Los Angeles County Climate Cost Study

Los Angeles County's Climate Cost Challenge

A $12.5 Billion Bill to Protect Communities Through 2040

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The Center for Climate Integrity

April 2024

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The Center for Climate Integrity empowers communities and elected officials with the knowledge and tools they need to hold oil and gas corporations accountable for the massive costs of climate change.
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This study and the data it produced are available at climateintegrity.org/la-county-costs.

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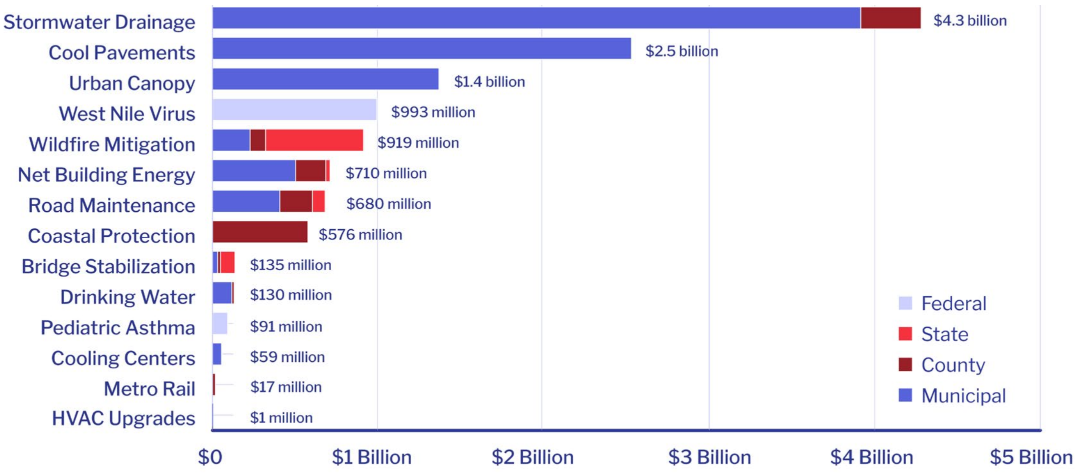
Executive Summary

Within the first two months of 2024, the City of Los Angeles had already exceeded its average annual rainfall, receiving nearly 15 inches of rain in back-to-back deluges.[1] The storms flooded roads, brought massive wind gusts, ripped down trees, and killed nine people.[2] The year prior was the hottest year ever recorded, including unseasonably hot weather into the fall months in Southern California. In October 2023, a wildfire ripped through rural lands southeast of the City of Los Angeles, destroying multiple buildings and forcing approximately 4,000 people to evacuate.[3]

With climate-driven disasters in Southern California growing more intense every year, it's more important than ever for communities to invest in a growing range of climate adaptation and resilience projects. This study is the first-ever attempt to calculate the costs of preparing for and adapting to 14 different climate impacts on municipal, county, state, and federal governments in Los Angeles County.

We estimate municipal, county, state, and federal governments will need to spend at least $12.5 billion through 2040, over $9 billion of which will be incurred by municipal governments. The total cost equates to approximately $780 million per year to protect communities in Los Angeles County from extreme heat, changing precipitation, wildfires, rising sea levels, and climate-induced public health threats.

Figure 1: Total cost for each adaptation strategy from 2024 through 2040.



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[1] Kathryn Prociv, "Soaked California Faces Another Day of Flood Watches as Los Angeles Already Hits Yearly Rainfall Average," *NBC News*, February 21, 2024, https://www.nbcnews.com/news/weather/soaked-california-faces-another-day-flood-watches-los-angeles-already-rcna139745.

[2] Grace Toohey, "9 People Killed in California's Massive Storm: Here's How They Died," *Los Angeles Times*, February 8, 2024, sec. California, https://www.latimes.com/california/story/2024-02-07/californias-storm-claimed-nine-lives-heres-what-we-know.

[3] Dani Anguiano, "California Wildfire Threatens 1,300 Homes South-East of Los Angeles," *The Guardian*, October 31, 2023, https://www.theguardian.com/us-news/2023/oct/31/california-wildfire-evacuation-santa-ana-winds.

We calculate taxpayers in Los Angeles County will face the following climate adaptation costs through 2040:

- **$4.3 billion** to improve stormwater management to mitigate flooding
- **$2.5 billion** to invest in cool pavements to combat heat
- **$1.4 billion** to plant and maintain trees to combat urban heat islands
- **$1.1 billion** to respond to an increase of childhood asthma and West Nile Virus cases
- **$919 million** to mitigate wildfire damage
- **$710 million** to heat and cool public buildings in response to changing temperatures
- **$680 million** to increasing road maintenance because of heavy rain and heat stress
- **$576 million** to build coastal defenses to protect infrastructure from rising seas
- **$135 million** to reinforce bridges against anticipated climate wear and tear
- **$130 million** to treat drinking water during increased droughts
- **$59 million** to expand and operate cooling centers
- **$17 million** to make metro rail tracks resilient to increasing temperatures
- **$1 million** to upgrade air conditioning in public buildings

Across the country, local governments are paying for the vast majority of climate adaptation and resilience measures. Taxpayers in Los Angeles are no exception, and as climate impacts grow more destructive, the need for these adaptive measures will only become more acute. While local leaders could seek additional financial support from the federal government, there is no source of federal funds for adaptation at this scale — and the funding that is available is still coming from taxpayers.

How to Interpret These Costs

Where possible, this report delegates the costs of climate adaptations to each local government type that would be responsible for paying for the costs depending on ownership of structures, land, and/or services. In cases where it is not clear how governments divide responsibility, costs have been assigned to the municipality where the adaptations are being made, or based on the entity that owns the infrastructure in question — for example stormwater infrastructure improvements are assigned to the municipality the infrastructure is in, while the state is assigned costs for a state-owned highway.

For a full explanation of how costs are assigned for each climate adaptation, see Table A2 in Appendix A.2.

Meanwhile, the major oil and gas companies that knew their products would lead to catastrophic climate change, and then deceived the public and policy-makers about it for decades, pay nothing.[4] A more just alternative would be to make the polluters most responsible for the climate crisis pay their fair share of the climate adaptation and resilience costs facing Los Angeles County communities. We are in a climate crisis because Big Oil companies lied about their products for decades; it's only right that they pay their share for the costs they have imposed on communities.

Dozens of states and communities, including the State of California and eight California municipalities, have filed lawsuits to recover the costs of climate damages from major oil companies, following the same legal framework as landmark tobacco and opioid lawsuits.[5] Each and every community in Los Angeles County should consider bringing similar legal actions to hold climate polluters accountable and ensure that taxpayers aren't left to pay the bill alone.

How We Calculated These Costs

These findings are based on a moderate climate scenario (Shared Socioeconomic Pathway 2 - 4.5 [SSP2-4.5]) and do not account for the costs of recovering from any climate-driven disasters that will almost certainly occur, creating additional damages. This study is confined to costs created by only 14 out of many climate impacts (see Appendix Table A3) that communities will ultimately face (Figure 1). The costs are calculated in 2023 dollars, use generally accepted standard engineering protocols, and assume that governments will make less expensive proactive adaptation repairs as opposed to potentially more expensive reactive repairs. This report uses publicly available data to determine which local governments will be responsible for paying for the evaluated climate costs. Local governments, in turn, will ultimately be responsible for deciding whether or not to implement the adaptations necessary to protect their constituents from worsening climate change. Failing to spend these dollars will almost certainly result in much larger costs in the future, both to recover from preventable climate damages, and to implement more costly adaptive measures down the road. Finally, these calculations are limited to the cost of adapting to these climate impacts, not reversing them.

Wildfire smoke obscures Los Angeles skyscrapers: September 12, 2020.

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[4] René Marsh, "Big Oil Has Engaged in a Long-Running Climate Disinformation Campaign While Raking in Record Profits, Lawmakers Find | CNN Politics," *CNN*, December 9, 2022, https://www.cnn.com/2022/12/09/politics/big-oil-disinformation-record-profits-climate/index.html.

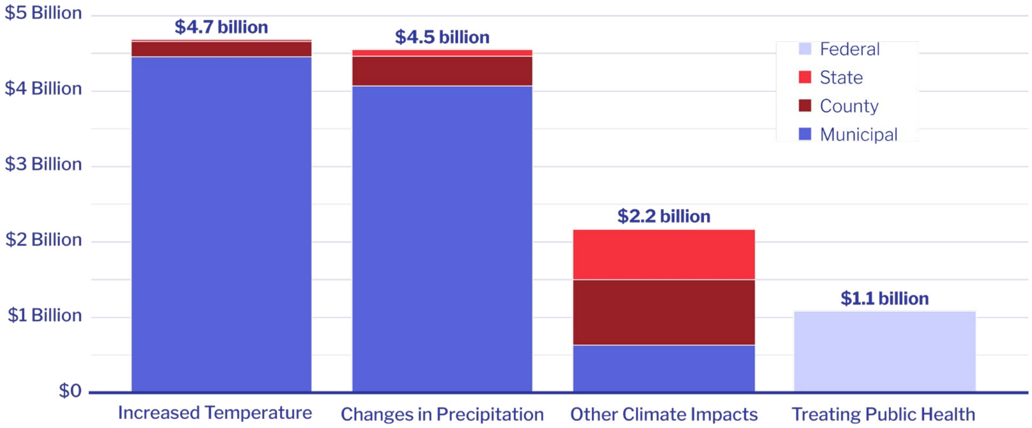
[5] Center for Climate Integrity, Cases, accessed March 14, 2024, https://climateintegrity.org/cases.

Key Findings

Combating floods from increased precipitation and more severe storms is the most expensive climate cost we identified facing communities in Los Angeles County. Investing in stormwater drainage infrastructure such as porous pavement, bioswales, and bioinfiltration — the least expensive stormwater infrastructure — to manage increased precipitation will cost communities in Los Angeles County $4.3 billion from 2024 through 2040. That is equivalent to about $252 million per year, or approximately 14% of the county's Water Resources budget for Fiscal Year 2023 (Appendix G.2).[6]

The second most expensive climate adaptation measure identified is the cost to address urban heat islands — areas where heat is intensified because of the near total absence of trees or green space, allowing buildings and roads to absorb, intensify, and radiate the sun's heat, making these areas up to 20°F hotter than surrounding, less urbanized areas.[7] To help counteract rising temperatures, it will cost $2.5 billion to install cool pavements — pavement that doesn't absorb as much heat — in public parking lots and $1.4 billion to plant and maintain urban trees across the county from 2024 through 2040. The yearly average cost of installing cool pavements across the Los Angeles County area would be about $149 million, equivalent to 16% of the county's 2023 transportation budget (Appendix G.2).[8]

Figure 2: The total costs local governments in Los Angeles County face through 2040 to protect communities from the worsening impacts of climate change.[9]



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[6] LA County, "LA County Open Budget Appropriation (Auditor-Controller)," January 3, 2024, https://data.lacounty.gov/datasets/lacounty::la-county-open-budget-appropriation-auditor-controller/explore.

[7] Anna Tzavali et al., "Urban Heat Island Intensity: A Literature Review," *Fresenius Environmental Bulletin* 24, no. 12b (2015): 4537–54, https://www.researchgate.net/publication/298083233_Urban_heat_island_intensity_A_literature_review.

[8] LA County, "LA County Open Budget Appropriation (Auditor-Controller)."

[9] The increased temperature adaptations are installing cool pavements, increasing urban canopy, net building energy usage, protecting residents during heatwaves, applying reflective coating to metro rail tracks, and upgrading HVAC capacity. The changes in precipitation adaptations are increasing stormwater drainage capacity, bridge stabilization, and increased drinking water treatment. The other climate impact adaptations are wildfire mitigation, proactive road maintenance, and protecting infrastructure from sea level rise. Treating public health includes pediatric asthma and West Nile Virus treatment.

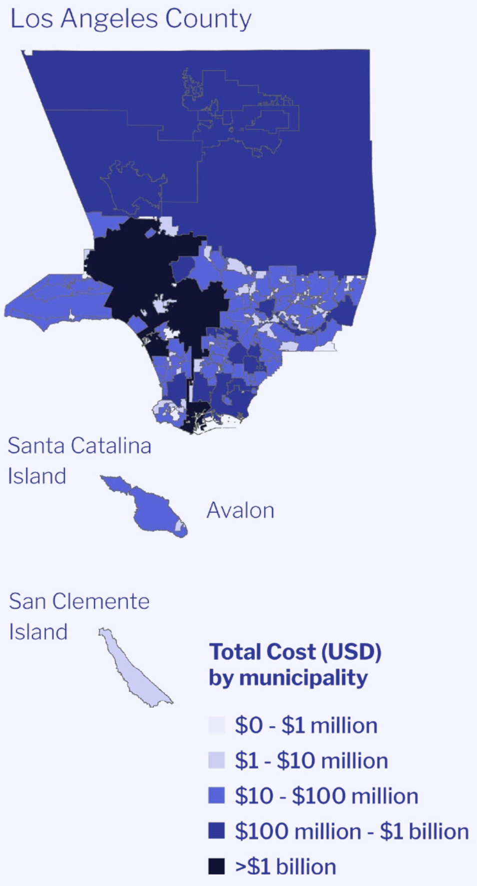
Table 1: Local governments facing the highest costs for 10 municipal climate adaptations from 2024 through 2040.

Rank	Municipality	Total Cost	Municipal Cost	County Cost	State Cost	Federal Cost
1	Los Angeles	$3,753,831,000	$3,656,890,000	$66,433,000	$30,482,000	$26,000
2	Antelope Valley	$538,925,000	N/A* *unincorporated	$226,995,000	$308,443,000	$3,487,000
3	Long Beach	$507,080,000	$505,544,000	$204,000	$1,332,000	N/A* *no wildfires
4	Santa Clarita	$340,237,000	$313,518,000	$2,700,000	$23,969,000	$50,000
5	Santa Clarita Valley	$271,629,000	N/A* *unincorporated	$96,832,000	$173,691,000	$1,106,000

Climate impacts present enormous and difficult choices for communities. With finite resources and growing budget demands, investing in climate resilience may mean not spending on other services such as firefighting, police, schools, senior centers, libraries, sanitation, and more. Faced with these trade offs, communities often delay or fail to implement climate adaptation initiatives until after a major disaster, if even then. This invariably costs taxpayers more in the end.[10]

As an example, we examined proactive road maintenance versus reactive repairs. We found that Los Angeles County communities are not only more likely to repair roads after they are damaged rather than upgrade them beforehand, but that this will cost at least $340 million more than proactive road repairs through 2040. In addition, climate adaptation projects in unincorporated areas of Los Angeles County — home to about one million residents — will fall on the responsibility of the county and stress the county budget, as the unincorporated areas do not have municipal governments.[11] The cost of climate adaptations in the unincorporated areas of the county is estimated at about $86 million per year, or about 60% of Los Angeles County's 2023 Municipal Services budget, which is the budget used for services in unincorporated areas of Los Angeles County.

Figure 3: The total cost of implementing 10 municipal climate adaptations through 2040. The costs are concentrated in high-population urban cities and large unincorporated areas.



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[10] The costs associated with protecting infrastructure from rising sea levels, applying reflective coating to metro rail tracks, treating pediatric asthma, and treating West Nile Virus are unable to be assigned to municipalities (Appendix A.2).

[11] Public Works Los Angeles County, "Municipal Services," LA County Public Works, 2024, https://content.pw.lacounty.gov/core-service-areas/municipal-services/.

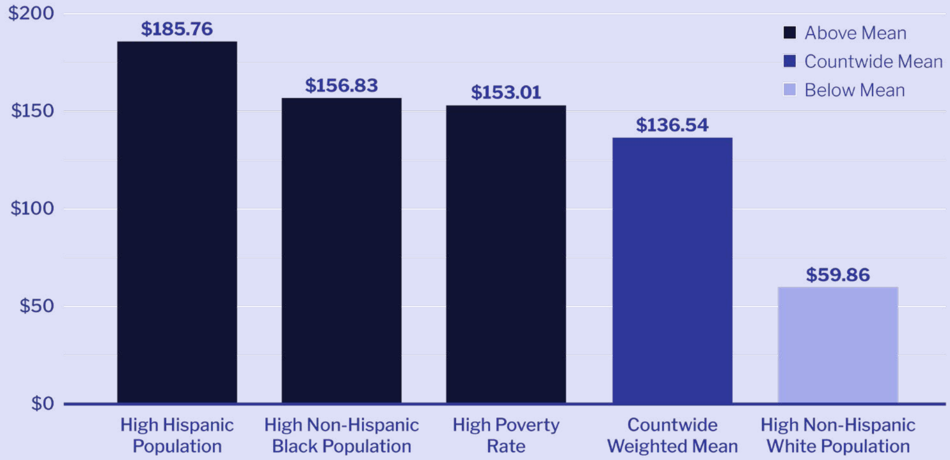
Finally, while there is no community that can escape the impacts of climate change, the burden of the climate crisis does not fall equally on Los Angeles municipalities. Of all 162 municipalities in this study, the City of Los Angeles faces the highest climate adaptation costs. The city is also very diverse and has significant wealth disparity[12] across various racial and ethnic groups, meaning the costs for climate adaptation will be felt differently throughout the city (see Appendix A.4 for more information).

The burden of life-threatening heat does not fall equally across Los Angeles County communities.

Lower income and higher diversity communities disproportionately lack green spaces that can cool urban environments, meaning these same populations will face the highest per capita costs to combat worsening heat islands. Our analysis confirmed that the costs of adapting to climate impacts, particularly heat, are greatest in communities of color and those with lower income. The per capita costs of heat adaptation and cooling measures in census tracts with high non-Hispanic Black and Hispanic populations is nearly three times higher than those with higher than average white populations.

Statistics of demographic characteristics in Los Angeles County come from the 2020 American Community Survey 5-Year Data (ACS-5) compiled by the U.S. Census Bureau (Appendix G.1). We use the demographic terminology reported in the ACS-5 throughout this report.

