Climate Change IN BERKELEY

Effects and Adaptations

PASCAL POLONIK

Berkeley
UNIVERSITY OF CALIFORNIA
OFFICE OF SUSTAINABILITY

The University of California, Berkeley, a leader in public higher education, is also a leader and innovator in climate action planning and implementation. This year, ahead of schedule, Berkeley announced the campus had met its first greenhouse gas emissions reduction target, reducing the carbon footprint to levels lower than it was 25 years ago. This milestone resulted from student engagement, innovative planning, broad partnerships, financial investment, and through mitigation strategies - the implementation of hundreds of energy efficiency initiatives and transportation fuel reduction efforts.

The campus is now focused on reaching carbon neutrality from building energy and fleet vehicle use by the year 2025 – as called for by an initiative of UC President Napolitano. Achieving this target in the next 11 years is very ambitious – one that will require deep infrastructure investments, new financial resources, and inclusive and reliable partnerships between the campus, the community, and other stakeholders. While implementing efficiency measures will remain important, a significant focus will need to be on the acquisition of renewable energy – both electricity and fuels.

Additionally this next phase of climate planning and action will need to more closely address how we adapt to the impacts of climate change that are already inevitable or might occur. For example, it will be important for the campus to model how rising temperatures could increase our energy demands for cooling or how our investments in public transit could contribute to operational resiliency during a climate related disaster. Further, by better integrating adaption as a reality into our climate planning, new regional partnerships and strategies are likely to emerge – ones that will make us more responsive and resilient.

Kira Stoll, Sustainability Manager
University of California Berkeley

INTRODUCTION

Climate change is a global environmental, health, and economic problem. Temperatures are expected to increase, sea levels are expected to rise, and precipitation patterns are expected to change. There is a strong scientific consensus that climate change effects are real and are caused by anthropogenic greenhouse gases – mainly carbon dioxide (CO_2) and methane (CH_4) among many others.[1]

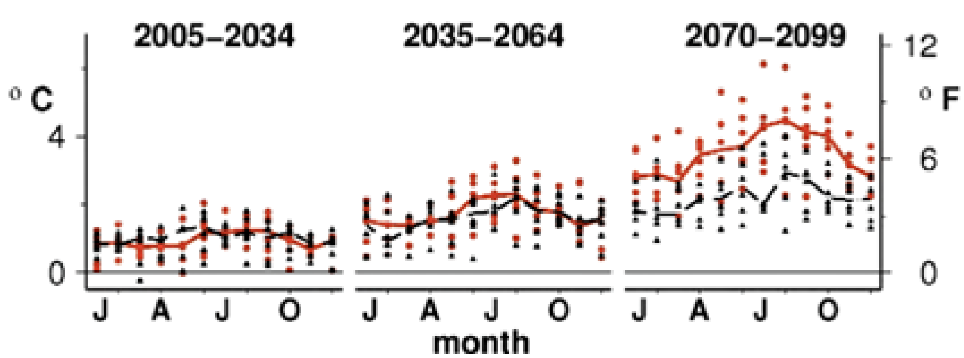
The Earth's climate is a result of complex interactions between land, oceans, and the atmosphere, which makes it difficult to fully understand. However, mathematical models have been created in an attempt to predict future climates under different greenhouse gas emission scenarios. The Intergovernmental Panel on Climate Change (IPCC), a United Nations scientific body made up of thousands of scientists, looks at many models based on four different emissions scenarios.[2] There can be uncertainties in science but repetition by independent scientists has yielded consistent results regarding climate change.[3]

Depending on future concentrations of greenhouse gases, global temperatures are expected to rise by different amounts by the end of the century. Compared to the 1986-2005 average, the estimates range from 0.3°C to 4.8°C. Under all the future considered concentrations, however, it is likely that the temperature increase will exceed 1.5°C compared to the 1850-1900 average. It is also at least "more likely than not" that these temperature increases will exceed 2°C under all but the lowest emission scenario.[4]

An increase of 2°C compared to a preindustrial baseline was set as the desired limit in the UN's Copenhagen Accord in 2009 to prevent dangerous interference with the climate. Global warming since before industrial times is already about 0.8°C, [5] so if this goal is to be achieved, emissions will need to be significantly reduced.

Regardless of global average increases, the impacts of climate change are expected to vary depending on geographic location. In Berkeley, average temperatures are predicted to rise about 1.5°C (2.7°F) by 2050 under both high and low emissions scenarios. By 2100, average temperatures are predicted to have risen by anywhere from 2°C (3.6°F) to 6°C (10.8°F) depending on future greenhouse gas emissions[5]. That means that regardless of future emissions, local temperatures will almost certainly rise and will require people and environments to adapt.

Although there are many negative effects predicted, there are also many actions that can be taken in the near future in order to lessen these effects. Due to the large scope of change, it is impossible to include all of the possible effects and adaptations. This report simply attempts to provide a holistic overview of these topics in a manner that is accessible to a general audience. Additional resources and information about the following topics can be found in the notes and citations.



Monthly BDSD Simulated Temperature Changes for the East Bay Grid Cell for Six GCMs. Changes (from 1961-1990) are shown for three time periods. Changes are shown in each panel for January to December. Black and red symbols show changes for B1 and A2 emission scenarios, respectively. [5]

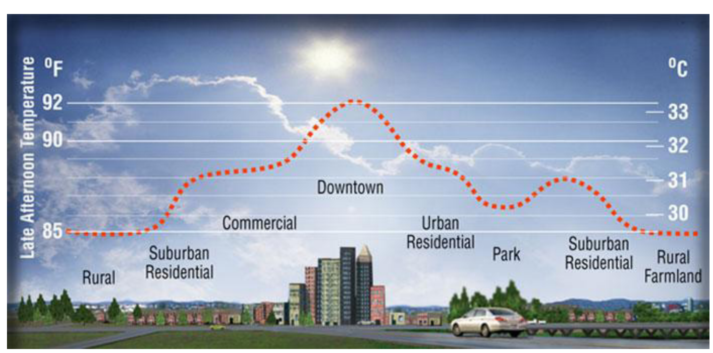
HEATWAVES

Heat waves are periods of three or more days of unusually high heat. Although it may seem like Berkeley is at low risk of dangerous heat because of its mild climate, the current science suggests otherwise.

