proliferation of climate change resources can create confusion. It puts planners who are not climate experts in the difficult position of evaluating the many different tools and selecting which ones portrays “the best available” data for their region. However, if the distinction between the various tools is made clear, having many complementary resources can actually be an asset. As Newkirk explains:

Everyone and their brother have one of these things now. Cal-Adapt, NOAA’s tool, Our Coast Our Future, everybody’s working on them. I think that that’s great.... The underlying science is different but the tools themselves are all basically great. They all are designed to convey and highlight different pieces of information.

While a community may have vast resources of its own, chances are that gaps still exist and there will be questions that cannot be answered by the local specialists on the ground. Sonoma County relied on other tools in addition to the data they collected through TBC3. For sea level rise they used information produced by OCOF. For temperature related information such as the number of high-heat days and warm nights, they relied on Cal-Adapt. This suggests that having information at many scales can work. Are there steps tool developers can take to make their tools work with others resources more effectively? How should developers communicate the relationship and difference between the tools?
What resolution is needed?

The literature on climate data suggests that there are a number of substantive issues with downsampled climate data. Scholars point out that projections are marred with high levels of uncertainty and decision makers must be careful about relying too heavily on uncertain data (Barsugli et al., 2012; Enserink, Kwakkel, and Veenman, 2013; Enserink et al., 2013; Hayhoe, Stoner, and Wake, 2013). During my research I found that decision makers are concerned about using data responsibly and questioned Cal-Adapt because it did not explicitly provide guidance on how much decision makers could rely on the projections. In contrast, the designers of OCOF decided that the best tactic was to be upfront about the uncertainty and included many disclaimers throughout the website. This allows users to make informed judgment calls themselves. CRT and Sonoma County addressed this concern by having users work directly with the scientists. This allowed them to ask questions when they arose and to learn about the responsible use of climate science during the process. Future work should focus on whether addressing uncertainty in tool design actually leads to more responsible use of climate data.

A different but related finding concerning resolution came from my case study on Sonoma County. Micheli noted that higher resolution climate projections do not necessarily allow for better decision-making. Instead, they allow for information to be more easily aggregated into boundaries that make sense to decision makers. In other words, it is easier to reschedule projections into a county boundary or a watershed boundary if information is downsampled to eighteen-acre pixels compared to one downsampled to 12-kilometer pixels (or 2956 acres). The smaller scale will also show a greater range of potential changes within the boundary than the less downsampled data. This has advantages, because as Hallegatte (2009) argues, the ultimate goal of adaptation is to plan for the range of possibilities rather than a specific threshold. The risk, however, is that uninformed users will think they can make parcel level decisions using highly uncertain data. Future research
should address this tension between the benefits of downscaling and the potential risks. It should also address how these risks can best be communicated.

Who is the audience?

In chapter 3, I argued that one difficulty faced by the producers of Cal-Adapt was that they were trying to build a tool that served too many audiences. With such a broad set of potential users, it is very difficult to market the tool to the right groups, conduct stakeholder engagement efforts to find out what users need, or do usability assessments after the tool is built to ensure it is fulfilling users’ expectations. In my own research, I defined the potential users as primarily city and county staff working on climate adaptation. I assumed that they were the ones who needed climate information to inform key decisions.

However, as I looked at CRT and Sonoma County, I was forced to question this original assumption. In Ventura, the Nature Conservancy learned that their tool not only had to resonate with staff members trying to make key decisions and advocacy groups who were already knowledgeable about the issues. The information also had to be persuasive to the actual elected officials who could choose to support or deny requests from departmental staff. Similarly, in Sonoma County, Cornwall commented that having numerical data helps convince those who are less familiar with the on-the-ground need. She commented:

Even if a professional staff person is really convinced in their gut, really knows what needs to happen and they’re much more informed than their decision makers are, I think they’re going to need the data. They need evidence. I particularly think this is true when the ultimate decision makers don’t want to rock the boat without compelling evidence.

This suggests that the literature may need to re-conceptualize what climate tools are actually used for. Perhaps the data is not primarily being used to drive decisions. Instead, it simply gives decision makers the ammunition they need to push through the policies they already know they
need (or more likely can determine that they need with relatively coarse data). This challenges the assumption that better and more exact data is helpful for smart decisions. Instead, it suggests that well-educated and experienced staff members can already make guesses about what their future needs are based on available data, but must do more robust analysis to convince the people who are actually in charge. If this is the case, how does that change what “usable climate science” looks like?

Final Thoughts

The team behind Cal-Adapt has accomplished something worthwhile, but must recognize where it falls short of its goals. They took complex climate science and built a tool that can be used by non-experts to explore climate change impacts. The current version of Cal-Adapt has potential applicability for public education. Even more, some communities have already used maps and data from Cal-Adapt for their vulnerability assessments and climate action plans. These are meaningful uses that should be promoted more. Looking forward, the tool has tremendous potential. It can become more than simply a data resource. It could be an actual decision support tool that will drive adaptation policy. To get there, the state must be sensitive to local needs and better define state objectives.

More broadly, the findings and lessons of this research suggest that tools obtain their power in one of two ways. First, they can gain power through a community process. Through collaboration, tool developers can figure out what users need and how to deliver usable climate science. Additionally, users learn along the way and leave the process with a greater understanding of how to move forward with climate adaptation. The alternative is that tools can get their power from above. If the state issues a mandate that local governments must address climate adaptation and offer a tool to facilitate this work, users are more likely to rely on the tool to meet their
obligations. A savvy tool developer will look for opportunities to leverage both the “bottom up” and “top down” sources of power. They will find existing regulations and institutional mandates that the tool can specifically address. They will also carefully find ways to incorporate users on the ground during the tool development phase to learn practical information regarding what these users need and to ensure that these users know the tools exists, understand how to use it, and see the tool as credible.

Even with collaboration, top-down direction provides value. As Moore explains: “Just creating a fancy tool that everybody thinks is great and fun to use misses the point”. Knowing that sea level will rise is not useful if there are no mechanisms to have that information influence decisions such as permitting rules or decisions to build coastal infrastructure. If tools can be designed to support specific policy requirements, local officials would not have to connect the dots themselves.

California state officials might not feel that they have the expertise to dictate which decisions should take climate change into account and who should be doing this assessment. They might argue that local governments simply are more in touch with their own needs and that mandating action would be overstepping their bounds. The reality is that most people I spoke with were open to more top-down direction. It certainly is not an easy task, but if the state wants real progress it might be necessary.
Works Cited


## Table A.1: Phase 1 Interview List

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<th>Category for Purpose of analysis</th>
<th>Working at What Scale</th>
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<td>Central Coast Wetlands Group at Moss Landing Marine Laboratories</td>
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<td>Alex Hall</td>
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<td>Shankar Prasad</td>
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### Table A.2: Phase II Interview List
#### Who Informed Which Tool History?

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<td>Misty Mersich</td>
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<td>Caitlin Cornwall</td>
<td>North Bay Climate Adaptation Initiative and Sonoma Ecology Center</td>
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<td>Lisa Micheli</td>
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<td>Sara Moore</td>
<td>Freelance Climate Adaptation Consultant</td>
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<td>The Gulf of the Farallones the National Marine Sanctuary, USGS, the San Francisco Bay National Estuarine Research Reserve, Pont Blue Conservation Science, NOAA, Coravai, the National Parks Service, and the Bay Area Ecosystem Change Consortium</td>
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<td>Climate Information Provided</td>
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<td>Process for designing tool</td>
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