Figure 4: The cost to increase urban canopy is disproportionately higher in areas of the county with higher Hispanic (3.1 times higher compared to high white areas) and non-Hispanic Black (2.6 times higher compared to high white areas) populations, as well as communities with higher rates of poverty (2.6 times higher compared to high white areas).



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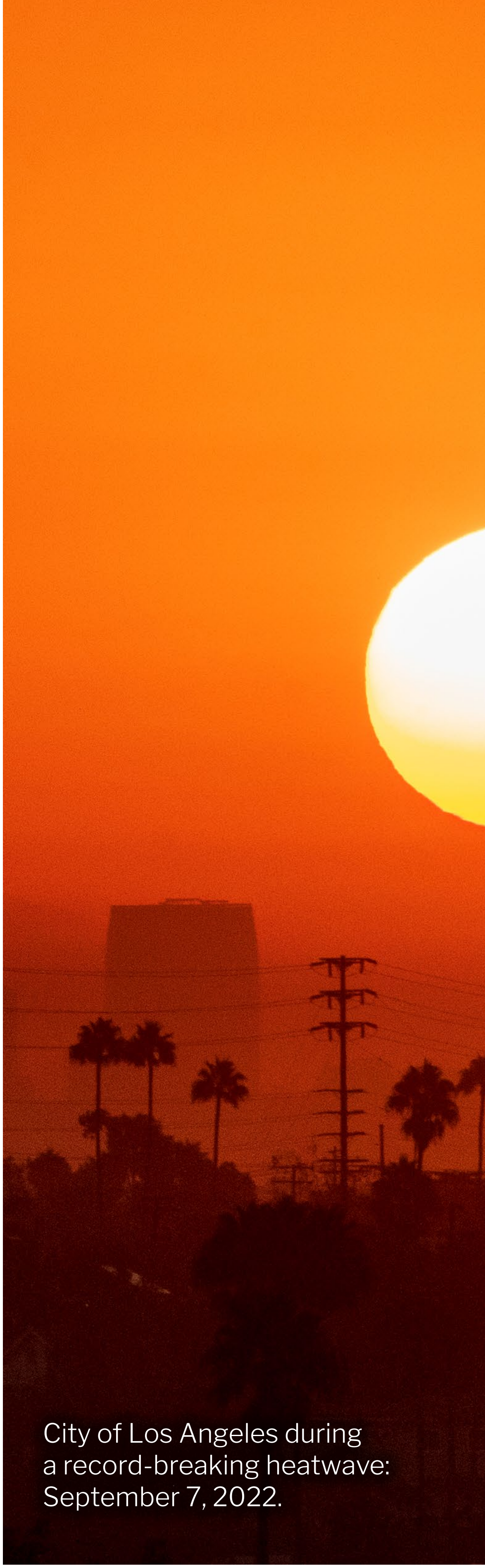
[12] "The Color of Wealth in Los Angeles," *The Samuel DuBois Cook Center on Social Equity at Duke University* (blog), March 16, 2016, https://socialequity.duke.edu/portfolio-item/the-color-of-wealth-in-los-angeles/.

Cost to Adapt to Hotter Temperatures
$4.7 Billion

As the climate crisis continues to escalate, Los Angeles County's traditionally moderate climate will get much hotter. The region is expected to experience an average of 48.5 days above 90°F per year during the study period (2024 through 2040), or about 12.5 more hot days per year than communities experienced from 1994 to 2013. The increase in days above 90°F will vary significantly across the county, leaving some communities with many more extreme heat days than others.

To combat the dangers of this rising heat risk, communities in Los Angeles County can invest in installing cool pavements, expanding urban green space, painting metro rail tracks with reflective paint to keep them at an operable temperature, and upgrading cooling systems for public buildings like schools. (See Appendix A.3 for a more comprehensive list of adaptations).

Converting public parking lots to cool pavements that reflect instead of absorb sunlight, thus lowering the proximal temperature and reducing heat islands, is an effective and simple way to moderate the urban heat island effect. It is also the highest temperature-related cost facing communities in the county at $2.5 billion through 2040. Per year, cool pavements will cost an average of about $149 million to implement throughout the Los Angeles County region, or the equivalent of 16% of the county's 2023 transportation budget. In the City of Long Beach, the cost to install cool pavement is about $9 million annually, which is 55% of what the city budgeted annually for their 5-year Climate Adaptation and Action Plan ($16 million).[13]



City of Los Angeles during a record-breaking heatwave: September 7, 2022.

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[13] The City of Long Beach, "Innovation & Efficiency," 2023, https://longbeach.gov/globalassets/finance/media-library/documents/city-budget-and-finances/budget/budget-documents/fy-24-proposed-budget/fy-24-innovation-and-efficiency?_gl=1*10yobop*_ga*MTM2MjAxOTc0MS4xNzA5MTU1OTQ2*_ga_DH0765KYTY*MTcwOTE1NTk0Ni4xLjEuMTcwOTE1NjEyOC41My4wLjA.

Cool pavements are a complementary investment to tree planting — another proven way to reduce dangerous urban heat islands — which is the second largest temperature adaptation cost facing the Los Angeles County area. Notably, tree planting requires additional water usage for maintenance.

Figure 5: Percent of the total temperature cost for each of five[14] temperature-related adaptation strategies.

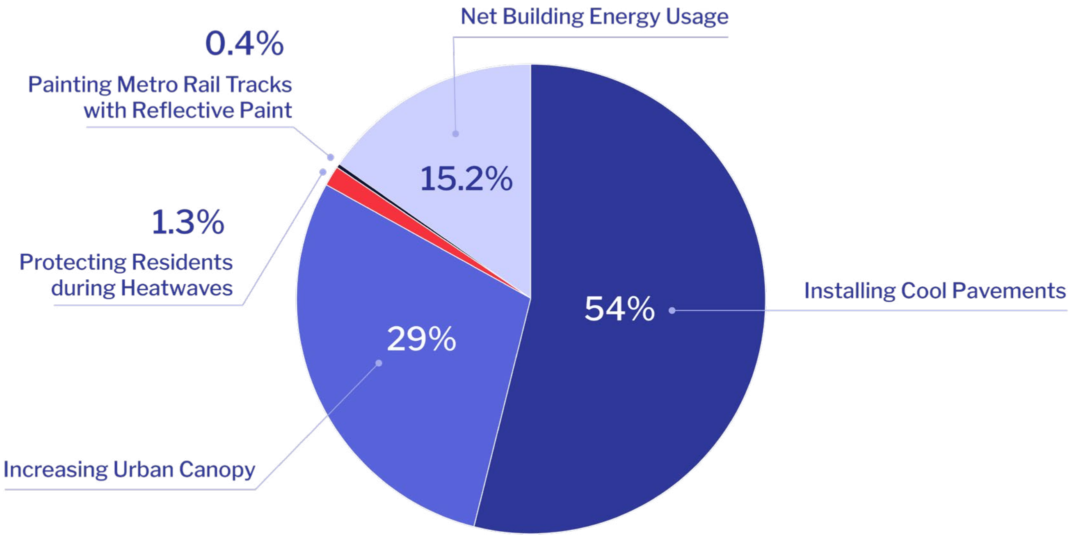

Table 2: Local governments facing highest costs from five temperature-related climate impacts[15] through 2040. County and state costs are incurred for net building energy costs and upgrading air conditioning capacity.

Rank	Municipality	Total Cost	Municipal Cost	County Cost	State Cost
1	Los Angeles	$1,469,324,000	$1,394,112,000	$66,433,000	$8,779,000
2	Long Beach	$242,676,000	$241,965,000	$204,000	$507,000
3	Lancaster	$197,197,000	$182,006,000	$7,804,000	$7,387,000
4	Carson	$149,278,000	$149,070,000	$19,000	$189,000
5	Palmdale	$135,301,000	$135,243,000	$58,000	N/A

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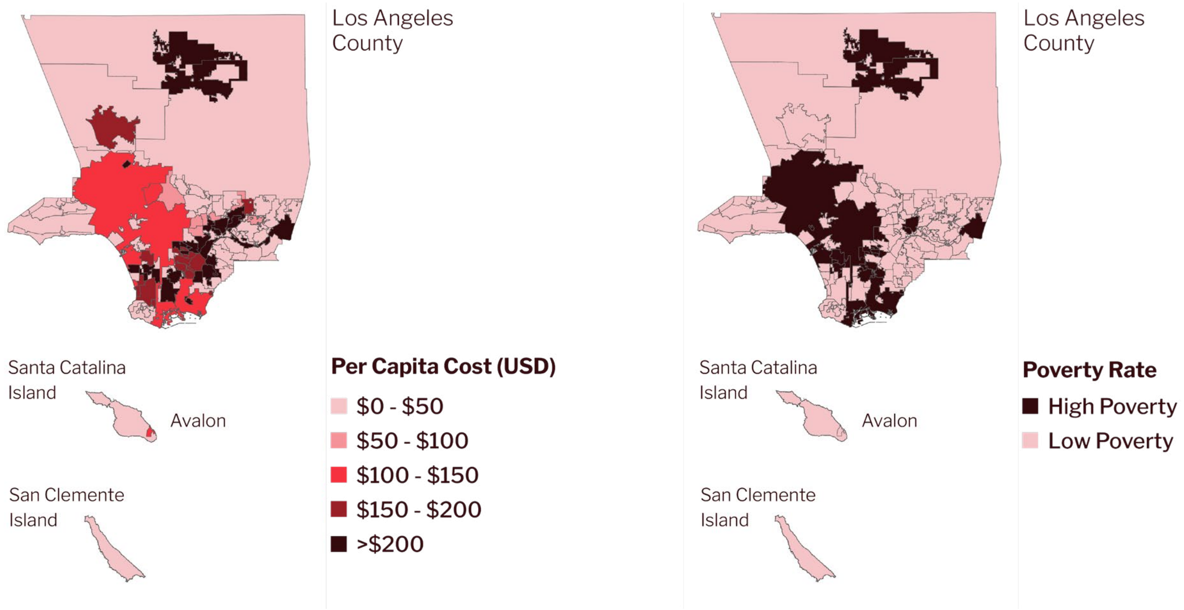
[14] Upgrading air conditioning capacity, the sixth temperature adaptation cost, will cost around $1 million, which is equivalent to 0% of the total cost. As such, it is not illustrated in the pie chart.

[15] The county is responsible for making metro rail tracks more resilient to increased temperature through application of reflective paint. As such, this cost is not reflected in this table.

The inequitable impact of climate change is apparent when it comes to the costs of combating urban heat islands across Los Angeles County. Heat islands are typically more prevalent in low income areas with higher than average populations of non-Hispanic Black and Hispanic residents[16] that have historically received less investments in green space. Because of this deficit, these areas of the county will require greater investment costs to combat the rising risk of heat. While the average per capita tree planting cost for the county is $136.54, high Hispanic and high non-Hispanic Black areas of the county face $185.76 and $156.83 per capita planting costs, respectively. Areas of the county with a higher than average non-Hispanic white population[17] face $59.86 per capita to plant trees through 2040. It will cost the City of Los Angeles about $28 million per year to increase green space by planting and maintaining trees, which is equal to the city's entire Street Tree and Parkway Maintenance Appropriated Budget for 2024.[18]

Figure 6: Per capita costs to combat urban heat islands through planting and maintaining urban trees (increasing urban canopy) across Los Angeles County (left). Areas with high poverty rate (above 13.9%) across Los Angeles County correspond to areas with higher per capita urban canopy costs (right).



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[16] Municipalities that are high non-Hispanic Black have more than 7.9% non-Hispanic Black populations and municipalities that are high Hispanic have more than 48% Hispanic populations.

[17] Municipalities that have above average non-Hispanic white populations have more than 32.5% non-Hispanic white populations.

[18] City of Los Angeles, "LA City Open Budget: Bureau of Street Services," 2024, https://openbudget.lacity.org/#!/year/2024/operating/0/department_name/Bureau+of+Street+Services/0/program_name.

Cost to Adapt to Changes in Precipitation

$4.5 Billion

Studies show that climate change will increase the number of severe storms and extreme wet years,[19] creating bouts of significant rainfall that will increase flood risk in Los Angeles County.[20] This shift can already be observed: a series of major storms hit Los Angeles County in the winter of 2023-24, flooding streets, creating life-threatening conditions, and revealing how the region's stormwater system is unprepared for the increasing threat of precipitation.[21] Expanding stormwater drainage capacity to manage this increase in rainfall is the most expensive climate adaptation cost analyzed by this report facing the Los Angeles County area. To mitigate the impacts of climate-driven rainfall, communities in Los Angeles County will face $4.3 billion to expand stormwater drainage infrastructure, like installing bioswales and porous pavement, through 2040. These 'green infrastructure' upgrades are the least expensive option to cope with increasing extreme rainfall events, and easier to implement in urban areas where increasing the size and scale of hard infrastructure like drain pipes is far more expensive and unwieldy. Investing in green infrastructure represents 94% of the total precipitation-related costs calculated by this report.

Water Treatment

While Los Angeles County can expect an increase in heavy rainfall, a changing climate will also contribute to an increase in drought conditions. Times of drought lead to an increase in sediment and nutrient concentration in drinking water, which causes additional drought-induced water treatment costs. Los Angeles County will experience an annual average of 1.4 more months of climate-induced drought from 2024 through 2040 compared to the baseline period of 1965 through 2014. If residents are restricted to 80 gallons of water per day per person, as they are encouraged to during times of drought,[21] it will cost Los Angeles County about $130 million more to treat residential water from 2024 through 2040. However, if Los Angeles County residents do not cut water use and continue to use their average of 120 gallons per person per day[22] during times of drought, it will cost the region $176 million more to treat the water over the next 17 years.

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[19] Lu Dong et al., "Contributions of Extreme and Non-Extreme Precipitation to California Precipitation Seasonality Changes Under Warming," *Geophysical Research Letters* 46, no. 22 (2019): 13470–78, https://doi.org/10.1029/2019GL084225.

[20] Alex Hall et al., "California's Fourth Climate Change Assessment: Los Angeles Region Report," University of California, Los Angeles, 2019, https://www.energy.ca.gov/sites/default/files/2019-11/Statewide_Reports-SUM-CCCA4-2018-013_Statewide_Summary_Report_ADA.pdf.

[21] Andrew Freedman, "Deadly Storm Pummeling California Dumps Historic Rains over LA," *Axios*, February 7, 2024, https://www.axios.com/2024/02/05/california-storm-floods-los-angeles.

[22] Hayley Smith and Ian James, "To Survive Drought, Parts of SoCal Must Cut Water Use by 35%. The New Limit: 80 Gallons a Day," *Los Angeles Times*, April 30, 2022, sec. California, https://www.latimes.com/california/story/2022-04-30/can-you-get-by-on-just-80-gallons-of-water-a-day.

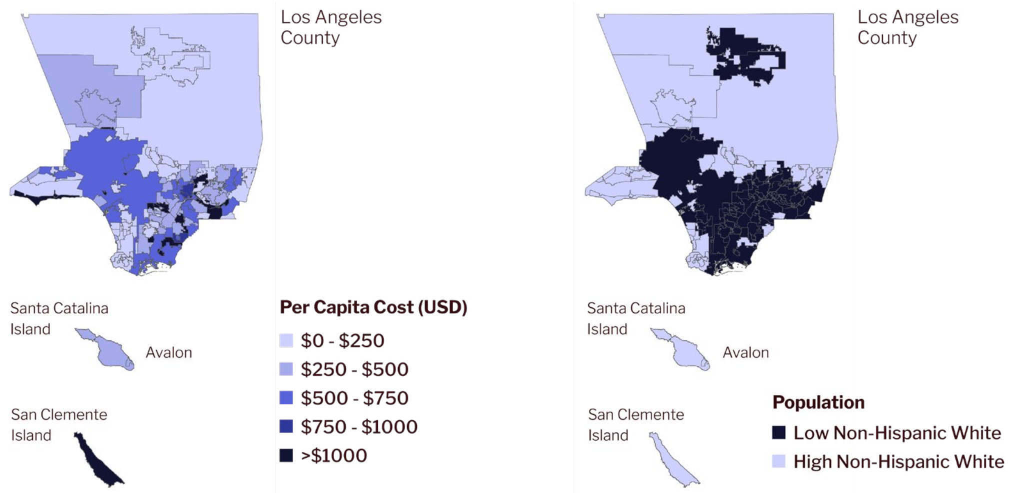
[23] "Our County Water Briefing," 2018, https://ourcountyla.lacounty.gov/wp-content/uploads/2018/08/Our-County-Water-Briefing_For-Web.pdf.

Table 3: Local governments facing highest costs from three precipitation-related climate impacts through 2040.

Rank	Municipality	Total Cost	Municipal Cost	County Cost	State Cost
1	Los Angeles	$2,048,702,000	$2,048,702,000	N/A	N/A
2	Long Beach	$250,566,000	$250,566,000	N/A	N/A
3	Santa Clarita	$141,432,000	$122,268,000	$1,640,000	$17,524,000
4	El Monte	$91,147,000	$91,147,000	N/A	N/A
5	Lakewood	$84,280,000	$84,280,000	N/A	N/A

On average, mitigating the impact of increased rainfall by increasing stormwater drainage capacity will cost the region about $252 million per year from 2024 through 2040. Some municipalities could be especially hard hit. In Santa Clarita, it will cost about $6 million per year to mitigate the rising flood risk by increasing stormwater drainage capacity, equivalent to 121% of the city's Stormwater Utility budget for 2023-2024."[24] In the City of Los Angeles, the annual cost of about $118 million is nearly four times the city's Capital Improvements - Flood Control budget for 2024.[25] The per capita costs are also expected to be higher for communities that have greater non-white populations compared to areas of the county with predominantly white populations.[26]

Figure 7: The per capita cost for each municipality across Los Angeles County to increase stormwater drainage capacity from 2024 through 2040. The largest per capita costs will be incurred by residents in urban areas with large amounts of impervious surfaces (left). Areas with low non-Hispanic white populations (below 32.5%) across Los Angeles County correspond to areas with higher per capita costs to increase stormwater drainage capacity (right).