The 2006 California heat wave caused over 16,000 additional emergency department visits and over 1,100 additional hospitalizations throughout the state.[6] Although this heat wave was not necessarily a direct result of climate change, it does demonstrate California's high vulnerability to extreme heat. In addition, **of over 39,000 census areas from around the country that were evaluated for heat vulnerability, thirteen areas were particularly vulnerable – eight of these were in San Francisco and Alameda counties.**[7] In urban areas the heat is often exacerbated by a phenomenon know as the urban heat island effect. As can be seen in the image, dark pavement and roofs can significantly increase local temperatures by absorbing more visible light from the sun.[P1]

Senior citizens, young children, and low-income individuals are the most vulnerable to the increased heat. Berkeley's temperature rise may be somewhat mitigated by its proximity to the ocean so temperatures will not increase to anywhere near desert temperatures, and yet Alameda County is at very high health risk from heat. How is this possible? The Bay Area has historically had very mild temperatures, which means that people are not prepared for heat as a health threat – often this means they do not have air conditioners. The increase from safe to potentially dangerous heat is what puts Berkeley and the surrounding area at a particularly high risk. Although heat itself does not usually cause serious health problems, the extra heat can exacerbate existing health conditions such as cardiovascular and respiratory diseases.[8]

How bad will the heat waves be? There are still serious concerns with modeling climate on small spatial scales, but one such model predicted that Berkeley's extreme heat days will rise from a long-term average of about 4 per year, to about 25 under a low emissions scenario and about 70 under a high emissions scenario.[9]



A graphical representation of temperature variations in and around a city due to the heat island effect from http://heatisland.lbl.gov.

The good news is that there are multiple local ways to adapt to the health threat from increasing temperatures. For example, the heat island effect can be greatly reduced by expanding the size of the urban forest. This means planting new trees to create shade for homes and roads that retain large amounts of heat. In fact, the City of Berkeley is one of two California cities that have a plan to plant trees to lessen the heat island effect. Due to this plan, there are 4,470 more city trees now than there were in 2000.[10] The other California city, Los Angeles, has pledged to plant one million trees for a number of reasons including heat island mitigation. As a comparison, the city of Berkeley has a total of 46,000 trees in its parks and along its streets. In total it was estimated that trees in Berkeley provide about $1.37 of benefit for every $1.00 of cost.[Note1]

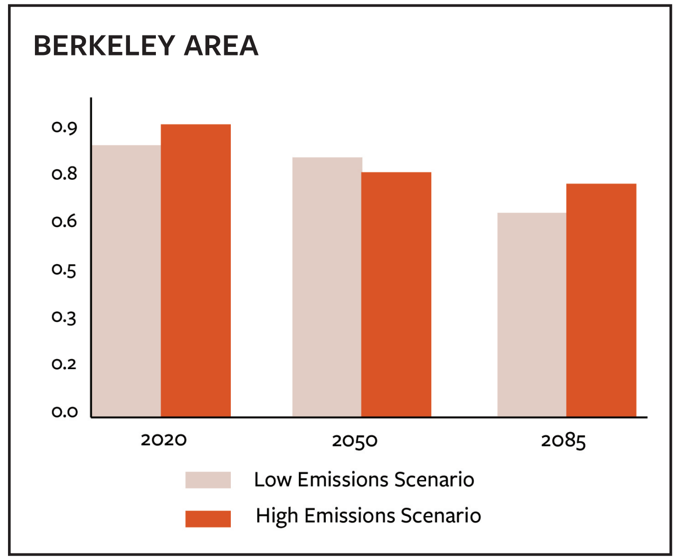
Another adaptation strategy is to increase access to air conditioning for vulnerable populations. Often poorer populations have less access to air-conditioning, which makes this an adaptation with both health and social justice ramifications. The only major downside to this strategy is that it requires energy, which most likely means more CO_2 emissions that might add to the warming problem. To address both of these problems it may be useful to have designated cooling centers, because this would prevent high individual costs and would be a more efficient use of energy. Some of these centers have been opened in the greater Bay Area but not near Berkeley.[11]

CLIMATE VS. WEATHER

The distinction between climate and weather is an important one when talking about both global and local climate change. It is no coincidence that it is referred to as "climate" change instead of "weather" change. Climate is defined as weather over a long period of time. That is to say that weather defines climate but only when viewed over an extended time. When people say that Berkeley has a moderate climate, they mean that the average temperature is about 65°F and the monthly averages (from January to September) only vary by 17°F. This, however, does not mean that if the high on one summer day in 2000 is 107°F (which was the record high) that Berkeley's climate is suddenly no longer moderate.[39] A few extremely hot or extremely cold days quickly average out when looking at a longer period of time like a year or a decade.

For this reason it is very difficult to reference individual weather events as evidence for or against climate change. This includes heat waves, periods of cold, hurricanes, and many other events. However, the probability of such weather events can increase or decrease as worldwide temperature averages increase. So it may be possible to say that a certain size of hurricane or a certain number of heat waves in only a couple years would be highly unlikely without the influences of climate change. Each individual event however, would still have some (possibly small) probability of occurring regardless of human influences.

FIRE

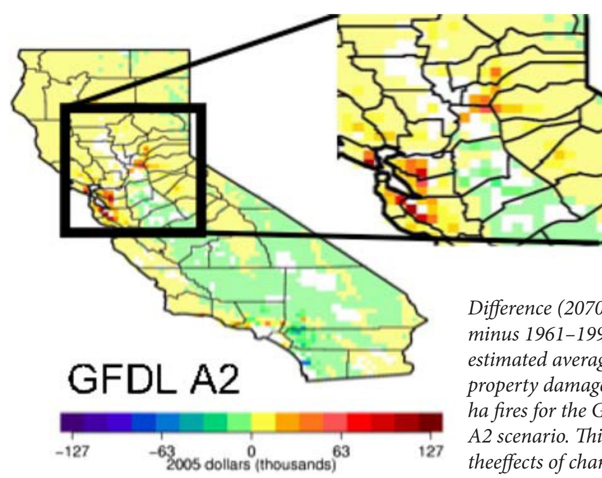


Projected increase in area burned under a high emissions scenario from http://cal-adapt.org/fire.

As temperatures increase, the fire risk in much of California is expected to increase due to hotter, drier, and sometimes windier conditions. **In Berkeley (based only on changes in climate), the area burned may almost double.** Although this increase is not as high as in other regions of California (especially the northern mountainous regions), the change could cause considerable damage. As was demonstrated in the 1991 Oakland hills fire, the damage can be quite extensive. In that fire, 25 people were killed, about 150 people were injured and there were about 1.5 billion dollars worth of damages.[12] Much of the Berkeley and Oakland hills are considered part of the "very high fire hazard zone" as designated by CAL FIRE.[13]

One method of local adaptation to fire risk is already underway, although not necessarily only because of the risk of climate change. Strawberry Canyon and Claremont Canyon, located on UC Berkeley property east and southeast of the main campus respectively, have many eucalyptus trees that are known to be highly volatile fuel sources. Their oil content ranges from an impressive 10-20 percent of their dry weight, which is higher than any other plant tested during a 1973 study.[14, 15] The University identified 48,000 eucalyptus trees in FEMA Pre-Disaster Mitigation Grants that are to be removed to allow native, more fire resistant species to take their place.[16] After nine years of review the final stages of the environmental risk assessment for this project are currently underway. Despite this long process, 19,000 trees have been removed to date. In fact, **there was a small fire in Claremont Canyon in January 2014 that burned in the litter of native plants. Had the eucalyptus trees not been removed from that area, the fire could have potentially spread much more rapidly and caused significant damage.** Of course, although there are fire prevention benefits to this plan, there are many other aspects that need to be considered. This is why the review process has lasted nearly a decade.

On a state level, CAL FIRE has laid out some climate change mitigation and adaptation strategies. These include both fuel reduction and land use improvement for public safety – both of which apply to the university's eucalyptus project. Some of their other adaptation strategies include incorporating existing information into policy and planning, implementing high priority research, and monitoring forest health and policy effectiveness.[17]



Difference (2070–2099 minus 1961–1990) in estimated average annual property damages due to 200 ha fires for the GFDL A2 scenario. This represents theeffects of changes in the frequency of 200 ha fires [40]

SEA LEVEL RISE

"Why should I care about sea level rise in Berkeley? – I live on a hill!"

Globally, small increases of sea level could result in the displacement of hundreds of thousands of people since large portions of the world's population live on coastlines. Citizens of small island nations like the Maldives will likely become refugees as their country disappears underwater. In the United States – especially in Florida - coastlines will also be seriously affected, forcing people to move inland as the coastline recedes. In comparison, the effects in California are fairly small, but that does not mean that they can be ignored – especially not in the Bay Area where much infrastructure is located at very low elevations.[P2]

Ninety three percent of the San Francisco and Oakland International Airports (SFO, OAK) is expected to be at risk from storm surge with the expected sea level rise (a storm surge is the increase in sea level that occurs during storms, largely because of the increased wind speeds.).[18] The Bay Area has 7.15 million residents[19] and San Francisco had an estimated 16.5 million visitors in 2012.[20] Of course not all of these people pass through Berkeley, but the logistics involved in moving over 23 million people are extremely complex. The effects of sea level rise could have serious impacts on the infrastructure that allows for this mobility.

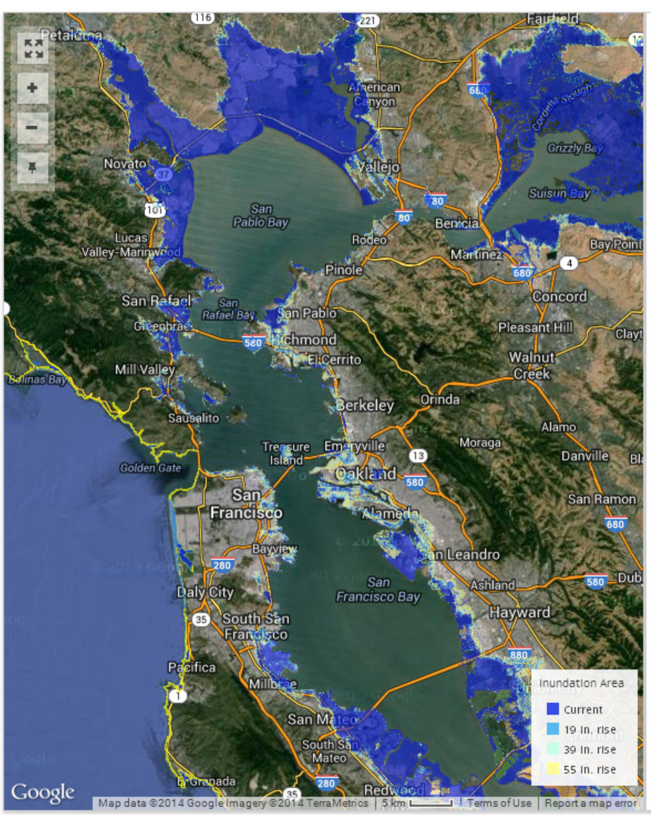
A project such as building a new airport is a long-term and costly investment, so there are several more favorable adaptation options for the near future that should be considered before this type of massive undertaking. SFO has a seawall that should provide protection until the middle of the century, but it will probably need to be raised after that.

BART could also be affected by rising sea levels. As was seen with the major flooding of the New York subway during hurricane Katrina, subway systems are potentially very vulnerable.

The current adaptation methods being considered involve building sea walls or barriers to keep the ocean off the land. However, other ideas include floating developments that would naturally adjust to changing sea levels and floodable developments that can flood without being destroyed. Wetlands could also be established around the bay – this could help absorb some of the storm surge so that the mainland is not seriously affected. Lastly, a more radical solution would be to allow the sea level rise to take place and prohibit new developments from being built in vulnerable areas.[16]

UC Berkeley is currently planning to build a Richmond Campus at low elevation. Richmond is a city about seven miles north of Berkeley that is also located directly on the Bay. The plans to build a campus there are only in the early planning stages, but a Berkeley faculty member quickly pointed out in a meeting that the rising water will have to be a major consideration. Although the additional required infrastructure could be expensive, this type of planning is necessary to avoid future costs and potential safety threats.

SEA LEVEL RISE: THREATENED AREAS MAP

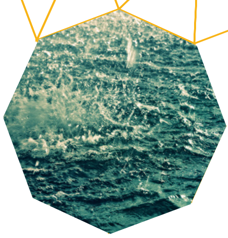


Areas that may be in threat of inundation during an extreme flood event (100 year flood) for different levels of sea level rise from http://cal-adapt.org/sealevel.