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[24] City of Santa Clarita, "Annual Operating Budget & Capital Improvement Program: FY2023-2024," 2023, https://filecenter.santa-clarita.com/cmo/FY%202023-24%20Budget%20-%20opt.pdf.

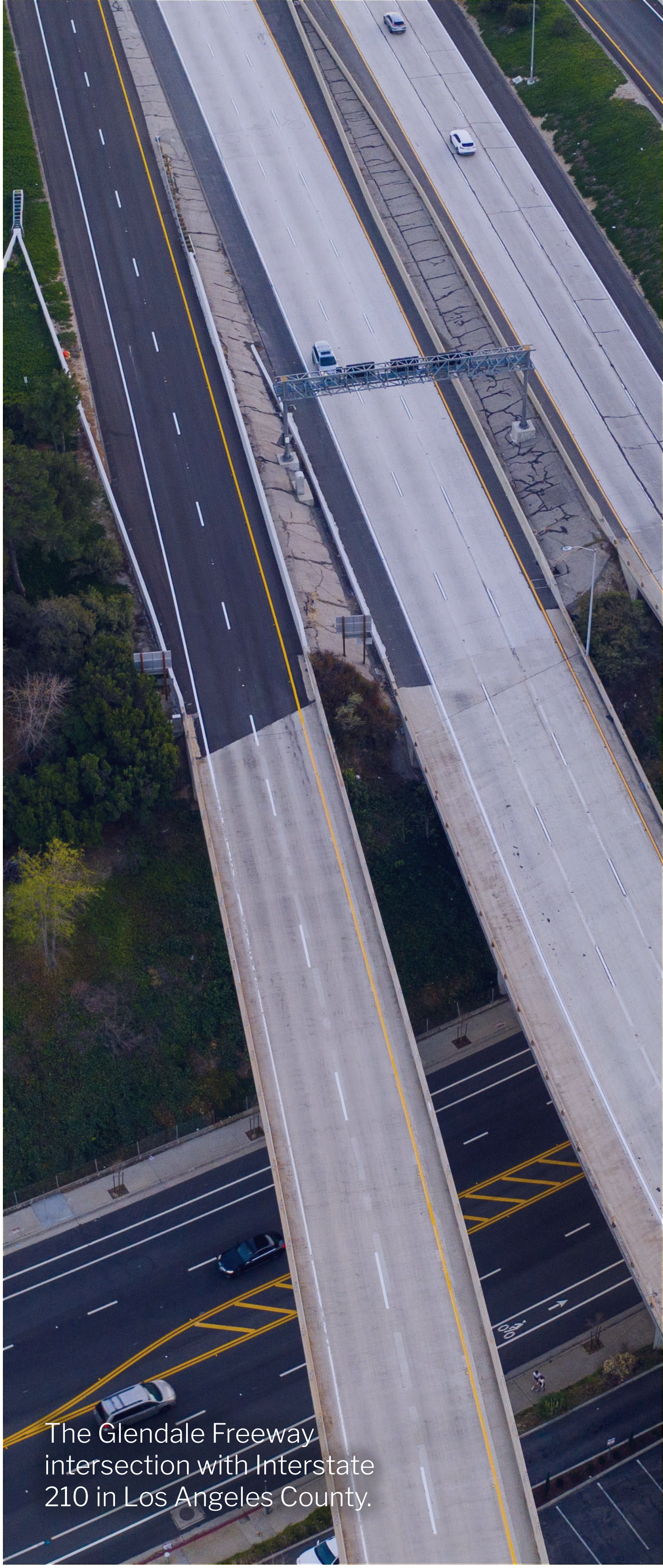
[25] City of Los Angeles, "LA City Open Budget: Capital Improvements - Flood Control," 2024, https://openbudget.lacity.org/#!/year/2024/operating/0/program_name/Capital+Improvements+-+Flood+Control/0/department_name?vis=barChart.

[26] Predominantly white areas are areas with ≥32.5% non-Hispanic white population (see Appendix G.1; Table G4).

Cost to Proactively Maintain Roads $680 Million

Climate change is brutal on roads. Higher temperatures soften road surfaces and increase degradation rates, making roadways cracked and rutted. Higher precipitation increases erosion, which weakens the road base and creates more maintenance demands in order to keep the infrastructure functioning as designed. Southern California will experience both from now through 2040. Even if regional governments take the less expensive, proactive approach to maintain the current service level of roads across the county, governments still face $680 million in climate-related adaptations for roads in the Los Angeles County area through 2040. Like the other analyses in this report, this cost only covers adapting to climate-impacts on roads and does not include costs that may be associated with additional unexpected climate disasters.

The City of Los Angeles faces the highest costs of proactive road investments at $164 million through 2040. It will cost the city $10 million per year to proactively maintain its municipal roads, which is comparable to 8.5% of the City of Los Angeles' 2024 $112 million budget for pavement preservation.[27]



The Glendale Freeway intersection with Interstate 210 in Los Angeles County.

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[27] City of Los Angeles, "LA City Open Budget: Pavement Preservation," 2024, https://openbudget.lacity.org/#!/year/2024/operating/0/department_name/Bureau+of+Street+Services/0/program_name/Pavement+Preservation/0/source_fund_name.

Table 4: Top five municipalities with the greatest difference in total reactive vs. proactive road maintenance costs from 2024 through 2040.

Municipality	Reactive Cost	Proactive Cost	Difference in Cost	Percent Increase
Los Angeles	$356,012,000	$185,842,000	$170,170,000	92%
Glendale	$33,329,000	$21,233,000	$12,096,000	57%
Santa Clarita	$44,632,000	$33,614,000	$11,018,000	33%
Downey	$13,428,000	$4,633,000	$8,795,000	190%
Torrance	$17,248,000	$9,713,000	$7,535,000	78%

Freeway overpasses in Los Angeles County.

Cost to Mitigate Wildfires

$919 Million

Los Angeles County will face an average of 36 more high fire days[28] through 2040 and up to 58 more high fire days in certain areas like West Los Angeles under a moderate climate change scenario, as compared to a baseline of high fire days from 1994 to 2013. Wildfires regularly wreak havoc on the county. The Woolsey Fire in 2018 burned nearly 100,000 acres, destroyed more than 1,000 residential and commercial buildings, and killed three people, not to mention the additional health damages that result from wildfire smoke.[29] It's estimated the Woolsey Fire cost between $3 to $5 billion in insured losses alone.[30] In the past two years, two major insurance companies have stopped writing home and business insurance policies in California, citing increasing wildfire risk and the massive cost recovery associated with it.[31]

Wildfire mitigation through mechanical intervention, or clearing fuel from land around infrastructure in Los Angeles County will cost municipal, county, state, and federal governments $919 million from 2024 through 2040. Antelope Valley, an unincorporated community at the western tip of the Mojave Desert, will face the highest preventative costs at $356 million.

Wildfire scorches the Santa Clarita Valley: August 2016.

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[28] High fire days are defined by the KBDI index. See methods section for more information.

[29] "Los Angeles County, California," Community Planning Assistance for Wildfire, accessed March 6, 2024, https://cpaw.headwaterseconomics.org/project/los-angeles-county-california/.

[30] Ibid.

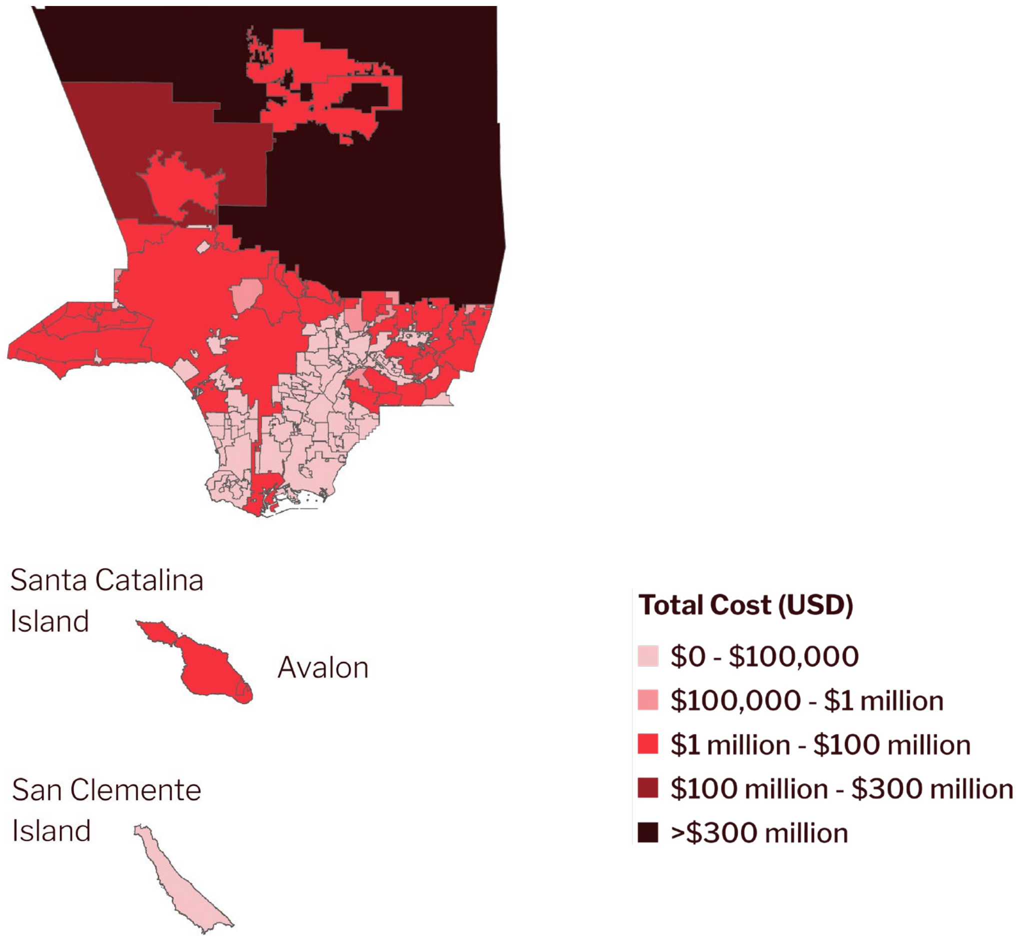
[31] Michael R. Blood, "California Insurance Market Rattled by Withdrawal of Major Companies," *AP News*, June 5, 2023, https://apnews.com/article/california-wildfire-insurance-e31bef0ed7eeddcde096a5b8f2c1768f.

The costs to fight and recover from wildfires are dramatically higher than the costs to mitigate wildfire impacts presented here.

Table 5: Local governments facing highest costs to mitigate wildfires through 2040.

Rank	Municipality	Total Cost	Municipal Cost	County Cost	State Cost	Federal Cost
1	Antelope Valley	$355,828,000	N/A* *unincorporated	$91,409,000	$260,932,000	$3,487,000
2	Santa Clarita Valley	$146,952,000	N/A* *unincorporated	$777,000	$145,069,000	$1,106,000
3	Santa Monica Mountains Coastal Zone	$83,233,000	N/A* *unincorporated	$41,000	$82,128,000	$1,064,000
4	Los Angeles	$46,963,000	$49,748,000	N/A* *incorporated	$189,000	$26,000
5	Santa Clarita	$48,875,000	$48,709,000	N/A* *incorporated	$116,000	$50,000

Figure 8: The total cost by municipality for wildfire mitigation from 2024 through 2040. The costs are concentrated in areas near the wildland-urban interface and largely affect unincorporated areas.



Cost to Protect Infrastructure from Sea Level Rise $576 Million

By 2050, sea levels are expected to rise by about one foot along the Los Angeles County coast,[32] putting coastal communities at greater risk for flooding and other infrastructure damage. Investing in coastal protection to mitigate the risk of rising seas will cost the region approximately $576 million.[33] The costs could be broken down to an annual price of about $34 million, which is equivalent to 34% of Los Angeles County's FY2023 Beaches & Harbors budget.[34]

High tides erode berms in Long Beach during Tropical Storm Kay: September 10, 2022.

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[32] William V. Sweet et al., "Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines" (National Ocean Service, Silver Spring, MD: National Atmospheric and Oceanic Administration, 2022), https://aambpublicoceanservice.blob.core.windows.net/oceanserviceprod/hazards/sealevelrise/noaa-nos-techrpt01-global-regional-SLR-scenarios-US.pdf.

[33] Sverre LeRoy et al., "High Tide Tax: The Price to Protect Coastal Communities from Rising Seas" (Center for Climate Integrity and Resilient Analytics, 2019), https://climatecosts2040.org/files/ClimateCosts2040_Report.pdf.

[34] LA County, "LA County Open Budget Appropriation (Auditor-Controller)."

Cost to Treat Climate-Induced Public Health Threats $1.1 Billion

As climate change alters temperatures, precipitation rates, and other weather patterns in the Los Angeles area, ecological conditions that contribute to various insect populations — and the corresponding diseases they carry — will also shift. Increasing populations of mosquitoes are expected to lead to about 500,000 new cases of West Nile Virus in Los Angeles County from 2024 through 2040, infecting about 5% of the population. This is equivalent to a 270% increase in West Nile Virus cases in Los Angeles County in 2040 as compared to 2024, which will cost an estimated $993 million to treat, or 92% of the total public health cost estimated in this study.

Climate change will also lead to an increase in pollen, leading to higher rates of pediatric asthma. **We estimate there will be about 160,000 new cases of pediatric asthma in Los Angeles County from 2024 through 2040, or about a 60% increase in cases in 2040 as compared to 2024.**

These findings only consider pediatric asthma triggered by increased allergen levels due to increased temperature. Wildfire- and other climate-induced pediatric asthma cases were not analyzed in this study, but they also pose a significant risk to children in the Los Angeles County area.

The yearly average treatment cost for both West Nile Virus and pediatric asthma cases in Los Angeles County is about $64 million from 2024 through 2040.

Comparison of Costs Across Governments

The majority of the climate adaptation costs analyzed in this report — about $9.2 billion — are expected to fall on municipal governments in Los Angeles County. Adaptation costs in the unincorporated areas of the county — areas that do not have a local municipal government — will fall on the county itself, ballooning Los Angeles County's climate adaptation costs through 2040 to about $1.5 billion, or to about $86 million annually, which is roughly 60% of the county's yearly municipal services budget.[35] The state will be responsible for $781 million and the federal government will face $1.1 billion in costs to adapt to the 14 climate impacts analyzed in this report.

Conclusion and Recommendations

This report identifies at least $12.5 billion in climate adaptation and resilience costs that governments in Los Angeles County face through 2040. These figures capture only a portion of the total bill that major climate polluters have racked up for local taxpayers. Without seeking other funding options, the burden of paying for these necessary measures will fall on the same residents who are suffering from intense flooding, deadly heat, and threatened infrastructure. In reality, local governments — and their taxpayers — will simply not be able to afford these costs to protect communities and infrastructure.

Los Angeles County communities that are suffering the most from the climate crisis did not create it — fossil fuel companies did. Just 100 companies are responsible for more than 70% of global carbon emissions since 1988, with ExxonMobil, Shell, Chevron, and BP ranking among the most egregious polluters.[36] It's only fair that major polluters that knowingly caused and profited from the climate crisis pay their share of the resulting costs.

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[35] Ibid.

[36] Paul Griffin, "New Report Shows Just 100 Companies Are Source of over 70% of Emissions," CDP, July 2017, https://www.cdp.net/en/articles/media/new-report-shows-just-100-companies-are-source-of-over-70-of-emissions.

When state and local governments have sought to hold corporations accountable and recover costs incurred by harmful products, they often turn to the courts. Successful legal actions to make tobacco companies, opioid manufacturers, and other deceitful actors pay for the damages they've caused provide a useful model.

In 2023, the State of California took legal action, suing BP, Chevron, ConocoPhillips, Exxon, Shell, and the American Petroleum Institute for climate damages and fraud. Previously in 2017 and 2018, eight California municipal governments — the counties of San Mateo, Santa Cruz, and Marin, as well as the cities of San Francisco, Oakland, Richmond, Santa Cruz, and Imperial Beach — filed suits to recover climate costs from many of the same defendants. Those cases are all advancing in varying stages in state court. Across the country, a growing number of state and local governments are taking legal action to hold oil majors accountable for the cost to protect communities from climate harms.

Los Angeles County municipal leaders have an opportunity to take bold action to protect their residents by holding fossil fuel companies accountable and demanding these polluters pay their fair share of the crisis they imposed on these communities.

Wildfire smoke visible above hills in Los Angeles County.

Appendix

Appendix A: Supplemental Information

Appendix A.1: Adaptation Definitions

Table A1: This report estimates the cost of 14 climate change adaptation strategies that Los Angeles County taxpayers will face, defined in the table below. Note that this report is not exhaustive and Los Angeles County taxpayers will likely incur further costs as a result of additional climate change adaptation strategies not assessed herein.