THE MECHANISM OF SEA LEVEL RISE

Almost everyone has heard that sea level is expected to rise as the climate warms, but not everyone may be aware why this actually happens. Part of the reason is that ice that is currently on land will melt and will add water to the ocean. It is important to note that the melting of sea ice (such as Arctic ice) does not increase sea level because that ice is already contributing to the current sea level through displacement. The ice sheets in Greenland however are melting quickly and are adding water to the ocean that has not been there for thousands of years.

But this is only part of the story – the biggest contributor to sea level rise is actually the temperature itself. How can temperature make water rise? Like all other materials, water expands when its temperature is increased. This physical phenomenon known as thermal expansion is estimated to account for up to 55% of total increases.[2]



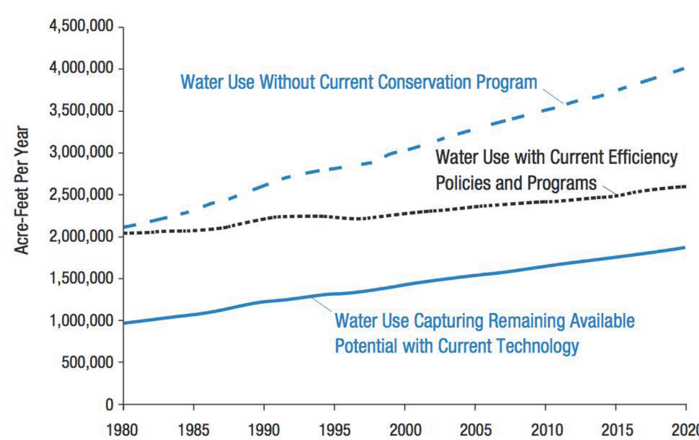
WATER

The Sierra snowpack is the main source of water for all of California, and there is already a downward trend in yearly snowpack due to rising temperatures. Berkeley gets its water from the Mokelumne River watershed in the Sierra Nevada. Historically, the snowpack has proven very convenient - the snow falls in the winter when the most populated areas of California get rain and then it melts in the spring and summer when those same areas are in need of water.

Modeling precipitation is very difficult, but current research suggests that although total precipitation in California will not change dramatically, there will be changes in its spatial and temporal distributions. Winter storms will probably become more intense in the northern part of the state and less intense in the southern part. There will also probably be an increase in the number of very dry years, which will be separated by very wet ones. As mentioned above, less of the precipitation will be in the form of snow in the Sierras, which means that on average, less water will be naturally stored as snow every year. Less natural storage means that there is a greater risk of floods and a greater need for artificial storage methods.[21]

These changing distributions are all very destabilizing to the current water system that relies on natural lags between precipitation and water flow and a predictable distribution of water resources. California has had "water wars" about water rights since the early 1900's and climate change will undoubtedly add a new dimension to these long-standing debates. However, there are several different adaptation measures being discussed and implemented in order to decrease the negative effects.

What do big dams, water conservation, and energy all have in common? They are all directly related to the effects of climate change on water. One proposal to combat the changing accessibility of fresh water is to raise existing dams or build entirely new ones. This would allow people to artificially control when water is



Graph showing the effect of past water conservation efforts and the potential for future conservation programs in California. [41]

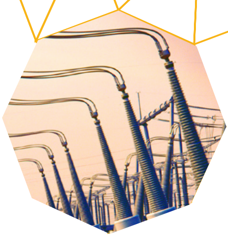
distributed so even if more snow melts in the winter or early fall, it will be more available throughout the summer. However, large dam projects have significant costs associated with them as well. In the implementation of these types of projects, extensive analyses are done in order to determine whether the pros outweigh the cons. This is often a complex and lengthy process and so cannot be adequately discussed here.

Another potential solution is water conservation. If less water is used throughout the year then the water stored in the existing dams could be sufficient. **There is huge potential for water conservation in California**.[P3] Through fixing leaks, water-efficient appliances, and conscientious water usage, the combined effort of many people can be its own adaptation method. Changing the habits of a large group of people can be a daunting task but with increased water rates as a realistic alternative, there may be a greater sense of immediacy. However, a large majority of California's water use comes from irrigated agriculture, which means that small changes in efficiency of agriculture can have an especially large effect. This requires large land use changes or technological innovation.

Another adaptation to a less stable water supply could be to build desalination plants. **Berkeley is located right next to a vast water supply known as the Pacific Ocean – why not use that?** Desalination is expensive because it is very energy intensive. However, using desalination would essentially guarantee constant fresh water. Although the process of removing salt from water requires a lot of energy, in some limited circumstances it can actually use less energy than the alternative of transporting water from some distant location. Marin County, located on the West side of the Bay, may be able to use limited desalination to reduce total energy usage instead of importing water during peak water demand periods.[22]

Currently, five major water districts in the Bay Area – including Berkeley's East Bay Municipal Utility District (EBMUD) – are considering a joint desalination project. This initiative has been underway since 2003 and had a short pilot project in Contra Costa County in late 2008 and 2009. Environmental effects are not being ignored in the process - more studies are currently underway and some of the main considerations for the feasibility of a larger project are the potential environmental and climate impacts. If a full-scale plant is built, construction is estimated to take place between 2018 and 2020.[23]

The possible fresh water scarcity is not only a problem for drinking water; it is also an important part of California agriculture, energy, and ecosystems. These topics will be discussed in more detail individually in later sections.



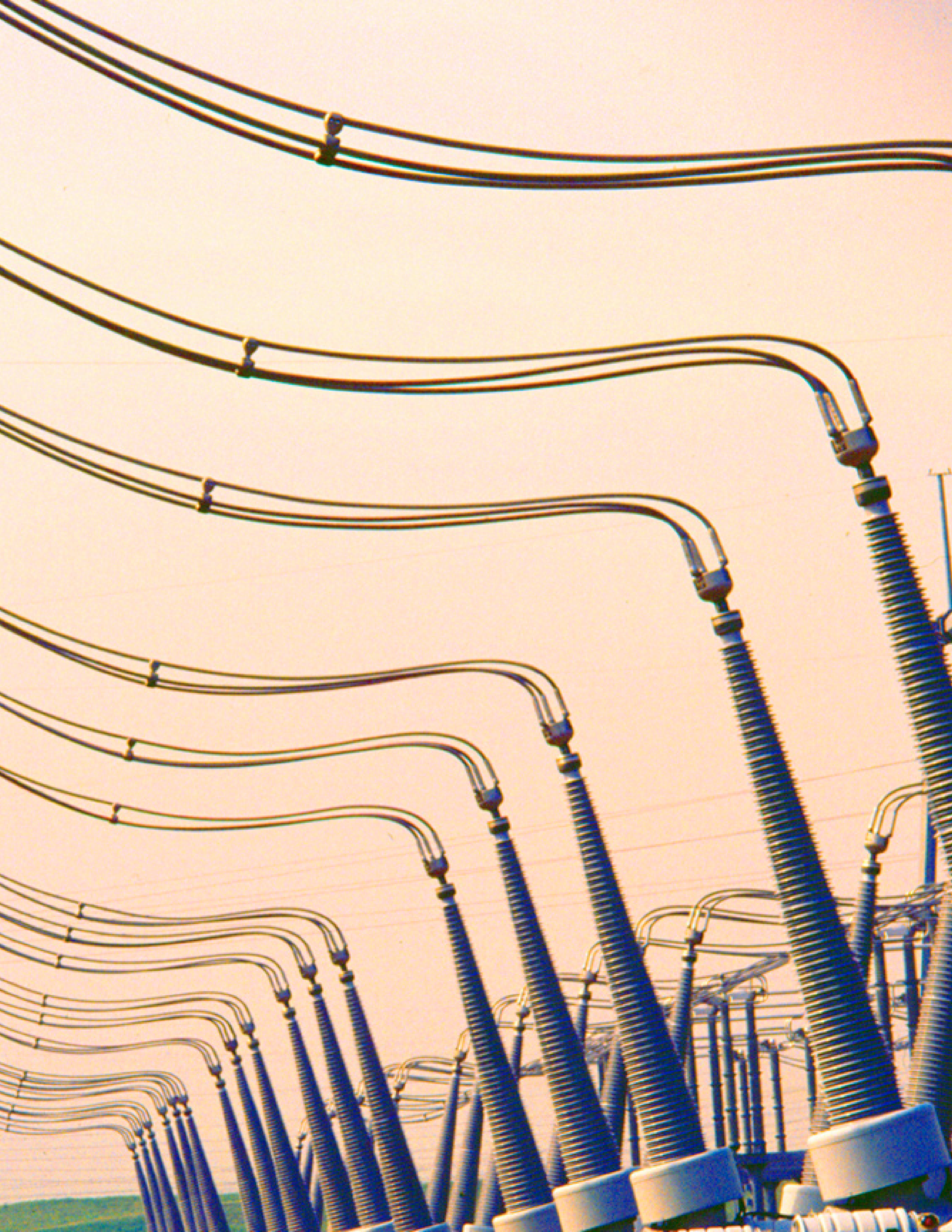
ENERGY

There are many links between energy and water management, supply, and consumption (often referred to as the "energy-water nexus"). Specifically, the movement of water from the Sierras to lower elevations can be used to generate electricity, while pumping water over hills uses energy. Once the water reaches the desired city, it also takes energy to heat water for residential uses. Climate change could decrease hydropower generation, which currently accounts for about 15% of total electricity production. However, due to some possible management adaptations, the amount of reduction is still unclear.[24]

Unrelated to water, energy usage in the Oakland area is predicted to rise slightly due to increased cooling needs, based on past energy use changes with changing temperatures. Other parts of the Bay area such as Sunnyvale are predicted to increase substantially more, partially because of the different microclimates around the Bay.[25] This demand increase, along with the decrease of generator efficiencies and transmission line efficiencies at high temperatures, has energy companies concerned about increases in peak demand. Peak demand is the period when the most energy is required at one time. If the demand is too high during periods of high temperatures, the companies have a hard time supplying the necessary energy. **By 2100, every summer day is expected to have a peak demand that is in what is now the 90th percentile.**[26]

However, since climate change is very likely to affect California's fresh water supply, and energy consumption is one of the major drivers of climate change, the energy-water nexus can be used as a means of adaptation for both the water and energy problems discussed. By simply taking shorter showers, individuals can have a significant impact. **An estimated 19% of electricity and 32% of natural gas consumed in the state goes to water-related activities.** To put this in perspective, 5 minutes of showering with hot water uses the equivalent of leaving a 60-watt light bulb on for about 14 hours.[27]

Energy infrastructure may also be at risk as temperature increases. **Twenty-five power plants around the state are expected to be at risk of flooding by the end of the century – thirteen of which are in the Bay area.** The expected increases in fires may also impact important transmission lines. The best adaptation method for these potential effects is early planning. Given enough time, power companies can add additional transmission lines to prevent a large blackout if one line fails, and they can build new power plants in less vulnerable locations.[28]



BIODIVERSITY

Globally, biodiversity loss from climate change is a huge concern. As temperatures change, species must either adapt or migrate to track suitable conditions in order to survive. On an evolutionary time scale, adaptation is often possible, but over the course of only a few decades, the ability for many species to adapt to major changes is limited.

It is difficult to study local effects of climate change since many species fall into very specific niches, and climate models are generally not precise enough yet to predict local variability. However, the fact that average temperatures will increase in the Bay area is well accepted. The change of temperature per kilometer per year for Mediterranean climates such as the one in Berkeley has been calculated to be about 0.26. That is, **on average, the temperature 0.26 kilometers (850 feet) away from one location will be the new temperature next year.** The implication of this over one year is small, but could be very significant for local species when considering longer timescales like decades.[29]