Climate Impact	Adaptation	Explanation	Taxpayer Costs	Analysis Method	Appendix
Increased temperature	Upgrading heating and cooling infrastructure.	Cost to upgrade HVAC system capacity in 100% of public buildings to cope with the need for increased usage due to climate change. Note we assume 100% of public buildings in Los Angeles County already have HVAC systems installed.	Municipal, county, state	One time cost	C.1
Increased temperature	Estimating the change in energy costs to heat and cool public buildings.	Changes in energy costs are estimated based on the number of days below (heating) or above (cooling) a certain threshold as compared to the climate baseline.	Municipal, county, state	Time series	C.1
Increased temperature	Expanding and operating cooling centers.	To help residents escape the increasing summer heat, cooling centers will need to be expanded and operated. The cost of opening and operating cooling centers due to increased days with temperatures above 80°F, as compared to the climate baseline are estimated.	Municipal (incorporated) and county (unincorporated)	Time series	C.2
Increased temperature	Planting and maintaining urban trees.	Planting trees can help decrease ambient air temperature by cooling the air through evapotranspiration. The adaptation is planting and maintaining trees in urban areas and accounts for both initial costs and yearly maintenance costs. The initial costs include labor and materials. The maintenance costs include water, fertilizer, pruning, and pest spraying.	Municipal	Time series	C.3
Increased temperature	Implementing cool pavements in public parking lots.	Converting existing areas of pavement to high-albedo cool pavement has been shown to decrease proximal ambient temperature and is a complementary approach to combat increased summer temperatures in urban areas. The cost to convert public parking lots to cool pavements is estimated.	Municipal	Time series	C.4

Climate Impact	Adaptation	Explanation	Taxpayer Costs	Analysis Method	Appendix
Increased temperature and precipitation	Proactively and reactively fixing roads.	When pavement temperature rises above its mixture threshold, increased degradation occurs. In the reactive scenario, this increased cracking requires more maintenance to avoid a decrease in the projected lifespan of the road. In the proactive scenario, adaptation includes installation of roads with pavement rated to projected future temperatures. Excess precipitation above what the road was designed to handle can also increase degradation. Road maintenance costs are informed by the percentage decrease in lifespan based on the level of projected damage as compared to the climate baseline. In the proactive road scenario, adaptation requires a strengthening the roadbase to resist the increased potential for erosion. In the reactive road scenario, adaptation is fixing roads after precipitation-induced damage.	Municipal, county, state	Time series	C.5
Increased high fire days	Implementing mechanical wildfire mitigation in intermix areas.	Mechanical intervention focuses on reducing fuel for a fire by manually cutting and removing undergrowth, as well as thinning the density of forested area. Due to an increase in the number of fire days (i.e., length of the fire season), controlled burns are not as feasible, as the available time for a controlled burn is being significantly reduced. Mechanical intervention costs $1,500 per acre.	Municipal, state, federal Unincorporated municipal costs assigned to the county.	Twice per decade	C.6
Increased temperature	Painting the metro rail tracks with high-albedo paint.	Los Angeles can avoid metro rail slow downs and shut downs by painting the tracks with a high-albedo (light reflecting) paint to keep the tracks cool. Australia, Italy, and Switzerland already implement this technique with success. For optimal results, we assume that Los Angeles should paint their rails every year.	County	Once per year	C.7

Climate Impact	Adaptation	Explanation	Taxpayer Costs	Analysis Method	Appendix
Increased precipitation	Installing drainage & stormwater infrastructure.	To combat increased inflow to the wastewater treatment plants, we estimate the cost to increase drainage area by implementing drainage & stormwater infrastructure. Drainage & stormwater infrastructure includes bio retention, porous pavement, bioinfiltration, and bioswale construction.	Municipal (incorporated) and county (unincorporated)	Time series	D.1
Increased precipitation	Proactively adapting bridges.	As rivers flow faster during extreme precipitation events, bridges will degrade faster due to enhanced scour. To combat enhanced damage to bridges, we estimate the cost to proactively rehabilitate bridges in order to prevent disruption. Rehabilitation consists of applying riprap to stabilize bridges and additional concrete to strengthen piers and abutments.	Municipal, county, state	One time cost	D.2
Increased drought	Increased drinking water treatment.	Drought increases sediment and nutrient concentration in drinking water. As such, municipalities incur drought-induced increased drinking water treatment costs. The cost has been estimated at $94.75 per million gallons more than water treatment during non-drought times. We estimate the excess cost to treat 80 gallons per capita for Los Angeles residents during the projected increase in drought conditions as compared to the climate baseline.	Municipal (incorporated) and county (unincorporated)	Time series	D.3
Sea Level Rise	Install coastal protection.	High tide flooding, storm surge, and coastal erosion from sea level rise threaten coastal infrastructure. We estimate the cost to protect critical infrastructure along Los Angeles County's coastline with seawalls.	County	One time cost	E
Public Health: Increased temperature	Increased costs from pediatric asthma hospital visits.	Increased temperatures correlates to increased pollen levels, which lead to more cases of pediatric asthma that require emergency room visits. We estimate the government-incurred cost of increased pediatric asthma visits as compared to the climate baseline.	Federal	Time series	F.1

Climate Impact	Adaptation	Explanation	Taxpayer Costs	Analysis Method	Appendix
Public Health: Increased temperature and increased precipitation	Initial and long-term costs to treat increased West Nile Virus manifestations.	Mosquitoes thrive in warm temperatures and near water, so increased temperatures and precipitation due to climate change will make West Nile Virus more prevalent. We estimate the increased government-incurred cost to treat both initial and long-term manifestations of West Nile Virus.	Federal	Time series	F.2

Appendix A.2: How to read this report.

In the report, we present municipal, county, state, federal, and total costs to adapt to climate change. We break down what each of these costs mean below:

Municipal Costs: Costs we assume will be incurred by the city/town government. When we cannot assign costs to specific government entities, we assume that municipalities are incurring the entirety of the cost. For example, the available data limit our ability to precisely assign the costs for increasing stormwater drainage capacity across multiple levels of government. As a result, we assume 100% of these costs will fall on the municipality, though we recognize that in some cases, the county, state, or federal government may incur some portion of this cost.

County Costs: Costs we can directly assign to Los Angeles County. We assume unincorporated municipalities cannot incur municipal costs and therefore assign those costs to the county.[1] Throughout the report, unincorporated municipalities will have $0 in municipal costs for all impacts analyzed. We also assign costs to the county when the data inventory allows us to assign ownership of structures and/or services to the county. In the case of metro rail, we assign all costs to the county because the county owns and operates this service.[2] Seawall costs are also aggregated county-wide, based on cost estimates from a previous study that calculated costs based on “census designated place.”

State Costs: Costs we can assign directly to the State of California. We assign state costs when the data inventory allows us to assign ownership of land, structures, and/or services to the state.

Federal Costs: Costs we can assign directly to the Federal government. We assign federal costs when the data inventory allows us to assign ownership of land and health care costs to the federal government.

Total Costs: The aggregate of municipal, county, state, and federal costs for the 14 impacts included.

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[1] Public Works Los Angeles County, “Municipal Services,” LA County Public Works, 2024, https://content.pw.lacounty.gov/core-service-areas/municipal-services/.

[2] CALCOG, “Los Angeles County Metropolitan Transportation Authority (Metro),” California Association of Councils of Governments, July 17, 2020, https://calcog.org/los-angeles-county-metropolitan-transportation-authority-metro/.

Table A2: The 14 climate adaptations and the government entities we assign the costs to.

Climate Impact	**Adaptation**	**Taxpayer Costs**
Increased temperature	Upgrading heating and cooling infrastructure.	Municipal, county, state
	Estimating the change in energy costs to heat and cool public buildings.	Municipal, county, state
	Expanding and operating cooling centers.	Municipal (incorporated) and county (unincorporated)
	Planting and maintaining urban trees.	Municipal
	Implementing cool pavements in public parking lots.	Municipal
	Painting the metro rail tracks with high-albedo paint.	County
Changes in precipitation	Installing drainage & stormwater infrastructure.	Municipal (incorporated) and county (unincorporated)
	Proactively adapting bridges.	Municipal, county, state
	Increased drinking water treatment due to drought.	Municipal (incorporated) and county (unincorporated)
Increased temperature and increased precipitation	Proactively and reactively fixing roads.	Municipal, county, state
Increased high fire days	Implementing mechanical wildfire mitigation in intermix areas.	Municipal, state, federal Unincorporated municipal costs assigned to the county
Sea Level Rise	Install coastal protection.	County
Public Health: Increased temperature	Increased costs from pediatric asthma hospital visits.	Federal
Public Health: Increased temperature and increased precipitation	Initial and long-term costs to treat increased West Nile Virus manifestations.	Federal

Appendix A.3: Other costs Los Angeles County may incur due to climate change.

Table A3: Climate change impacts the Los Angeles County area faces and some of the potential costs associated with these impacts. **Items in bolded text were analyzed in this report.** This list is not exhaustive and other costs may be incurred as a result of additional climate change impacts.

Climate Impact	Category	Potential Costs Incurred by Communities in Los Angeles County
Increased Precipitation	Structure and Infrastructure Projects	Remove, relocate, acquire, or demolish structures to minimize future flood losses.
		Install, reroute, increase capacity, or implement a routine cleaning plan of the storm drainage system.
		Add extra culverts, increase dimensions of existing culverts, or implement routine cleaning and repairing.
		Install detention or retention basins, relief drains, spillways, drain widening/dredging or rerouting, etc.
		Inspect and maintain drainage systems and flood control structures (dams, levees, etc.).
		Inspect bridges in order to identify and/or implement repairs or retrofits or clean under low bridges.
		Resurface roads with more permeable pavement and concrete.
		Elevate roads and bridges above the base flood elevation (BFE)[3] to maintain dry access.
		Elevate structures above the BFE, or relocate utilities, water heaters, etc. above BFE.
		Floodproof inside of municipal buildings, for example by installing check valves, sump pumps, or backflow prevention devices.
		Floodproof wastewater treatment facilities located in flood hazard areas.
		Floodproof water treatment facilities located in flood hazard areas.
		Protect emergency operations by requiring or moving all emergency operations centers, police stations, and fire department facilities outside of flood-prone areas.
		Protect critical and emergency facilities by requiring all critical facilities be built one foot above the 500-year flood elevation (to meet requirements of FEMA Executive Order 11988).[4]
		Protect critical and emergency facilities from floods using any other technique, for example, raising components above BFE, installing pumping systems or back-up generators for pumping, building dikes, or stabilizing banks.
		Construct floodwalls, small berms, revetments, bioengineered bank stabilization, or other small structural mitigants.
	Natural Flood Mitigation	Protect and enhance natural floodplain mitigation features (such as wetlands, dunes, and vegetative buffers) to help prevent flooding in other areas.

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[3] Base flood elevation (BFE), as defined by FEMA, is "the elevation of surface water resulting from a flood that has a 1% chance of equaling or exceeding that level in any given year."

[4] Federal Emergency Management Agency, "Executive Order 11988: Floodplain Management," www.fema.gov/executive-order-11988-floodplain-management.

Climate Impact	Category	Potential Costs Incurred by Communities in Los Angeles County
	Local Planning and Regulation	Update flood risk maps and flood zones.[5]
		Develop a floodplain management plan.
		Adopt a stormwater management or drainage plan.
		Adopt, apply, and enforce building codes to ensure buildings can withstand flooding.
		Obtain easements to use privately-owned land for temporary water retention and drainage.
		Join or improve compliance with the National Flood Insurance Program (NFIP).[6]
		Apply for Floodplain Management, Protection, and Risk Awareness Grants through California Department of Water Resources.[7]
		Preserve floodplains as open space using any of several land use planning tools: develop a plan that targets hazard areas for acquisition, reuse, and preservation, a land banking program, use of transfer of development rights to keep floodplains vacant, easements to prevent development, or acquiring properties in the floodplain and turning them into open space.
	Education and Awareness Programs	Increase public outreach to encourage flood insurance purchase; educate residents in flood safety, flood mitigation, technical assistance availability, funding sources, and best practices.
		Locate new utilities and critical facilities outside of susceptible areas.
		Identify, map, or track erosion hazard areas.

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[5] Brett Sanders et al., "Large and Inequitable Flood Risks in Los Angeles, California," *Nature Sustainability* 6, no. 1 (2023): 47–57, https://doi.org/10.1038/s41893-022-00977-7.

[6] U.S. Federal Emergency Management Agency (FEMA), The National Flood Insurance Program (NFIP), at www.fema.gov/national-flood-insurance-program Policy Information by State (https://nfipservices.floodsmart.gov//reports-flood-insurance-data), accessed August 10, 2023; Los Angeles County only has one active NFIP policy in place, which covers $212,000. For comparison, Kern County has over 1,755 active policies covering over $390 million.

[7] California Department of Water Resources, "Floodplain Management, Protection, and Risk Awareness Grant Program," Accessed August 11, 2023, https://water.ca.gov/Work-With-Us/Grants-And-Loans/Flood-Management-Protection-Risk-Awareness-Program.

Climate Impact	**Category**	**Potential Costs Incurred by Communities in Los Angeles County**
Sea Level Rise	Structure and Infrastructure Projects	Stabilize susceptible coastal slopes and cliffs and shorelines using grading techniques, planting vegetation, riprap or geotextile fabric, or bioengineering.
		Refer to "Structure and infrastructure projects" from "Increased Precipitation," as they also apply here.
	Coastal Protection	Protect critical infrastructure using techniques like beach nourishment, jetties, and **seawalls**.
		Restore natural wetland areas.
	Local Planning and Regulation	Identify, map, and track coastal erosion and flood hazards.
		Develop and enforce a coastal zone management plan.
		Develop site and building standards.
		Other local planning and regulation as suggested by the Legislative Analyst's Office.[8]
	Education and Awareness Programs	Increase awareness by disclosing location of high-risk areas to current and future property owners; offer mitigation technique information.
		Locate new utilities and critical facilities outside of susceptible areas.
		Identify, map, or track erosion hazard areas.
		Other education and awareness programs as suggested by the Legislative Analyst's Office.[9]
Increased Temperature	Structure and Infrastructure Projects	Energy efficiency retrofits in public and private buildings and housing, including costs for the design and development of standards.
		Increased cooling costs for all public buildings, including green roofs or cool roofing systems on public buildings and new AC installation or upgrade costs for schools.
		Increased road damage due to more frequent extreme heat events.
		Plan for and increase capacity for increased energy demands due to both increased daytime and nighttime temperature.
		Increase high-albedo surfaces on buildings, roads, or where feasible.
	Public Health Projects	**Build and manage more cooling centers, including staffing and tracking of high-risk individuals.**
		Increased demand for publicly financed air conditioning targeted to low income families and public housing.
		Control the increase of vector borne illness – education and physical and chemical controls for ticks and mosquitoes.
		Treat victims of vector borne illness.
		Increase in asthma attacks requiring hospitalization (resulting from increased heat and ground level ozone, and the increase in airborne allergens).
		Reduce the urban heat island effect by planting trees.
		Protect drinking water supplies from hazardous algae blooms.

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[8] Gabriel Petek, "Preparing for Rising Seas: How the State Can Help Support Local Coastal Adaptation Efforts," Legislative Analyst's Office, 2019, https://lao.ca.gov/reports/2019/4121/coastal-adaptation-121019.pdf.

[9] Ibid.

Climate Impact	Category	Potential Costs Incurred by Communities in Los Angeles County
Increased Drought	Water Management	Individual purchase of water during water scarce times.[10]
		Public health costs related to increased exposure to water-borne illnesses.[11]
		Replace old pipelines that have water leak issues.[12]
		Use climate science to update water treatment, wastewater treatment, and other energy infrastructure.[13]
		Reinforce roads, bridges, and buildings to withstand prolonged drought.
	Wildfires	Increase fire suppression, including staffing and aviation.
		Rebuild or relocate damaged properties and public infrastructure, such as homes and utility lines.
		Relocate public infrastructure where necessary.
		Update power lines to withstand dust from wildfires.
		Implement fire mitigation strategies for the future like burying utility lines underground.
		Plan for and disburse community aid after wildfires.
		Implement fire detection strategies, like solar-powered sensors.[14]
		Rehabilitate the landscape post-fire to reduce the risk of erosion and invasive species and mitigate future fire risk.
		Increased hospitalization costs for asthma attacks and other chronic health conditions (resulting from decreased air quality due to wildfire smoke).
	Local Planning and Regulation	Organize meetings to create water scarcity management plans.[15]
		Develop tools for monitoring ground and surface water resources for public use.[16]
	Education and Awareness Programs	Public education, outreach, and awareness campaigns about water conservation.[17]
		Increase public outreach to encourage wildfire risk management; educate residents in wildfire safety, technical assistance availability, funding sources, and best practices.
Other Extreme Weather	Structure and Infrastructure Projects	Increased costs of storm recovery and clean-up.
		Protect power lines through pruning trees.
		Bury overhead power lines or install systems that allow small sections of power lines to fail rather than the complete system.

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[10] Zoë Roller et al., “Closing the Water Access Gap in the United States: A National Action Plan,” Dig Deep and US Water Alliance, 2022, https://static1.squarespace.com/static/5e80f1a64ed7dc3408525fb9/t/6092ddcc499e1b6a6a07ba3a/1620237782228/Dig-Deep_Closing-the-Water-Access-Gap-in-the-United-States_DIGITAL_compressed.pdf.

[11] Ibid.

[12] “Drought and Infrastructure - A Planning Guide” (Cybersecurity and Infrastructure Security Agency with the National Drought Resilience Partnership, 2021), https://www.cisa.gov/sites/default/files/publications/Drought_and_Infrastructure_A_Planning_Guide_508c.pdf.

[13] Ibid.

[14] Jennifer L, “Wildfires Cost Over $148B and 30% of Emissions,” Carbon Credits, January 30, 2023, https://carboncredits.com/wildfires-cost-emissions/; Western Fire Chiefs Association, “What Is the Financial Cost of a Wildfire?,” December 7, 2022, https://wfca.com/articles/cost-of-wildfires/.

[15] CISA, “Drought and Infrastructure - A Planning Guide.”

[16] Ibid.

[17] Ibid.

Climate Impact	Category	Potential Costs Incurred by Communities in Los Angeles County
Other Public Health Costs	Education and Awareness and Treatment	Increased allergen levels, food- and waterborne infections, and zoonotic diseases.[18]

Appendix A.4: City of Los Angeles.

We recognize that many cities across Los Angeles County have neighborhoods with vastly different demographic characteristics. To capture the disproportionate impacts on these demographics, we present a small case study of the City of Los Angeles that demonstrates some of the demographic differences within municipalities that should be accounted for when thinking about climate change and the costs associated with adaptation strategies (Table A4).

Table A4: Demographic characteristics for the City of Los Angeles. The minimum and maximum characteristic at the census tract level is presented along with the population-weighted mean characteristic, which was used in the equity analysis for this study.
The City of Los Angeles faces a per capita cost of $964.60 to adapt to the 14 climate impacts analyzed in this study. Demographic characteristics and social vulnerabilities vary widely across the city (Table A4; Figure A1). Therefore, it is likely that the per capita cost to adapt to climate change will be felt differently by residents within the city.

Demographic Characteristic	Minimum	Maximum	Weighted Mean
Median Household Income	$0	$250,001	$71,570
Poverty Rate	0%	100%	15%
Percent Non-Hispanic White	0%	94%	29%
Percent Non-Hispanic Black	0%	84%	8.5%
Percent Non-Hispanic Asian	0%	80%	12%
Percent Hispanic	0%	100%	47%
Percent without a High School Degree	0%	76%	21%
Percent with Limited Access to Internet	0%	100%	11%
Percent Disabled	0%	100%	10%
Percent Uninsured	0%	50%	11%
Percent Foreign Born	0%	82%	36%

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[18] Carmen Milanes et al., "Indicators of Climate Change in California," Office of Environmental Health Hazard Assessment, 2022, https://oehha.ca.gov/media/downloads/climate-change/report/2018caindicatorsreportmay2018.pdf.

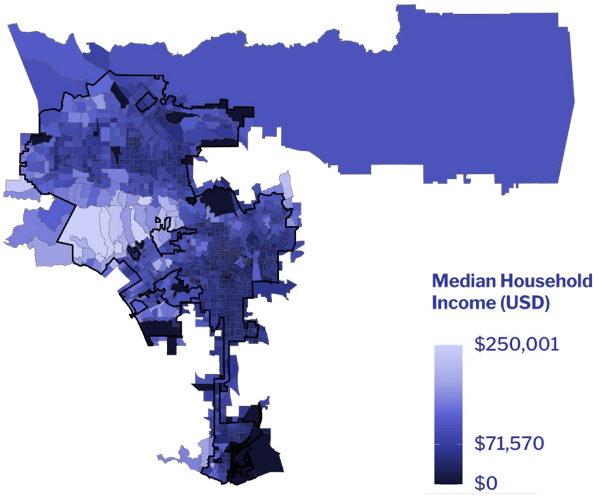

Figure A1: The black outline shows the Municipal boundary of the City of Los Angeles. Census tract bounds (gray) are colored by median household income. The map shows that in the City of Los Angeles, some census tracts have a median household income of $0, while others have a median household income of around $250,000. Dark blue areas highlight the census tracts in the City of Los Angeles that have lower household income than the citywide weighted average median household income ($71,570).

Appendix B: Climate Baselines

The climate projections in this report are derived from the Localized Constructed Analogs (LOCA) statistically downscaled Coupled Model Intercomparison Project Phase 6 (CMIP6) climate projections for North America. We selected different climate variables at 1/16th of a degree (approximately 3.7 mile^2) resolution[19] for 23 global climate models (GCMs) under a moderate greenhouse gas and aerosol emission scenario (Shared Socioeconomic Pathway 2-4.5 [SSP2-4.5]). In the report, the 50th percentile of the 23 model outputs is presented for each of the analyses. The projection time period used is a 17-year period that estimates total costs incurred through 2040 (2024-2040). We also make the data available for download. In the data download, the estimated cost through 2040 and through 2060 are presented. The projection time period for the 2060 cost is typically a 20-year period (2041-2060). The cost estimates for both time periods are also based on the 50th percentile of the 23 model outputs for SSP2-4.5 for each analysis. The climate baseline for temperature-related analyses in this study is derived from Livneh et al. (2015).[20] The climate baseline for precipitation-related analyses in this study is derived from Pierce et al. (2021).[21] We use at least a 20-year baseline time period for all analyses presented. A shapefile of Los Angeles County municipal boundaries is used throughout the study.[22]

We present a cumulative cost over the projection time period for all costs. The two main ways adaptation costs are estimated are either as a time series (Table A1) or assessed once in 2040 and then again in 2060 (one time costs; Table A1). Two adaptations, mechanical intervention for wildfires and painting metro rail tracks, are one time costs but are incurred twice per decade or once per year, respectively (Table A1).

We assume all municipal costs incurred in unincorporated municipalities are incurred instead by the county.

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[19] David W. Pierce, Daniel R. Cayan, and Bridget L. Thrasher, “Statistical Downscaling Using Localized Constructed Analogs (LOCA),” *Journal of Hydrometeorology* 15, no. 6 (December 1, 2014): 2558–85, https://doi.org/10.1175/JHM-D-14-0082.1; David W. Pierce et al., “Improved Bias Correction Techniques for Hydrological Simulations of Climate Change,” *Journal of Hydrometeorology* 16, no. 6 (December 1, 2015): 2421–42, https://doi.org/10.1175/JHM-D-14-0236.1.

[20] Ben Livneh et al., “A Spatially Comprehensive, Hydrometeorological Data Set for Mexico, the U.S., and Southern Canada 1950–2013,” *Scientific Data* 2, no. 1 (August 18, 2015): 150042, https://doi.org/10.1038/sdata.2015.42.

[21] David W. Pierce et al., “An Extreme-Preserving Long-Term Gridded Daily Precipitation Dataset for the Conterminous United States,” *Journal of Hydrometeorology* 22, no. 7 (July 1, 2021): 1883–95, https://doi.org/10.1175/JHM-D-20-0212.1.

[22] County of Los Angeles, “City and Unincorporated Community Boundary (Regional Planning),” 2023, https://data.lacounty.gov/datasets/lacounty::city-and-unincorporated-community-boundary-regional-planning/about.

Appendix C: Methodologies for estimating the cost to address temperature-related impacts

Appendix C.1: Installing and Upgrading Building Heating and Cooling Infrastructure and Estimating the Change in Energy Cost

Taxpayer costs were analyzed at the municipal, county, and state level.

Buildings Inventory

We create a buildings database that is based on public datasets to inform building location, area, owner, and use type. Building location and footprint are based on the USA Structures data published by the Federal Emergency Management Agency (FEMA).[23] Building height is assumed based on the classification as published within the United States Geological Survey (USGS) national dataset of average building height[24] using the United States Census (Census) block groups.[25] Each block group is sorted into one of four classifications based on the average number of stories per building. These classifications are sourced from a National Aeronautics and Space Administration (NASA) dataset of Census block group data, which is based on LiDAR data collected in 2000 and verified and published in 2016.[26] This data provides a conservative height estimate, as we assume that the building height classification in any given block group has either increased or remains unchanged since the dataset was verified. Total building floor area is calculated by multiplying a given building's footprint by the average number of stories in the block group where the building is located. Building owner is determined based on a text scrape algorithm of the Los Angeles County Assessor Publicly Owned Parcels database[27] for keywords in the building type related to each of the local governments of concern.[28] For example, buildings with "State" in their name are filtered into the state-owned category. Lastly, building type is based on the Homeland Security buildings database[29] and the Department of Housing and Urban Development public housing database.[30] Each building within the inventory is assigned a building type from the Department of Energy (DOE) energy models in order to inform the energy, install, and upgrade calculations. The costs associated with municipal buildings in unincorporated areas are assigned to the county. Please note that the buildings inventory may not be an exhaustive representation of all public buildings that exist.

Climate Metrics

The number of cooling degree days (CDD)[31] and heating degree days (HDD)[32] for the baseline and projection time periods for each building are computed to determine changes in energy costs. The 20-year average number of annual CDDs and HDDs are reported. A degree day base of 50°F[33] is utilized

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[23] FEMA, "USA Structures" (Federal Emergency Management Agency Geospatial Resource Center, 2022), https://gis-fema.hub.arcgis.com/pages/usa-structures.

[24] James A. Falcone, "U.S. National Categorical Mapping of Building Heights by Block Group from Shuttle Radar Topography Mission Data" (U.S. Geological Survey, 2016), https://doi.org/10.5066/F7W09416.

[25] United States Census Bureau, "Glossary," under "Block Group," (accessed September 27, 2023), https://www.census.gov/glossary/?term=Block+Group+%28BG%29.

[26] Falcone, "U.S. National Categorical Mapping of Building Heights by Block Group from Shuttle Radar Topography Mission Data."

[27] County of Los Angeles, "Assessor Publicly Owned Parcels (Current)," May 10, 2023, https://data.lacounty.gov/datasets/c42fd5850b5b40d88e79c7d4204b9371_0/about.

[28] U.S. Department of Homeland Security, "Homeland Infrastructure Foundation-Level Data (HIFLD)" (Geospatial Management Office, 2021), https://hifld-geoplatform.opendata.arcgis.com/.

[29] Ibid.

[30] Department of Housing and Urban Development, "Public Housing Buildings" (HUD GIS Helpdesk: Office of Policy Development and Research (PD&R), 2023), https://hudgis-hud.opendata.arcgis.com/datasets/HUD::public-housing-developments/about.

[31] Cooling degree days (CDD) is a daily measure of how much (in degrees) the average outside air temperature is above a specified temperature threshold.

[32] Heating degree days (HDD) is a daily measure of how much (in degrees) the average outside air temperature is below a specified temperature threshold.

[33] In this context, CDD and HDD with a base of 50°F are used as climate variables. The base temperature does not inform when any given building is in cooling or heating mode (which typically has a threshold of 65°F).

for each because it demonstrates a better relationship with building cooling capacity and energy usage than other temperature metrics, such as degree days with a base of 65°F.

Degree Day Relationships

The DOE Commercial Reference Building models define the characteristics of a representative building for each climate zone[34] based on nationwide survey data.[35] Models are available for buildings built pre-1980, post-1980, and new. We used only the post-1980 models for the purposes of this study. Cooling system type, heating system type, cooling system capacity, cooling system energy usage, heating system energy usage, and building square footage as defined by the DOE Reference Building Models were used to calculate cooling capacity intensity (ft^2/ton), cooling energy use intensity (kWh/ft^2) and heating energy use intensity (kWh/ft^2 for electricity or MJ/ft^2 for gas) for a representative building in each climate zone.

Each building type within the building inventory is matched with a building type from the DOE representative energy models as outlined in the table below (Table C1).

Table C1: Building types within the building inventory and their corresponding building type within the DOE reference building energy models.

Inventory Building Type	DOE Building Type
Court House	Office
EMS	Office
Fire Station	Office
Hospital	Hospital
Library	Office
Post Office	Office
Prison	Hotel
Public Health Department	Office
Public Housing	Midrise Apartment
Primary School	Primary School
Secondary School	Secondary School
Town Hall	Office

Cooling Days

A relationship was established between the annual CDDs with base 50°F (CDD50) reported in ASHRAE 90.1 2004[36] and both the cooling capacity intensity and the cooling energy use intensity for each representative building. This relationship was used to calculate cooling system capacity and energy usage for all buildings using inputs of baseline and projected CDD50, building area, and building type.

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[34] There are eight main climate zones that are subdivided into moist, dry, and marine subsets to make 16 total classifications. The zones are determined based on a location's historic weather characteristics, in this case as defined by Briggs et al., (2003), https://www.proquest.com/openview/d1c49b47cddf83d4cb8ffc7b2ec1b075/1?pq-origsite=gscholar&cbl=34619.

[35] U.S. Department of Energy, "Commercial Reference Buildings" (Department of Energy: Office of Energy Efficiency & Renewable Energy, 2010), https://www.energy.gov/eere/buildings/existing-commercial-reference-buildings-constructed-or-after-1980.

[36] ASHRAE, ANSI/ASHRAE/IESNA Standard 90.1-2004: Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings, distributed by ASHRAE, (2004).

Heating Days

A relationship was established between the annual HDD50 reported in ASHRAE 90.1 2004[37] and the heating energy use intensity for each representative building. This relationship was used to calculate heating system energy usage for all buildings using inputs of baseline and projected HDD50, building area, and building type.

Cost Estimates: Cooling System Capacity

Cost per ton of cooling is calculated for install and upgrade. System install and upgrade use the same $/ton costs based on RSMeans Assembly costs in the 2021 edition of the RSMeans Square Foot Cost Book.[38] System types in the DOE Commercial Reference Building documentation were matched with the most appropriate assembly type (Table C1) in the RSMeans construction cost estimating data.

Costs are in Q2-2023 dollars and include material, labor, sales tax (6%), general requirements (10%), general contractor overhead (5%) and profit (5%), and an average location factor for Los Angeles County based on the national average.[39] No architect fee or contingency was added. Percentages follow RSMeans methodology. Additional costs will vary on a case-by-case basis and are outside of the scope of this study.

Cooling system installation costs were calculated for each building in the database based on projected capacity needs. Cooling system upgrade costs were calculated for each building in the database based on the projected capacity increase from baseline. An upgrade was assumed to be necessary if the change in cooling system capacity in a given projection was more than 10% higher than the cooling system capacity for the baseline. Only the increased cost from the change in baseline capacity was estimated, rather than the full system capacity, so that only impacts on system size arising from anthropogenic climate change were captured. Costs are presented on a municipal, county, and state basis by summing upgrade and install costs for all buildings within the respective jurisdiction that are owned by the jurisdiction(s) of interest.

Since the prevalence of air conditioning within most building types is unknown, the upgrade and installation costs for these building types are presented in a series of bins according to the prevalence of air conditioning across the jurisdiction's building stock. As an example, the 25% bin implies that 25% of a jurisdiction's buildings have existing cooling, and so 25% of the upgrade costs are reported while 75% of the installation costs are reported. In Los Angeles County, we assume all buildings have air conditioning[40] and therefore only upgrade costs are reported (0% of buildings need air conditioning installed, 100% of buildings are subject to upgrade costs).

Cost Estimates: Cooling and Heating Energy

Cost per kWh of electricity and per MW of natural gas are based on statewide 2022 annual average values as reported by the United States Energy Information Administration (US EIA).[41] Costs presented are based on 2022 average utility costs rather than projected costs. Available energy cost projections include substantial uncertainty and only extend to 2050. Additionally, use of present-day dollar amounts maintains consistency with the other analyses, which do the same. Energy costs assume all buildings have cooling and heating, while the percent change in costs will apply to any prevalence of buildings with both cooling and heating.

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[37] ASHRAE, ANSI/ASHRAE/IESNA Standard 90.1-2004: Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings, distributed by ASHRAE, (2004).

[38] RSMeans, Building Construction Cost Data, (2021), distributed by Gordian, https://www.rsmeans.com/.

[39] Attilio Rivetti, "Turner Building Cost Index: 2023 Second Quarter Forecast" (Turner Construction Company, 2023), https://www.turnerconstruction.com/cost-index.

[40] Matt Barnum, "Exclusive: Too Hot to Learn: Records Show Nearly a Dozen of the Biggest School Districts Lack Air Conditioning," June 14, 2017, https://www.the74million.org/article/exclusive-too-hot-to-learn-records-show-nearly-a-dozen-of-the-biggest-school-districts-lack-air-conditioning/.

[41] U.S. Energy Information Administration, "Electricity Data Browser," 2022, https://www.eia.gov/electricity/data/browser/; U.S. Energy Information Administration, "Natural Gas Prices," 2022, https://www.eia.gov/dnav/ng/ng_pri_sum_a_EPG0_PCS_DMcf_a.htm.

Assumptions

System type is as reported in DOE Commercial Reference Building models. Only components[42] that are included in the RSMeans assemblies were included in our estimate. Other items that may incur costs but were not included in analysis include: required code improvements, structural improvements, asbestos abatement, redundant equipment, electrical upgrades, inflation, design fees, permitting, inspections, crane, constructability, demolition, waste and disposal. Costs are based on the average $/ton across all system capacities reported in RSMeans.

The cooling capacity intensity relationship with CDD50 was calculated without the equipment sizing factor of 1.2[43] used by the DOE Reference Building models.

Appendix C.2: Protecting Residents during Heatwaves

Taxpayer costs were analyzed at the municipal level. Costs for unincorporated municipalities are assigned to the county.

We quantified how much it will cost Los Angeles County to expand and operate cooling centers in order to protect residents from extreme heat in "vulnerable areas." We used 2019 U.S. Census block data and the Los Angeles County Municipal Bounds to identify the "vulnerable areas" within each municipality, defined as an area that has a median income at or below twice the poverty line for a family of four ($55,500).[44] We used ArcGIS to assess the vulnerable area (mile^2) within each municipality.

Using Census block groups[45] to identify vulnerable areas in rural communities results in large regions of undeveloped areas being considered vulnerable, and therefore overestimates the amount of cooling centers required. To remedy this, we only used areas classified as medium or high intensity developed areas by the National Land Cover Database (NLCD) developed areas. In ArcGIS, we layered the NLCD classifications over the previously created vulnerable block groups. We saved only the overlapping NLCD developed areas, which leaves developed areas that are within vulnerable areas. As such, we determined the quantity of vulnerable areas within each municipality.

We assume that a cooling center within a vulnerable area must be within a 0.5 mile radius walking distance, thus every cooling center covers 0.785 sq. mi. To determine the number of cooling centers required in a given municipality, we divided the vulnerable area of each municipality by 0.785. Based on a report from the Center for Disease Control,[46] we assume that 62% of cooling centers do not incur additional costs, 15% incur only additional HVAC costs, and 23% incur both additional HVAC and staffing costs when operating for 8-hours. Though 62% of cooling centers did not incur additional costs for the first 8-hours of operation, 54% of all cooling centers operate on a 12-hour schedule and will incur an additional 4-hours of HVAC and staffing costs.[47] For this reason, we separated costs into 8-hours and 4-hours (see example computation below; Table C2). We estimated operational costs by using a report

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[42] The RSMeans system costs include the parts typical to cooling systems like the air handling unit, piping, valves, insulation, etc. These costs are for a generalized system and any given installation would likely see variations to meet the specific needs of that system.

[43] The DOE reference building models include a 20% safety factor when sizing a cooling system. We remove this safety factor to determine the minimum amount of cooling a building needs.

[44] "What Is the Federal Poverty Level (FPL)?," healthinsurance.org, accessed December 13, 2023, https://www.healthinsurance.org/glossary/federal-poverty-level/.

[45] United States Census Bureau, "Glossary," under "Block Group," accessed September 27, 2023, https://www.census.gov/glossary/?term=Block+Group+%28BG%29.