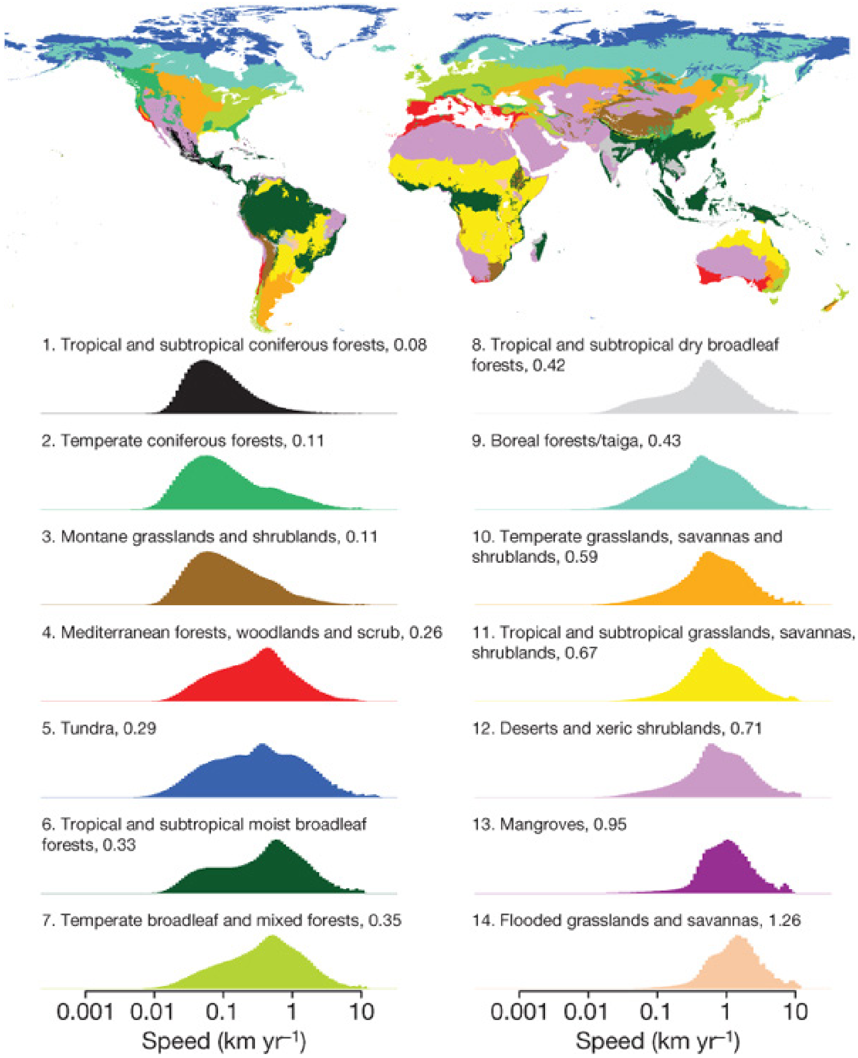
Although average citizens cannot directly help species adapt to new climates, there have been several suggestions on the institutional level. One major proposal has been to expand the network of protected habitats. Since animals and plants cannot easily travel across large urban areas, the idea is to give them pathways throughout the state, sometimes referred to as habitat corridors, so that they can move to new, more suitable environments.[30] Another proposal has been to increase "adaptive management." This approach suggests that because of the unpredictable nature of ecosystem response to rapid changes, land use policy should be able to react to new observations as they arise. Adaptive management also entails identifying the important gaps in knowledge as land managers become aware of them and then conduct research on those gaps.[31]

Biodiversity can also be impacted by invasive species, which are more likely to succeed in the face of climate change. Many invasives are good at surviving under a variety of conditions, which is what allows them to become invasive in the first place. One example of this in the Bay Area is the yellow star thistle. **It was found that under conditions with CO_2 concentrations 300 parts per million greater than current conditions, the yellow star thistle grew six times larger than it does now.** This is a problem because the thistle uses a lot of soil moisture so it outcompetes native grasses. In addition, cattle cannot eat it, which creates a problem for local agriculture.[32]

Another problem associated with biodiversity loss is the loss of ecosystem services. This is the idea that nature provides tangible value to people by simply performing its normal tasks. Some simple examples are tourism from an intact environment, timber from forests, and water from rain. However some less obvious examples are soil nutrient cycling by biogeochemical cycles, water

quality control from microbes, and carbon sequestration.

Carbon sequestration is already being used by the State of California as a method of adaptation through carbon credits. These credits encourage environmentally friendly land use that allows plants to flourish and remove carbon from the atmosphere. On a more global scale, the UN has a similar program known as REDD+ that is meant to encourage nations to reduce deforestation in order to keep atmospheric CO_2 as low as possible. Although there are major political and ethical arguments around both of these programs, their underlying objective is to assign a monetary value to ecosystem services in order to mitigate and adapt to climate change.



A map of biomes and histograms of the speed of temperature change within each biome. Histograms are ordered by increasing velocity according to their geometric means. [29]

FOOD

The effects of climate change on Berkeley's food supply are somewhat unclear, but studies have been done on the effects on agriculture throughout California and the rest of the country. Higher temperatures and increased carbon dioxide levels can actually lead to more growth, but sometimes also fewer seeds in grains, which are important for the United States' food supply. Therefore, the impact on staple grains from these factors is unclear. Other effects such as increased droughts and floods are likely to make farming more difficult.[33]

More locally, temperature increases are expected to cause agricultural changes because the ideal locations for plants are expected to change. In addition, the more extreme temperatures could increase the chances of poor yield years for some major California crops**. In 2011, specialty crops were a $10.9 billion dollar industry for California. Although not all of these crops are in serious danger, a number of California perennial crops are considered temperature sensitive** including almonds, grapes, berries, citrus, and stone fruits. Some of this sensitivity is attributed to the expected decreases in winter chills, which are necessary for some of these crops.

However, there are some adaptation methods being proposed. The most prominent idea is for farmers to breed crops so they can better withstand different conditions. It may be possible through further research to improve the ability of some crops to thrive with a warmer climate.[34] Another "adaptation" would be to shift crops to different areas. This could mean that some areas benefit from new crops such as wine grapes that are very temperature sensitive, while areas that currently grow wine will greatly decrease production. **By 2050 an estimated 25%-73% of currently suitable land for viticulture will no longer be suitable.** Parts of the Sierras and the northern redwoods may however see significant increases.[35]

Another effect on California's food is the reduced availability of water. Farmers in California often receive less water than they were promised due to long term over-allocation, but if they receive too little, they cannot grow their crops. **According to state officials, due to the current drought, in 2014 some farmers may not receive any of their expected water, which would likely have a negative effect on California's $44.9 billion agriculture industry**.[36] [37] Although this drought cannot be linked directly to climate change, the effects of low water availability are clear.

Some farmers in other parts of the U.S. are attempting to adapt to water shortages by using new farming techniques that could eventually also be used in California. Farmers in Nevada are attempting to adapt to water shortages by utilizing indoor farming, which reduces water lost to evaporation and seepage. Farmers in Texas are experimenting with growing corn without first watering the ground, which could potentially also save a lot of water.[38]

CONCLUSION

Although effects and adaptations are the focus of this report, it is also important to note that many of the discussed effects have large ranges of possibilities that are often the result of uncertainty in future emissions. Mitigation and adaptation both need to be considered for future planning. For more information on UC Berkeley's efforts in mitigation, please see the Annual Sustainability Report.