[46] Stasia Widerynski et al., "The Use of Cooling Centers to Prevent Heat-Related Illness: Summary of Evidence and Strategies for Implementation Climate and Health Technical Report Series Climate and Health Program, Centers for Disease Control and Prevention," Climate and Health Technical Report Series (Climate and Health Program: Centers for Disease Control and Prevention, 2017), https://www.researchgate.net/publication/319112587_The_Use_of_Cooling_Centers_to_Prevent_Heat-Related_Illness_Summary_of_Evidence_and_Strategies_for_Implementation_Climate_and_Health_Technical_Report_Series_Climate_and_Health_Program_Centers_for_Disea.

[47] Ibid.

from the City of Los Angeles that details the city's cooling center costs. They report that HVAC costs were $26.86 per hour (HC), and HVAC and staffing costs (HSC) were $292.79 per hour.[48]

Table C2: An example for how to calculate the cost to operate cooling centers in a Los Angeles County municipality.

Vulnerable Area (A)	**# of Cooling Centers (CC)**	**Additional HVAC Costs (AHC)**	**Additional HVAC and Staffing Costs (AHSC)**	**8 Hour Costs (C8)**	**4 Additional Hours Costs (C4)**	**Total Daily Costs**
	A/0.785, round up to nearest whole number	CC*0.15*HC*8	CC*0.23*HSC*8	AHC + AHSC	((CC*0.62)*0.54)*HSC*4	C8 + C4

This method calculates the daily operation cost for cooling centers for each municipality in Los Angeles County. The next step is to multiply the daily costs by the number of days that each municipality experiences over 80°F. The resulting amount will be the rough estimation for each municipality's cooling center costs on a yearly basis.

Note that because some areas are vulnerable but will not require cooling centers (rural areas) there is an additional filter that if a municipality has a vulnerable area less than half of the area covered by a cooling center (0.785 sq. mi) then it is determined that area does not require a cooling center. Areas with this occurrence are most likely rural areas with low populations relative to other urban environments.

Appendix C.3: Combating Heat Islands – Urban Trees

Taxpayer costs were analyzed at the municipal level.

We quantified how much it will cost Los Angeles County municipalities to increase urban tree canopy in order to adapt to an urban heat island exacerbated by higher temperatures. An urban tree constitutes any tree located in a developed area of medium or high intensity according to the NLCD. We did not determine the cost of planting urban trees in municipalities with less than 500 pop/mi^2 or municipalities with less than 100 people as the total population as these are not "urban" areas and are excluded from the analysis.

Quantifying canopy coverage in Los Angeles County urban environments

We used NLCD 2021 Land Cover data and NLCD 2021 Canopy Coverage to quantify the current canopy coverage in municipalities across Los Angeles County.

Cost Data

We used RSMeans to collect cost data.[49] We broke the initial planting data into labor costs and material costs. Labor and material costs were estimated using an average across multiple planting sizes as well as a variety of representative sapling species. We calculated tree maintenance costs by combining water, fertilizer, pruning, and pest spraying. We adjusted the costs to 2023 values using an inflation rate of 13.84%, per the Turner Building Cost Index.[50] Additionally, we adjusted the national average to Los Angeles County specific city cost index data.

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[48] C.P. Parks, "Cooling Center Operations in Los Angeles City." (City of Los Angeles Emergency Management Department, 2022), https://clkrep.lacity.org/onlinedocs/2021/21-1277_rpt_07-29-22.pdf.

[49] Derrick Hale, "Site Work & Landscape Costs with RSMeans Data" (The Gordian Group, 2021), https://www.rsmeans.com/media/wysiwyg/2021-SiteWork-TOCs.pdf.

[50] Rivetti, "Turner Building Cost Index: 2023 Second Quarter Forecast."

Determining Ideal Canopy Numbers

We combined canopy cover from 16 metropolitan areas across the country to serve as representative models for different size municipalities in Los Angeles County including each city's canopy coverage goal percent, canopy goal year, current canopy coverage, the year the current canopy coverage was calculated, and the current population density. Regressing on these variables with goal canopy percent as the dependent variable resulted in an adjusted R squared value of 0.73.

The output regression formula is:

$$\begin{aligned}\text{Canopy Cover Goal \%} \;=\; & -5.4913424 + (-3.74075\text{E-}06 * (\text{Pop Density})) \\ & + (1.073584308 * (\text{Initial Canopy Cover})) \\ & + (0.003353585 * (\text{Year Assessed})) \\ & + (-0.000552275 * (\text{Target Year}))\end{aligned}$$

We used the formula to calculate goals for municipalities for each development level as shown below. We used a target year of 2033 based on a 10-year period for trees to reach their average canopy cover (Table C3).

Table C3: Los Angeles County urban canopy model. Note that each municipality has an average current and goal canopy cover. The percentages in this table represent the average of those current and goal canopy covers across all incorporated municipalities.

Incorporated Municipalities		
Population Density	6,411	
Year Assessed	2023	
Target Year	2033	
Developed Area	**Current Canopy Cover (%)**	**Goal Canopy Cover (%)**
Medium Intensity	5.60	6.16
High Intensity	0.85	1.05

Table C4: The urban tree canopy coverage increase needed to meet the goal canopy cover for Los Angeles County. The table also shows how much it will cost to increase canopy coverage and the approximate number of trees to do so.

Developed Area	**Needed Increase (sq. ft.)**	**Cost to Increase**	**~# of Trees**
Medium Intensity	219,087,480	$39,435,746	697,931
High Intensity	46,223,874	$8,320,297	147,252
Total	**265,311,353**	**$47,756,044**	**845,183**

Cost Estimates

Table C5: Cost model for urban canopy in Los Angeles County showing an initial planting cost and then the costs in Year 1 (Y1), Y2, and Y3.

Developed Area	Initial Planting Cost	Y1 (2023)	Y2 (2024)	Y3 (2025)
Medium & High Intensity	$330,764,632	$47,282,063	$47,282,063	$47,282,063
Tree Mortality Cost	–	–	$22,491,995	$22,491,995
Total	**$330,764,632**	**$47,282,063**	**$69,774,058**	**$69,774,058**

The cost model uses a variety of inputs to calculate a final cost value. Important inputs include:

- Average canopy cover per tree (sq. ft.)
  - Average canopy cover in Los Angeles was determined by referencing a document released by Tree People listing approved street trees for the City of Los Angeles.[51] This list was then cross referenced against the Southern Nevada Water Authority regional plant list[52] which provides canopy coverage in square feet. Together these documents provided a list of 27 recommended trees and their coverage to average.
- Average annual cost to maintain an urban tree ($)
  - Explained above
- Initial cost to plant a tree ($)
  - Explained above
- Cost per canopy ($/sq. ft.)
  - Calculated by dividing cost to maintain an urban tree by the average canopy cover per tree
- Tree mortality rate Years 1-5 and Year 6+[53]

Next, we priced out these costs into the future. Year one costs include both the initial maintenance cost as well as the initial cost to plant trees. After year one, the maintenance cost stays the same. However, there is a tree mortality cost: for years 1-5 there is an assumed 6.8% loss of trees per year, and there is an assumed 3.3% loss for year 6+.[54] Each year, this loss is translated into the cost to replace that amount of trees. The cost model can be extended for as many years as desired and inflation costs can be incorporated based on whatever rate is deemed appropriate. Note that the model does not specify where trees are planted within the municipalities.

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[51] TreePeople, "City of Los Angeles Approved Street Tree List," 2021, https://www.treepeople.org/wp-content/uploads/2021/02/TreePeoples-LA-City-Approved-Street-Tree-List.pdf.

[52] Southern Nevada Water Authority and Southern Nevada Regional Planning Coalition, "Regional Plant List," 2021, https://www.snwa.com/assets/pdf/water-smart-plant-list.pdf.

[53] Deborah R. Hilbert et al., "Urban Tree Mortality: What the Literature Shows Us," *Arborist News*. Oct: 22-26. Oct (2019): 22, https://www.fs.usda.gov/research/treesearch/59819.

[54] Ibid.

Appendix C.4: Combating Heat Islands – Cool Pavements

Taxpayer costs were analyzed at the municipal level.

It is possible that future drought conditions will hinder Los Angeles County's ability to support a robust tree canopy. In such a scenario, other approaches to urban temperature reduction will be required to maintain a favorable temperature in the urban environment. Converting existing areas of pavement to high-albedo cool pavement has been shown to decrease proximal ambient temperature and is a complementary approach to urban tree canopy that was considered as part of this report, as the City of Los Angeles has enacted an ordinance to "reduce nonroof heat islands for 75% of pathways, patios, or other paved areas" by utilizing both urban trees and cool pavements, as well as other strategies not considered in this study.[55]

Quantifying parking lot area in Los Angeles County

Only parking lots were considered for cool pavement adaptations due to the large surface area that parking lots cover in Los Angeles County and to maintain a conservative cost estimate. Parking lots also offer a more consistent canvas for cool pavement conversion than the variation existing among driveways, sidewalks, and other impermeable surfaces. Los Angeles County's official GIS website hosts information on the boundary of all parking lots in the county and was used to determine the current square footage of parking lots in incorporated areas of Los Angeles County.[56]

Cost Estimates

RSMeans[57] and an Environmental Protection Agency (EPA) study on cool pavement costs[58] informed the cost estimates used herein. Labor and material costs were estimated using an average across several cool pavement methods, including white topping, micro surfacing, and chip seal. Costs from the EPA document were adjusted to 2023 dollars using the National Highway Construction Cost Index (NHCCI).[59] RSMeans nationwide average costs were adjusted by a city cost index of $109.85 from the national average based on cities within Los Angeles County and also adjusted to 2023 dollars.

To determine final unit costs, we used a conservative method utilizing the lower cost of the range presented by the EPA along with the longer estimated service life for each method. For example, the EPA lists ultra-thin white topping as costing $1.50-$6.50 per installed square foot with an estimated lifespan between 10-15 years. For this method we use $1.50 per square foot and a lifespan of 15 years to factor into an average across multiple methods. A mix of methods were used due to the variety of current surfaces and conditions parking lots may exist in. Thus, variations of white topping, micro surfacing, and chip seal were all averaged to result in a $0.06/ft^2 annual cost for a 20-year estimate (Table C6). We present the cumulative 17-year cost in this study.

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[55] Council of the City of Los Angeles, "Ordinance No. 187208" (2021), https://www.ladbs.org/docs/default-source/publications/ordinances/20-1139_ord_187208.pdf?sfvrsn=6acdc153_9.

[56] County of Los Angeles, "Parking Lots (2014) from LARIAC," 2023, https://egis-lacounty.hub.arcgis.com/datasets/413ba9befacf41a68f7dcad55a08f9a8_0/explore?location=33.867487%2C-118.278003%2C15.90.

[57] Hale, "Site Work & Landscape Costs with RSMeans Data."

[58] U.S. Environmental Protection Agency, *Reducing Urban Heat Islands: Compendium of Strategies. Cool Pavements,* 2012, https://www.epa.gov/sites/default/files/2017-05/documents/reducing_urban_heat_islands_ch_5.pdf.

[59] Federal Highway Administration, "National Highway Construction Cost Index (NHCCI)," 2023, https://data.bts.gov/Research-and-Statistics/National-Highway-Construction-Cost-Index-NHCCI-/wgzr-nyxc.

Table C6: The minimum cost per square foot, the minimum lifespan, and the total 20-year cost for the various cool pavement techniques used in this analysis.

Source	**Technique**	**$/sq ft.**	**Lifespan (years)**	**20-Year Cost ($/sq ft.)**
EPA	Ultra-thin whitetopping	2.63	15	3.51
EPA	Microsurfacing	0.61	10	1.23
EPA	Chip Seal with light aggregate	0.18	8	0.44
RSMEANS	Chip Seal, Medium Fine, Parking lot	0.38	8	0.95
RSMEANS	Chip Seal, Medium, Parking lot	0.43	8	1.08
RSMEANS	Microsurfacing, Type II-MSE, Parking Lot	0.37	10	0.73
RSMEANS	Microsurfacing, Type IIa-MSE, Parking Lot	0.53	10	1.06

Appendix C.5: Maintaining Roads

Taxpayer costs were analyzed at the municipal, county, and state level.

To determine the potential future damage to municipal, county, and state roads in Los Angeles County, we analyzed both the historic environment and projected future conditions to determine how climate change will affect the as-designed condition of road infrastructure. Increasing temperatures cause more surface degradation[60] and decreases road lifespan.[61] Increasing precipitation levels cause erosion, which weakens the roadbase, causing increases in cracking, potholes, and breakage.[62] We designed distinct stressor-response functions for paved (assumed to be asphalt), gravel, and unpaved roads. Furthermore, within each category we made refinements for primary, secondary, and tertiary roads.[63] We identified local roads using a database containing Los Angeles County roads that are owned by municipalities, counties, or states. Ownership is determined for each road segment based on classification from the Census.[64] The costs associated with municipal roads in unincorporated areas are assigned to the county.

Temperature

Pavement temperature determines the required pavement design or the ability for the pavement to withstand temperature-related degradation.[65] We find a relationship between pavement temperature and 7-day maximum ambient air temperature ($T\text{-}7_{max}$), so we use historic and projected $T\text{-}7_{max}$ to determine when a projected change in temperature will be significant enough to cause climate-based damage to road infrastructure.

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[60] Degradation is the projected increase in raveling and cracking that will occur due to pavement weakening.

[61] Transportation Research Board, "Superpave: Performance by Design," 2005, https://www.trb.org/publications/sp/superpave.pdf.

[62] James E. Neumann et al., "Climate Change Risks to US Infrastructure: Impacts on Roads, Bridges, Coastal Development, and Urban Drainage," *Climatic Change* 131, no. 1 (July 1, 2015): 97–109, https://doi.org/10.1007/s10584-013-1037-4.

[63] Paul Chinowsky and Channing Arndt, "Climate Change and Roads: A Dynamic Stressor–Response Model," *Review of Development Economics* 16, no. 3 (2012): 448–62, https://doi.org/10.1111/j.1467-9361.2012.00673.x.

[64] U.S. Census Bureau, "TIGER/Line Shapefiles," 2022, https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html.

[65] Patrick Lavin, *Asphalt Pavements: A Practical Guide to Design, Production and Maintenance for Engineers and Architects* (London: CRC Press, 2003), https://doi.org/10.1201/9781482267716.

We used guidance from Superpave increments of pavement temperature to determine the exceedance parameters.[66] When pavement temperature rose above the mixture threshold, we calculated the increased degradation based on published material studies.[67] In the reactive scenario, this increased cracking requires more maintenance to avoid a decrease in the projected lifespan of the road.[68] In the proactive scenario, adaptation includes installation of roads with pavement rated to projected future temperatures.

Precipitation

We used historic and projected maximum monthly precipitation amounts to determine if excessive erosion will increase damage to the roadbase. We compared the historic maximum monthly precipitation to the projected change in maximum monthly precipitation rates at the time-slice of interest. We used a threshold based on the type of road surface to determine whether increased damage will occur to the road. If a threshold is exceeded, then a percentage decrease in lifespan is calculated based on the level of projected damage. In the proactive road scenario, adaptation for this scenario requires a strengthening of the roadbase to resist the increased potential for erosion. In the reactive road scenario, adaptation is fixing roads after precipitation-induced damage.

Cost Estimates

We conducted this analysis with the goal of retaining the original design life and service level of the roadways. We present costs for both a proactive and reactive adaptation approach.

Proactive: The proactive scenario includes the additional costs required to adapt design and construction to defend against projected changes in climate expected to occur over the asset's lifespan. We estimated total costs based on the cost associated with enhancing the materials selected or alternate design requirements. First, we generated stressor-response values for infrastructure elements. Next, we designed infrastructure to a level that protects against the future changes in climate conditions and the accompanying changes in material or design requirements. Last, we subjected any new or rehabilitated structures to material changes when it was anticipated that a significant climate change stressor would occur during the lifespan.

Reactive: Reactive adaptation costs were calculated to understand the cost-benefit of proactive adaptation. Reactive adaptation involves fixing roads as problems arise and is usually more expensive than a proactive approach. Damage threshold exceedance data from each grid within the climate model data is used to determine the level of additional maintenance and repair required for any given segment of road on an annual basis. This is then fed into the cost module where a per-mile maintenance cost is applied to each mile of road segment within each affected grid. Lastly, road maintenance costs are aggregated from a grid-level to a municipality-level using an area-based weighted average approach.

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[66] Transportation Research Board, "Superpave: Performance by Design."

[67] M Miradi, "Artificial Neural Network (ANN) Models for Prediction and Analysis of Ravelling Severity and Material Composition Properties," ed. M. Mohammadian, *CIMCA* 2004, 2004, 892–903, https://research.tudelft.nl/en/publications/artificial-neural-network-ann-models-for-prediction-and-analysis-.

[68] Ibid.

Appendix C.6: Wildfires

Taxpayer costs were analyzed at the municipal, state, and federal level. Costs for unincorporated municipalities were then assigned to the county.

Wildfire mitigation typically consists of two different strategies: controlled burns and mechanical intervention. Controlled burns focus on reducing fuel areas by intentionally lighting a fire in a small area of forest to eliminate fuel while reducing potential burn area in a larger blaze. Mechanical intervention focuses on reducing fuel for a fire by manually cutting and removing undergrowth, as well as thinning the density of forested area. Due to an increase in the number of fire days (i.e., length of the fire season),[69] controlled burns are not as feasible, as the available time for a controlled burn is being significantly reduced.[70] Thus, we estimate the cost of mechanical intervention for vulnerable areas in Los Angeles County. This approach requires more effort and cost, but it has the advantage of potentially generating revenue with harvested timber. Additionally, mechanical intervention can take place at any time of the year (i.e., it is not limited to low fire days).

Determining At-Risk Areas

We first identify the extent of the at-risk areas by determining the amount of area that falls within local fire responsibility areas and wildland urban interface[71]/intermix that has increased fire risk, as quantified through the Keetch-Byram Drought Index (KBDI). We focus on the wildland urban interface (WUI) that is under the responsibility of municipal or county firefighters. These areas include both forested areas and scrub brush areas known as chaparral as determined by the NLCD.[72] We use data from Cal Fire to find the amount of area that falls within each of the firefighting responsibility bounds.[73]

Data

- Wildland Urban Interface[74]
- Firefighting Responsibility Bounds[75]
- Los Angeles County Boundary
- Los Angeles County Municipalities
- NLCD 2021 Landforms[76]
- Keetch-Byram Drought Index (KBDI)[77]

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[69] A.L. Westerling et al., "Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity," *Science* 313 (2006): 940–43, https://doi.org/10.1126/science.1128834.