The topic of global climate change is often referred to as the biggest problem of the 21st century. As was described above in some detail, there are many negative effects that can occur globally and locally from increased temperatures. However, hopefully this report has also outlined some adaptations that can be used to lessen these undesirable consequences of global change.

Of course, not all effects and adaptations are listed. Some effects are extremely difficult to predict, such as the local impacts of disasters elsewhere in the country and effects on long-term food prices. The resources listed throughout this report are intended as a starting point for those who wish to explore these topics further; each topic is more complex that can be discussed fully here. Hopefully this report serves as a good summary of the topic of local climate change and will encourage readers to consider these topics in their own lives.

CITATIONS

1. W. R. L. Anderegg, “Expert Credibility in Climate Change,” Proceedings of the National Academy of Sciences Vol. 107 No. 27, 12107-12109 (21 June 2010); DOI: 10.1073/pnas.1003187107.

2. ”Projections of Future Changes in Climate.” - AR4 WGI Summary for Policymakers. IPCC, n.d. Web. 21 Aug. 2013. <http://www.ipcc.ch/publications_and_data/ar4/wg1/en/spmsspm-projections-of.html>.

3. Climate Change The Physical Basis Summary for Policy Makers. Rep. no. 5. IPCC, Oct. 2013. Web. < http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf>.

4. United Nations. UNFCCC. Copenhagen Accord. Copenhagen: n.p., 2009. 18 Dec. 2009. Web. < http://unfccc.int/resource/docs/2009/cop15/eng/l07.pdf>.

5. Cayan, Dan, Mary Tyree, and Sam Iacobellis. Climate Change Scenarios for the San Francisco Region. Rep. California Energy Commission’s California Climate Change Center, July 2012. Web. <http://www.energy.ca.gov/2012publications/CEC-500-2012-042/CEC-500-2012-042.pdf>.

6. Knowlton, Kim, Miriam Rotkin-Ellman, Galatea King, Helene G. Margolis, Daniel Smith, Gina Solomon, Roger Trent, and Paul English. “Abstract.” National Center for Biotechnology Information. U.S. National Library of Medicine, 22 Aug. 2008. Web. 30 Aug. 2013. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2627866/>.

7. Reid, Colleen, Marie O’Neill, Carina Gronlund, Shannon Brines, Dan Brown, Ana Diez-Roux, and Joel Schwartz. “Mapping Community Determinants of Heat Vulnerability.” Environmental Health Perspectives (2009): n. pag. 10 June 2009. Web. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2801183/>.

8. World Health Organization. Europe. Public Health Advice on Preventing Health Effects of Heat. WHO, 2011. Web. <http://www.euro.who.int/__data/assets/pdf_file/0007/147265/Heat_informa tion_sheet.pdf>.

9. “Local Climate Snapshots.” Cal-Adapt. California Energy Commission, n.d. Web. <http://cal-adapt.org/tools/factsheet/>.

10. “Urban Forestry Management Program.” Trees/Parks. City of Berkeley, Web. Mar. 2014. <http://www.ci.berkeley.ca.us/Parks_Rec_Waterfront/Trees_Parks/Trees_and_Urban_Forestry_Mangement.aspx>.

11. “Cooling Centers Open to Help Bay Area Residents Beat the Heat.” ABC Local. ABC News, 28 June 2013. Web. <http://abclocal.go.com/kgo/story?id=9155906>.

12. Routley, J. G., comp. The East Bay Hills Fire Oakland-Berkeley, California. Rep. no. 060. N.p.: n.p., 1991. USFA, FEMA. Web. <http://www.usfa.fema.gov/downloads/pdf/publications/tr-060.pdf>.

13. “Very High Fire Hazard Severity Zones In LRA As Recommended By CAL FIRE.” Map. California Department of Forestry and Fire Protection. Fire and Resource Assessment Program, 3 Sept. 2008. Web. <http://frap.cdf.ca.gov/webdata/maps/alameda/fhszl_map.1.jpg>.

14. Rice, Carol. The Science Behind Eucalyptus Fire Hazards. Rep. N.p., n.d. Web. <http://claremontcanyon.org/bibliography/eucalyptus_fire_hazard_carol_rice.pdf>.

15. “Questions and Answers About Eucalyptus Trees in Claremont Canyon.” Claremont Canyon Conservancy. Claremont Canyon Conservancy, Sept. 2013. Web. <http://claremontcanyon.org/press_questions_and_answers.php>.

16. Knobel, Lance. “Cal Seeks Funds to Cut down 22,000 Non-native Trees.” Berkeleyside. Berkeleyside, 17 May 2013. Web. <http://www.berkeleyside.com/2013/05/17/uc-berkeley-seeks-funds-to-cut- down-22000-non-native-trees/>.

17. “CAL FIRE Climate Change Program.” CAL FIRE. CAL FIRE, n.d. Web. <http://calfire.ca.gov/resource_mgt/climate-change-index.php>.

18. Tam, Laura. “Climate Adaptation and Sea-Level Rise in the San Francisco Bay Area.” Climate Adaptation and Sea-Level Rise in the San Francisco Bay Area. American Planning Association, 12 Jan. 2012. Web. <http://www.planning.org/planning/2012/jan/waterwarriorsside2.htm>.

19. “San Francisco Bay Area.” Bay Area Census. Metropolitain Transportation Commission. Web. <1. http://www.bayareacensus.ca.gov/bayarea.htm>.

20. “San Francisco Visitor Industry Statistics.” San Francisco Travel. Web. <http://www.sanfrancisco.travel/research/>.

21. Bales, Roger, and Norm Miller. “Viewpoints Q&A: How Climate Change May Affect Californians.” California Forum. The Sacramento Bee, 23 June 2013. Web. <Viewpoints Q&A: How climate change may affect Californians Read more here: http://www.sacbee.com/2013/06/23/5515648/how-climate-change-may-affect.html#storylink=cpy>.

22. Cohen, Ronnie, Barry Nelson, and Gary Wolff. Energy Down the Drain: The Hidden Cost of California’s Water Supply. Rep. N.p.: National Resource Defence Council, 2004. Print.

23. “About the Project.” Bay Area Regional Desalination Project, n.d. Web. <http://www.regionaldesal.com/about.html>.

24. Moser, Susanne, Julia Ekstrom, and Guido Franco. Our Changing Climate 2012 Vulnerability & Adaptation to the Increasing Risks from Climate Change in California. Rep. California Climate Change Center, July 2012. Web. <http://www.energy.ca.gov/2012publications/CEC-500-2012-007/CEC-500- 2012-007.pdf>.

25. Sathaye, Jayan, Larry Dale, Peter Larsen, Gary Fitts, Kevin Koy, and Sarah Lewis. Estimating Risk To California Energy Infrastructure From Projected Climate Change. Rep. California Energy Commission, July 2012. Web. <http://www.energy.ca.gov/2012publications/CEC-500-2012-057/CEC-500-2012-057.pdf>.

24. Auffhammer, Maximilian, and Anin Aroonruengsawat. Impacts of Climate Change of San Francisco Bay Area Residential Electrcity Consumption: Evidence from Billing Data. Rep. California Energy Commission, July 2012. Web. <http://www.energy.ca.gov/2012publications/

CEC-500-2012-035/CEC-500- 2012-035.pdf>.

27. Cooley, Heather, and Kristina Donnelly. “Water-Energy Synergies: Coordinating Efficiency Programs in California.” Pacific Institute, 4 Sept. 2013. Web.

28. Chao, Julie. “Climate Adaptation and Sea-Level Rise in the San Francisco Bay Area.” Impact of Climate Change on California’s Electricity Infrastructure Could Be Costly. Lawrence Berkeley National Laboratory News Center, 18 Dec. 2012. Web. <http://newscenter.lbl.gov/feature-stories/2012/12/18/impact-of-climate-change-on-california-electricity-infrastructure-could-be-costly/>.

29. Loarie, Scott R., Philip D. Duffy, Healy Hamilton, Gregory P. Asner, Christopher B. Field, and David D. Ackerly. “The Velocity of Climate Change.” Nature 462 (2009): 1052-055. Nature. Nature, 10 Dec. 2009. Web. <http://www.nature.com/nature/journal/v462/n7276/full/nature08649.html>.

30. Climate Change Consortium for Specialty Crops: Impacts and Strategies for Resilience. Rep. California Department of Food and Agriculture, 2013. Web. <http://goo.gl/9dg5wV>.

31. Peterson, G., G.A. De Leo, J.J. Hellmann, M.A. Janssen, A. Kinzig, J.R. Malcolm, K.L. O’Brien, S.E. Pope, D.S. Rothman, E. Shevliakova, and R.R.T. Tinch. “Uncertainty, Climate Change, and Adaptive Management. Conservation Ecology” Ecology and Society. Ecology and Society. Web. <http://www.consecol.org/vol1/iss2/art4/>.

32. Rebecca Chaplin- Kramer (University of California, Berkeley). 2012. Climate Change and the Agricultural Sector in the San Francisco Bay Area: Changes in Viticulture and Rangeland Forage Production Due to Altered Temperature and Precipitation Patterns. California Energy Commission. Publication number: CEC- 500- 2012- 033. < http://www.energy.ca.gov/2012publications/CEC-500-2012-033/CEC-500-2012-033.pdf>.

33. “Climate Impacts on Agriculture and Food Supply.” Agriculture and Food Supply. EPA, n.d. Web. 9 Sept. 2013. <http://www.epa.gov/climatechange/impacts-adaptation/agriculture-adaptation.html>.

34. California Department of Food and Agriculture. Climate Change Consortium for Specialty Crops Final Report Identifies Challenges and Makes Recommendations for Agriculture. 3 Oct. 2013. Web. <http://www.cdfa.ca.gov/egov/Press_Releases/Press_Release.asp?PRnum=13-032>.

35. Hannah Et Al., Lee. “Climate Change, Wine, and Conservation.” Proceedings of the National Academy of Sciences 110 (2013): 6907-912. 8 Apr. 2013. Web. <http://www.conservation.org/Documents/CI_PNAS_Climate-Change-Wine-production-Conservation_Lee-Hannah_March-2013.pdf>.

36. Bernstein, Sharon. “California Water Woes Hit Hard in Driest Year on Record.” Reuters. Reuters, 27 Nov. 2013. Web. <http://www.reuters.com/article/2013/11/27/us-usa-california-water- idUSBRE9AQ0M520131127?feedType=RSS&feedName=environmentNews>.

37 .Boxall, Bettina. “February Rains Ease Drought Restrictions Slightly.” Los Angeles Times. Los Angeles Times, 18 Mar. 2014. Web. <http://www.latimes.com/science/la-me-drought-delta-20140319%2C0%2C726563.story#axzz2wPkPTOI5>.

38. “Driest Year on Record Hurts California Agriculture.” Environmental Leader RSS, 2 Dec. 2013. Web. <http://www.environmentalleader.com/2013/12/02/driest-year-on-record-hurts-california-agriculture/>.

39. “Average Weather for Berkeley, CA - Temperature and Precipitation.” The Weather Channel, Web. <http://www.weather.com/weather/wxclimatology/monthly/graph/94704>.

40. Westerling, A. L., and B. P. Bryant. “Climate Change and Wildfire in California.” Climatic Change 87.S1 (2008): 231-49. Web. <http://tenaya.ucsd.edu/tioga/pdffiles/Westerling_wildfire_jan2008.pdf>.

41. Gleick, Peter H., Dana Haasz, Christine Henges-Jeck, Veena Srinivasan, Gary Wolff, Katherine K. Cushing, and Amardip Mann. Wa Ste Not, Want Not: T He Potential for Urban Water Conservation in California. Rep. Ed. Nicholas L. Cain. Pacific Institute for Studies in Development, Environment, and Security, Nov. 2003. Web. <http://www.pacinst.org/wp-content/

Note 1:
The annual energy savings from trees due to shading and climate effects were estimated to be over $550,000 and the savings from decreased storm water runoff totaled to over $200,000. (http://www.fs.fed.us/psw/programs/uesd/uep/products/cufr589_BerkeleyMBCA.pdf) Since the concentration of precipitation is expected to increase, this stormwater benefit may increase over time.

SPECIAL THANKS TO:

Professor David Ackerly

Professor Joe McBride

Professor Matt Kondolf

Tom Klatt

The Green Initiative Fund

The Green Initiative Fund
University of California, Berkeley