[70] Bruce R. Hartsough et al., "The Economics of Alternative Fuel Reduction Treatments in Western United States Dry Forests: Financial and Policy Implications from the National Fire and Fire Surrogate Study," *Forest Policy and Economics* 10, no. 6 (August 2008): 344–54, https://doi.org/10.1016/j.forpol.2008.02.001.

[71] Emilio Chuvieco et al., "Towards an Integrated Approach to Wildfire Risk Assessment: When, Where, What and How May the Landscapes Burn," *Fire* 6, no. 5 (May 2023): 215, https://doi.org/10.3390/fire6050215.

[72] Multi-Resolution Land Characteristics Consortium, "National Land Cover Database Class Legend and Description," accessed December 4, 2023, https://www.mrlc.gov/data/legends/national-land-cover-database-class-legend-and-description.

[73] Cal Fire, "GIS Mapping and Data Analytics," 2023, https://www.fire.ca.gov/what-we-do/fire-resource-assessment-program/gis-mapping-and-data-analytics.

[74] Franz Schug et al., "The Global Wildland–Urban Interface," *Nature* 621, no. 7977 (September 7, 2023): 94–99, https://doi.org/10.1038/s41586-023-06320-0; Spatial Analysis For Conservation and Sustainability Lab, "The Global Wildland-Urban Interface (WUI) – 2020," 2023, https://silvis.forest.wisc.edu/globalwui/.

[75] Cal Fire, "GIS Mapping and Data Analytics."

[76] "Multi-Resolution Land Characteristics (MRLC) Consortium," 2023, https://www.mrlc.gov/.

[77] U.S. Forest Service, "Keetch-Byram Drought Index (KBDI)," accessed November 28, 2023, https://www.drought.gov/data-maps-tools/keetch-byram-drought-index.

Estimating Costs

We use a cost of $1,500 per acre for mechanical intervention.[78] Given the area of potential mitigation responsibility and the cost per acre of treatment, the final element in the calculation is to determine what areas will require additional treatment. Historically, the fire season in Southern California runs from approximately July-October, or 120 days of mixed fire-risk days from low to extreme. The season generally ends with autumn rains and lower temperatures that arrive in November. However, climate change has caused temperatures to increase on both sides of the traditional fire season.[79] With this trend continuing, we utilize a threshold of 100 high or extreme fire days (as determined by KBDI measurements) as the indicator of whether mechanical treatments should be employed. This threshold reflects both an increase in the number of severe days during the traditional season as well as an increase in the number of days that are occurring outside the traditional season. Where the threshold is exceeded, the cost per acre is applied to the WUI area impacted by the increased number of fire days.

Appendix C.7: Los Angeles Metro Rail Improvements

Taxpayer costs were analyzed at the county level.

The Los Angeles metro rail system, and other light rail systems, are susceptible to damage from increasing temperatures similar to commercial Class 1 rail. Specifically, rails will deform as temperatures increase above a neutral temperature. This can cause separation between the rails as well as the potential for significant deformation if trains are allowed to continue to run on the rails in the hot temperatures.[80]

Adaptation Strategies

The traditional approach to minimizing this impact is to put slow-down orders in place which require operations to be slowed or stopped for a period of time until the temperatures return to normal operating levels. The adaptation to this impact is to either enhance the detection of heated rails to target slow-down orders, or to implement an approach to reduce the heating of the rails themselves. Currently, Los Angeles Metro (LA Metro), the operator of the Los Angeles County metro rail system, implements a combination of slow-down orders and heat sensors to reduce temperature-induced delays.[81] Slow-down orders are put in place when temperatures exceed 90°F. Concurrently, heat sensors have been installed to enable the system to put slowdown orders in on specific lines rather than over the entire system.[82]

The next step in adaptation is to focus on reducing the temperature of the rails during heat events. The approach adopted for this study is to coat the rails with reflective paint. This is an approach currently adopted in Europe and Australia and has been shown to have positive effects for reducing the temperature of rails.[83] While this is a new approach, initial studies have demonstrated the potential to reduce temperatures by 10°C or more.[84]

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[78] Ibid.

[79] Chunyu Dong et al., “The Season for Large Fires in Southern California Is Projected to Lengthen in a Changing Climate,” *Communications Earth & Environment* 3, no. 1 (2022): 22, https://doi.org/10.1038/s43247-022-00344-6.

[80] Paul Chinowsky et al., “Impacts of Climate Change on Operation of the US Rail Network,” *Transport Policy* 75 (March 1, 2019): 183–91, https://doi.org/10.1016/j.tranpol.2017.05.007.

[81] Ryan Fonseca, “Will LA Metro Be Ready To Take The Heat Of Climate Change? It’s ‘Complicated,’” *LAist*, September 20, 2019, sec. News, https://laist.com/news/la-metro-climate-change-extreme-heat.

[82] Karen Gorman, “Office of Inspector General ‘Is LA Metro Ready for Climate Change?,’” https://www.documentcloud.org/documents/6422665-la-metro-climate-change-presentation.html.

[83] Federal Railroad Administration, “Quantification of the Effectiveness of Low Solar Absorptivity Coatings for Reducing Rail Temperature,” 2015, https://railroads.dot.gov/sites/fra.dot.gov/files/fra_net/15600/Effectiveness_of_Solar_Coatings_final.pdf; Federal Railroad Administration, “Low Solar Absorption Coating for Reducing Rail Temperature and Preventing Buckling,” 2018, https://railroads.dot.gov/sites/fra.dot.gov/files/fra_net/18062/Low%20Solar%20Absorption%20Coating%20for%20Reducing%20Rail%20Temperature%20and%20Preventin..._.pdf; Julian Turner, “Cool Runnings: Is White Paint the Perfect Solution to Overheated Rail Tracks?,” *Railway Technology* (blog), December 4, 2019, https://www.railway-technology.com/features/solution-to-overheated-rail-tracks/.

[84] Hao Wang, Milad Salemi, and P. N. Balaguru, “Multifunctional Coating System for Rail Track Applications” (2017 Joint Rail Conference, American Society of Mechanical Engineers Digital Collection, 2017), https://doi.org/10.1115/JRC2017-2323.

The cost estimate of the coatings approach is based on the need for a crew to apply the coating across the LA Metro system. The LA Metro system consists of 109 miles of track. The track requires one coat of primer plus two coats of topcoat. It is estimated based on product information that 10 buckets of primer and 20 buckets of topcoat are required per mile. This is equivalent to $7,500 per mile in materials. Over the entire system, this would equate to $817,500.

The labor cost is based on a method developed in Australia that utilizes a mechanized approach with a vehicle and spray application.[85] Using a crew of four painters and a laborer applying coating at 5 km/hr, it is estimated that it will take about one week to do each coat, or three weeks to complete the application over the entire system. Labor cost is anticipated to be less than $100,000 in total.

The result of this would be an estimated $1 million per required application of coating. We present the cost of painting rail every year, as the Los Angeles County climate is similar to Rome, Italy, where rails have been painted annually for several decades. The summer temperatures between the two locations are similar with average temperatures within 5°F of each other and max temperatures within 10°F. Winter temperatures and rain amounts are also similar, making Rome and Los Angeles good comparisons. Given this relationship, it is assumed that an annual application is needed. This equates to a cumulative cost of $17 million from 2024 through 2040.

Appendix D: Methodologies for estimating the cost to address precipitation-related impacts

Appendix D.1: Drainage & Stormwater Infrastructure: Mitigating Urban Flooding and Inflow to Water Treatment Plants

Taxpayer costs were analyzed at the municipal level. Costs for unincorporated municipalities were assigned to the county.

We assessed the impact of increases in extreme wet weather events to wastewater conveyance systems and wastewater treatment plants and processes. The most significant impact of increased rainfall on wastewater conveyance systems are increased overflows, blockages, and breakages. Increased rainfall intensity and extreme weather events are likely to lead to increased occurrence of inflow and infiltration (I&I) into wastewater networks. This occurs when stormwater directly enters combined networks or infiltrates the sewer network through cracks, direct connections, and corroded manholes.[86]

The most significant impacts likely to affect treatment plants and processes are increased inflows and power outages. Increased rainfall will result in larger volumes and peak inflows into wastewater treatment plants as a result of flow from combined systems and I&I. While the volume or 'flow' of the wastewater increases during increased stormwater infiltration, the total suspended solids (TSS) of the wastewater remains the same, resulting in a dilution of the influent to the wastewater treatment plant, which can affect biological treatment processes.[87] During extreme weather events, system bypasses can be activated, diverting flows past part or all of the treatment process. This causes partially treated or untreated wastewater to directly enter the receiving environment.[88]

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[85] Pacific Edge Pty Ltd, "Rail Painting Process," 2005, https://www.solacoat.com.au/wp-content/uploads/2020/07/6-Solacoat-Railway-Painting-Process-Report.pdf.

[86] James Hughes et al., "Impacts and Implications of Climate Change on Wastewater Systems: A New Zealand Perspective," *Climate Risk Management* 31 (January 1, 2021): 100262, https://doi.org/10.1016/j.crm.2020.100262.

[87] Benedek Gy Plósz, Helge Liltved, and Harsha Ratnaweera, "Climate Change Impacts on Activated Sludge Wastewater Treatment: A Case Study from Norway," *Water Science and Technology: A Journal of the International Association on Water Pollution Research* 60, no. 2 (2009): 533–41, https://doi.org/10.2166/wst.2009.386.

[88] J. G. Langeveld, R. P. S. Schilperoort, and S. R. Weijers, "Climate Change and Urban Wastewater Infrastructure: There Is More to Explore," *Journal of Hydrology* 476 (January 7, 2013): 112–19, https://doi.org/10.1016/j.jhydrol.2012.10.021.

To combat increased inflow to wastewater treatment plants, we estimate how much it will cost to install drainage and stormwater infrastructure (referred to as green infrastructure in the engineering literature).[89] Drainage and stormwater infrastructure includes bio retention, porous pavement, bioinfiltration, and bioswale construction. By increasing pervious surfaces with drainage and stormwater infrastructure, flooding during wet weather events decreases, offsetting what would have been increased inflows to wastewater treatment plants from climate change. We choose this adaptation, as opposed to expanding or adding culverts and storm drains, as it is generally low-impact and less expensive. The California State Water Resources Control Board has a report on green (drainage and stormwater) infrastructure for Los Angeles.[90]

Change in wet weather events

We look at the change in magnitude of the 98% precipitation event and the 99.6% precipitation event. The 98% precipitation event represents the threshold for a "high-precipitation event," which occurs approximately seven times a year and could cause moderate increases of inflow into the wastewater treatment plants. The 99.6% precipitation event represents the extreme wet weather event that could cause large increases of inflow into the wastewater treatment plants and occurs approximately once per year.

We calculate the percent change in these events from the change in rainfall depth (inches) for a certain percentile between the two distributions (baseline distribution and the projected distribution). For example, if the 99.6% baseline wet weather event is 3 inches and the projected 99.6% wet weather event is 3.3 inches, then we would say the extreme wet weather event increased by 10%. We use the maximum of the high (98%) and extreme (99.6%) change for the next step.

Given a change in wet weather events, we assume that the municipality must invest to offset additional runoff (thus infiltration and inflow) into the wastewater treatment plant. We assume the offset is proportional to the change in wet weather events. For example, if the wet weather events are increasing by 10%, then 10% of the developed impervious area needs to be offset by drainage and stormwater infrastructure.

We calculate the developed impervious area using the NLCD.[91]

We derived the per-unit cost for drainage and stormwater infrastructure from the following equation:[92]

- $\text{Cost} = A * \Delta WWE * DSI$
- Where:
  - A is area of developed impervious surfaces (acres)
  - ΔWWE is the change in wet weather events (%)
  - DSI is the unit cost of drainage and stormwater (green) infrastructure ($ per impervious acre controlled)

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[89] S.E Gill et al., "Adapting Cities for Climate Change: The Role of the Green Infrastructure," *Built Environment* 33, no. 1 (March 13, 2007): 115–33, https://doi.org/10.2148/benv.33.1.115.

[90] California State Water Resources Control Board, "Green Infrastructure for Los Angeles: Addressing Urban Runoff and Water Supply Through Low Impact Development," 2009.

[91] Earth Resources Observation and Science (EROS) Center, "National Land Cover Database" (U.S. Geological Survey, 2021), https://www.usgs.gov/centers/eros/science/national-land-cover-database.

[92] Allegheny County Sanitary Authority, "Staring at the Source: How Our Region Can Work Together for Clean Water - Appendix E-3: GIS Cost Literature Review," 2015, https://www.alcosan.org/docs/default-source/clean-water-plan-documents/cwp-appendixe/cwp-appendix-e-3_gsi-cost-literature-review.pdf?sfvrsn=6d863977_2.

GSI unit costs are sourced from a green (drainage and stormwater) infrastructure report.[93] The unit costs are adjusted to Los Angeles County using an RSMeans location multiplier. Finally, the costs are adjusted to 2023 dollars.

Appendix D.2: Bridge Stabilization

Taxpayer costs were analyzed at the municipal, county, and state level.

Climate-driven changes in precipitation will increase the flow rates of waterways, thereby increasing the rate of wear and tear on the bridges that span them. To approximate bridge-related costs associated with the projected increase in precipitation, we developed a method that translates increases in 24-hour precipitation rates to changes in flow rates in waterways where bridges are present. From there, we calculated the potential increase in damage to bridges resulting from increases in scour around the base of the piers. While there are multiple climate-related costs associated with bridges, we chose to quantify the cost to proactively rehabilitate bridges in order to prevent disruption. We classify bridges into municipal, county, and state owned using the National Bridge Inventory ownership identifiers. The costs associated with municipal bridges in unincorporated areas are assigned to the county.

Methods based on the United States Department of Agriculture's Natural Resources Conservation Service (NRCS) TR-20 model were used to translate 24-hour rainfall "design-storm" depths to peak discharge.[94] This model is based on empirical runoff relationships referred to as the Soil Conservation Service Curve Number Method.[95] The bridge data is from the National Bridge Inventory,[96] from which we selected only inland bridges that spanned bodies of water. Changes in runoff were determined based on a study of the watersheds feeding the waterways. The location and details of the rivers were derived from the USGS Hydrologic Unit Code 8 (HUC 8) database for Los Angeles County.[97] We determine the increase in peak discharge based on a study of the watersheds at the HUC8 level feeding the local waterways. We utilize daily runoff data, which covers Los Angeles County. The LOCA Global Climate Model (GCM) projections provide daily precipitation outputs from the Coupled Model Intercomparison Project Phase 6 (CMIP6) as inputs.

Cost Estimates

We quantified the cost to proactively rehabilitate bridges to prevent disruptions by applying riprap to stabilize bridges and additional concrete to strengthen piers and abutments. We rehabilitate bridges only if they are known to be threatened by a near-term river flow level that crosses one of the thresholds. We stabilize bridges only if projected runoff increases by 20% compared to the baseline. We strengthen piers and abutments only when runoff increases by 60% compared to the baseline for bridges on non-sandy soils and by 100% compared to the baseline for bridges on sandy soils. The percent increase in runoff for the different soil types are based on federal guidelines and were also utilized in Wright et al. (2012).[98] This method may underestimate potential damages because proactive costs are likely far lower than repairing or rebuilding a failed bridge.[99] Notably, our analysis does not estimate damages associated with delays/disruptions from the bridge being closed.

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[93] Ibid.

[94] Len Wright et al., "Estimated Effects of Climate Change on Flood Vulnerability of U.S. Bridges," *Mitigation and Adaptation Strategies for Global Change* 17, no. 8 (December 1, 2012): 939–55, https://doi.org/10.1007/s11027-011-9354-2.

[95] Surendra Kumar Mishra and Vijay P. Singh, Soil Conservation Service Curve Number (SCS-CN) Methodology, vol. 42, *Water Science and Technology Library* (Dordrecht: Springer Netherlands, 2003), https://doi.org/10.1007/978-94-017-0147-1.

[96] Federal Highway Administration, "National Bridge Inventory," 2023, https://www.fhwa.dot.gov/bridge/nbi/ascii.cfm.

[97] "Hydrologic Unit Maps," United States Geological Survey, accessed December 13, 2023, https://water.usgs.gov/GIS/huc.html.

[98] Wright et al., "Estimated Effects of Climate Change on Flood Vulnerability of U.S. Bridges."

[99] Neumann et al., "Climate Change Risks to US Infrastructure."

Appendix D.3: Drought Impact on Drinking Water

Taxpayer costs were analyzed at the municipal level for incorporated municipalities and at the county level for unincorporated municipalities.

The impact of drought is broad, extending from agriculture to ground subsidence, and drinking water quality. In California, drought has been shown to impact water-related ecosystem services[100] and degrade drinking water quality[101] (both groundwater[102] and surface water). In this analysis, we focus on the additional cost of treating drinking water due to drought.[103]

Drinking water treatment costs are higher during drought events because increased sediment and nutrient concentration occur as drought conditions emerge. The Cadmus Group describes this effect as follows, "Because source water quality can be affected by drought conditions (i.e., sedimentation can increase and runoff is likely to have elevated concentrations of pollutants), drinking water utilities will likely face increased costs related to water treatment during drought."[104]

The cost of this impact is based on a study by Dearmont et al. (1998) that is still referenced as the basis for drought-based costs for water treatment.[105] Further from the study, "[the authors] determined that the cost of water treatment would increase by $94.75 per million gallons when elevated concentrations of chemical contaminants are present in source water." Adjusting this cost to 2023 dollars, the additional cost to treat drinking water during drought events is $223 per million gallons.

We use both the previous drought-related restriction of residential water use to 80 gallons per capita per day mandated by the Metropolitan Water District of Southern California[106] as a low-end estimate and the average consumptive demand for Los Angeles County of 120 gallons per capita per day as a high-end estimate of water use.[107] With a 2020 Census population of around 10 million,[108] the total residential water use for Los Angeles County is estimated at 801 million gallons per day during drought and 1.2 billion gallons per day on average. This means that it will cost Los Angeles County an additional $179,000 per day to treat water during drought events, depending on whether or not water restrictions are implemented and whether or not residents follow those restrictions. This equates to a monthly cost of around $5.4 million per additional month of projected drought.

We estimate the increase in drought days for the municipalities in Los Angeles County, which allows us to estimate an increase in water treatment costs due to climate change induced drought. This cost is divided among the municipalities in the county based on population as the individual municipalities contract with Los Angeles County for drinking water.

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[100] Heejun Chang and Matthew Ryan Bonnette, "Climate Change and Water-Related Ecosystem Services: Impacts of Drought in California, USA," *Ecosystem Health and Sustainability* 2, no. 12 (2016): e01254, https://doi.org/10.1002/ehs2.1254.

[101] Benjamen Wright et al., "Managing Water Quality Impacts from Drought on Drinking Water Supplies," *Journal of Water Supply: Research and Technology-Aqua* 63, no. 3 (November 7, 2013): 179–88, https://doi.org/10.2166/aqua.2013.123.

[102] Zeno F. Levy et al., "Critical Aquifer Overdraft Accelerates Degradation of Groundwater Quality in California's Central Valley During Drought," *Geophysical Research Letters* 48, no. 17 (2021): e2021GL094398, https://doi.org/10.1029/2021GL094398.

[103] "Water Utilities," 2023, Drought.gov, accessed December 13, 2023, https://www.drought.gov/sectors/water-utilities.

[104] Julie Blue et al., "Drought Management in a Changing Climate: Using Cost-Benefit Analyses to Assist Drinking Water Utilities" (Water Research Foundation and NOAA, 2015), https://cadmusgroup.com/wp-content/uploads/2015/08/WaterRF_Drought-Management.pdf.

[105] David Dearmont, Bruce A. McCarl, and Deborah A. Tolman, "Costs of Water Treatment Due to Diminished Water Quality: A Case Study in Texas," *Water Resources Research* 34, no. 4 (1998): 849–53, https://doi.org/10.1029/98WR00213.

[106] Hayley Smith and Ian James, "To Survive Drought, Parts of SoCal Must Cut Water Use by 35%. The New Limit: 80 Gallons a Day," *Los Angeles Times*, April 30, 2022, sec. California, https://www.latimes.com/california/story/2022-04-30/can-you-get-by-on-just-80-gallons-of-water-a-day.

[107] "Our County Water Briefing," 2018, https://ourcountyla.lacounty.gov/wp-content/uploads/2018/08/Our-County-Water-Briefing_For-Web.pdf.

[108] U.S. Census Bureau, "U.S. Census Bureau QuickFacts: Los Angeles County, California," 2022, https://www.census.gov/quickfacts/fact/table/losangelescountycalifornia/PST045222.

Note that we assume that drought-related water use restrictions will be implemented and residents will follow those restrictions. As such, we present the increased cost to treat an average of 80 gallons of water use per capita per day in the total cost to taxpayers in Los Angeles County in the report. The associated data download presents the increased cost to Los Angeles municipalities to treat 80 gallons of water use per capita per day.

Appendix E: Protecting Infrastructure from Sea Level Rise

Taxpayer costs were analyzed at the county level.

The methods used to estimate the cost of protecting infrastructure from sea level rise in Los Angeles County are from a previous study that estimated the price to protect coastal communities from sea level rise by constructing seawalls.[109] Note that this previous study used the Relative Concentration Pathway 4.5 (RCP4.5) instead of the SSP2-4.5, which is used in all other analyses in this report.

Appendix F: Methodologies for estimating the cost to treat climate-induced illnesses

In all public health analyses, a baseline year of 2010 was used to determine increased costs of hospitalizations due to climate change.

Appendix F.1: Treating Pediatric Asthma

Taxpayer costs for pediatric asthma were analyzed at the federal level.

Pediatric asthma-related emergency room visits are directly correlated to pollen levels, and therefore to climatic conditions that are projected to change in the coming decades. We quantify the cost of treatment for climate-induced respiratory illness for both the baseline and projected time periods. We define the asthma baseline as the average number of hospital visits for asthma in Los Angeles County per year from 2002 to 2019, which are documented in the National Environmental Public Health Tracking Network.[110] The baseline does not use data from 2020 onward because COVID-19 significantly reduced the number of pediatric asthma emergency department visits.[111] We use a distribution curve relating the number of asthma cases to pollen levels[112] to determine weekly asthma cases, since the National Environmental Public Health Tracking Network only reports asthma cases annually and ages are not included in the data. We use the documented pollen counts for trees, weeds, and grasses (pollen types) from 2018-2021 to set an average weekly level.[113] Average pollen load is determined by adding all pollen counts together and then dividing by the time period to smooth peaks that occur in some of the years.

The annual minimum temperature is used to calculate pollen counts for the asthma baseline and projection time periods to see a general trend in case counts.

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[109] Sverre LeRoy et al., “High Tide Tax: The Price to Protect Coastal Communities from Rising Seas” (Center for Climate Integrity and Resilient Analytics, 2019), https://climatecosts2040.org/files/ClimateCosts2040_Report.pdf.

[110] Centers for Disease Control and Prevention, “National Environmental Public Health Tracking Network,” n.d., https://ephtracking.cdc.gov/DataExplorer/.

[111] Tregony Simoneau et al., “Impact of the COVID-19 Pandemic on Pediatric Emergency Department Use for Asthma,” *Annals of the American Thoracic Society* 18, no. 4 (April 2021): 717–19, https://doi.org/10.1513/AnnalsATS.202007-765RL.

[112] Paul J Villeneuve et al., “Outdoor Air Pollution and Emergency Department Visits for Asthma among Children and Adults: A Case-Crossover Study in Northern Alberta, Canada,” *Environmental Health* 6 (December 24, 2007): 40, https://doi.org/10.1186/1476-069X-6-40.

[113] Allergy, Asthma, & Sinus Center, S.C., “Pollen Explorer,” 2023, https://myaasc.com/pollen-explorer.

Asthma Cases

We determine the impact of climate change on pollen loads by using the relationship between pollen load and annual cumulative minimum temperature.[114] The relationship used to determine pollen counts based on temperature comes from the slope of the best fit line in Figure F1. Using this relationship, we calculate the percent change in pollen load for each type of pollen (tree, grass, weed) through time compared to the baseline year (2010).

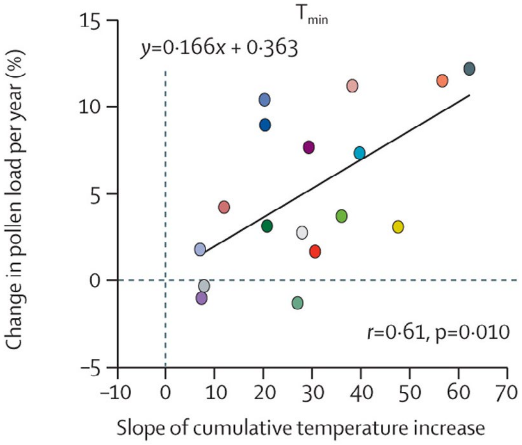

Figure F1: Slope of cumulative temperature increase (-) versus the change in pollen load per year (%) taken from Ziska et al. (2019).

Research has shown that pediatric emergency room visits increase in proportion to pollen loads.[115] Based on this research, we estimate the increase in cases from increase in pollen levels for each pollen type (Table F1).

Table F1: The 5-day average unit increase[116] for different pollen types and the corresponding increase in emergency room visits for pediatric asthma.

Pollen Type	5-day Average Pollen Concentration	5-day Average Pediatric Emergency Department Visits
Tree	664 unit increase	23% increase in visits
Grass	10 unit increase	2% increase in visits
Weed	10 unit increase	13% increase in visits

Cost Estimates

The yearly cost increase of the emergency room visits was established based on insurance type and what the individual scenarios cover.[117] The percent of patients with each insurance coverage and the corresponding cost per visit for that scenario (Table F2).

Table F2: The average breakdown of pediatric asthma visits in the United States.

Type of Insurance	Patient Count	Cost per Asthma Visit	Government Funded?
Uninsured	11.9%	$1,120	No
Medicaid	50.2%	$1,108	Yes – Federal
Medicare	0.5%	$414	Yes – Federal
Private	40.2%	$1,263	No

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[114] Lewis H. Ziska et al., “Temperature-Related Changes in Airborne Allergenic Pollen Abundance and Seasonality across the Northern Hemisphere: A Retrospective Data Analysis,” *The Lancet. Planetary Health* 3, no. 3 (March 2019): e124–31, https://doi.org/10.1016/S2542-5196(19)30015-4.

[115] Jessie A. Gleason, Leonard Bielory, and Jerald A. Fagliano, “Associations between Ozone, PM2.5, and Four Pollen Types on Emergency Department Pediatric Asthma Events during the Warm Season in New Jersey: A Case-Crossover Study,” *Environmental Research* 132 (July 2014): 421–29, https://doi.org/10.1016/j.envres.2014.03.035.

[116] 1 unit increase is 1 grain per cubic meter. Since each source contains a different amount of pollen, unit increases are different for each source.

[117] Tiffany Wang et al., “Emergency Department Charges for Asthma-Related Outpatient Visits by Insurance Status,” *Journal of Health Care for the Poor and Underserved* 25, no. 1 (February 2014): 396–405, https://doi.org/10.1353/hpu.2014.0051.

Appendix F.2: Treating Increasing Incidence of West Nile Virus

Taxpayer costs were analyzed at the federal level.

West Nile Virus (WNV) is carried and transmitted by a genus of mosquitoes that thrive in warmer climates.[118] WNV was first detected in mosquitoes in Los Angeles in September 2003[119] and the first case in a human was reported the year after. Studies have shown that warmer temperatures are linked to accelerated mosquito breeding, bite rates, and the incubation of WNV within mosquitoes.[120] Increased rainfall can also contribute to expanding the suitable breeding grounds for mosquitoes.[121] While most people infected with WNV experience no symptoms, a small percentage develop life-threatening illness.[122]

We modeled the increasing number of cases of WNV in Los Angeles County and the associated health costs as a result of rising temperatures. We established a current WNV-infection rate for Los Angeles County using data provided by the CDC.[123] We used both mean weekly maximum temperature and daily maximum precipitation to model the future WNV incidence rate for Los Angeles County. We distribute cases by week by using the weekly incidence curve[124] since the county data is reported annually.

If the week's mean weekly maximum temperature is at least 5°C higher than the climate baseline (1991-2010), we assume the incidence increases by 40% that week and the following three weeks.[125] If the following three weeks also meet the same criteria, we do not increase the incidence by 40% again (i.e., the incidence will increase by 40% only once, even if all four weeks meet the temperature criteria).

If the week does not have increased incidences because of temperature, we then look at daily maximum precipitation per week.[126] If one or more days in a week have more than 50 mm of precipitation, then we assume the incidence increases by 33% that week and the following two weeks. If the following two weeks also meet that criteria, we *do not* increase the incidence by 33% again.

Because people cannot get WNV more than once, when the total case count reaches the county's population, we stop counting incidences.[127] Most of those infected with WNV experience no symptoms, while those that do get sick can have wide ranging symptoms. Using CDC data, we distributed the yearly incidences by manifestation (Table F3).[128]

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[118] Pien Huang, "The U.S. Is Unprepared for the Growing Threat of Mosquito- and Tick-Borne Viruses," *NPR*, December 15, 2023, sec. Public Health, https://www.npr.org/sections/health-shots/2023/12/15/1219478835/arboviruses-mosquito-tick-borne-viruses-tropical-disease.

[119] Jennifer L. Kwan et al., "West Nile Virus Emergence and Persistence in Los Angeles, California, 2003–2008," *The American Journal of Tropical Medicine and Hygiene* 83, no. 2 (August 5, 2010): 400–412, https://doi.org/10.4269/ajtmh.2010.10-0076.

[120] David M. Hartley et al., "Effects of Temperature on Emergence and Seasonality of West Nile Virus in California," *The American Journal of Tropical Medicine and Hygiene* 86, no. 5 (May 1, 2012): 884–94, https://doi.org/10.4269/ajtmh.2012.11-0342; Shlomit Paz, "Climate Change Impacts on West Nile Virus Transmission in a Global Context," *Philosophical Transactions of the Royal Society B: Biological Sciences* 370, no. 1665 (April 5, 2015): 20130561, https://doi.org/10.1098/rstb.2013.0561; Nooshin Mojahed, Mohammad Ali Mohammadkhani, and Ashraf Mohamadkhani, "Climate Crises and Developing Vector-Borne Diseases: A Narrative Review," *Iranian Journal of Public Health* 51, no. 12 (December 2022): 2664–73, https://doi.org/10.18502/ijph.v51i12.11457.

[121] C. B. Beard et al., "Ch. 5: Vectorborne Diseases," *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment* (U.S. Global Change Research Program, Washington, DC, April 4, 2016), https://health2016.globalchange.gov/vectorborne-diseases.

[122] Centers for Disease Control and Prevention, "West Nile Virus," August 23, 2023, https://www.cdc.gov/westnile/index.html.

[123] Centers for Disease Control and Prevention, "West Nile Virus Historic Data (1999-2022)," June 13, 2023, https://www.cdc.gov/westnile/statsmaps/historic-data.html.

[124] Jonathan E. Soverow et al., "Infectious Disease in a Warming World: How Weather Influenced West Nile Virus in the United States (2001–2005)," *Environmental Health Perspective* 117, no. 7 (2009): 1049–52, https://doi.org/10.1289/ehp.0800487.

[125] Ibid.

[126] Ibid.

[127] Centers for Disease Control and Prevention, "West Nile Virus."

[128] Emily McDonald et al., "Surveillance for West Nile Virus Disease — United States, 2009–2018," *MMWR. Surveillance Summaries* 70 (2021), https://doi.org/10.15585/mmwr.ss7001a1.

Table F3: Initial and long-term cost to treat manifestations of West Nile Virus. Non-neuroinvasive manifestations only have an initial cost, and neuroinvasive manifestations have both an initial and long-term cost.

Manifestation Type	Initial Cost	Long-term Cost	Percent of Cases
Non-neuroinvasive	$5,873.07	$0	96.7%
Neuroinvasive			
Meningitis	$9,546.53	$181.44 per year	2.65%
Encephalitis	$19,900.34	$3,233,02 per year	0.35%
Acute Flaccid Paralysis	$27,313.00	$6,998.51 per year	0.15%

To account for death of a WNV patient due to the neuroinvasive WNV,[129] only 93.56% of the neuroinvasive cases are included in the long-term costs. This is because 6.44% of people with neuroinvasive WNV die within 90 days of symptom onset. To account for death for WNV patients that survive the first 90 days, 50% of the remaining 93.56% neuroinvasive WNV cases from 3 years prior starting in 2023 are removed. In other words, in 2023, 50% of the remaining 93.56% of neuroinvasive WNV cases are removed from 2020, in 2024, 50% of the remaining 93.56% of neuroinvasive WNV cases are removed from 2021, etc. This is because the median time between symptom onset and death is 3 years for people with neuroinvasive WNV if they did not die within the first 90 days. Thus, every year has an initial cost, a long-term cost, and a total yearly cost.[130]

Appendix G: Technical Documentation for Equity and Budget Analysis

Appendix G.1: Equity Analysis

All equity analysis was conducted in the R programming language.[131]

Data

The County of Los Angeles Enterprise GIS Hub[132] was used to determine census tract[133] and municipal[134] boundaries within Los Angeles County, as well as to obtain 11 demographic characteristics (Table G1) at the census tract level, which were collected by the Census Bureau as part of the 2020 American Community Survey 5-Year Data (ACS-5).[135]

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[129] David C.E. Philpott et al., "Acute and Delayed Deaths after West Nile Virus Infection, Texas, USA, 2002–2012," *Emerging Infectious Diseases* 25, no. 2 (February 2019): 256–64, https://doi.org/10.3201/eid2502.181250.

[130] J. Erin Staples et al., "Initial and Long-Term Costs of Patients Hospitalized with West Nile Virus Disease," *The American Journal of Tropical Medicine and Hygiene* 90, no. 3 (March 5, 2014): 402–9, https://doi.org/10.4269/ajtmh.13-0206.

[131] R Core Team (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, https://www.R-project.org/.

[132] County of Los Angeles, "County Of Los Angeles Enterprise GIS," 2024, https://egis-lacounty.hub.arcgis.com/.

[133] County of Los Angeles, "2020 Census Tracts," September 20, 2023, https://egis-lacounty.hub.arcgis.com/datasets/lacounty::2020-census-tracts-4/about.

[134] County of Los Angeles, "City and Unincorporated Community Boundary (Regional Planning)."

[135] United States Census Bureau, "American Community Survey 5-Year Data (2009-2022)," Census.gov, accessed January 29, 2024, https://www.census.gov/data/developers/data-sets/acs-5year.html.

Table G1: The 11 demographic characteristics from the ACS-5 analyzed in this study.

Equity Characteristic	**County of Los Angeles Dataset Name136**
Median Household Income	Census 2020 SRR and Demographic Characteristics[137]
Poverty Rate	
Percent Non-Hispanic White	
Percent Non-Hispanic Black	
Percent Non-Hispanic Asian	
Percent Hispanic	
Percent with Less Than a Highschool Education	
Percent without Internet	
Percent Disability	Disability Status (Census Tract)[138]
Percent Foreign Born Population	Foreign Born Population (Census Tract)[139]
Percent Uninsured	Health Insurance (Census Tract)[140]

Census tracts do not not align perfectly with municipal boundaries. A single census tract may intersect with more than one municipality and a municipality may contain multiple census tracts within its boundaries (Figure G1). Because the equity data is presented at the census tract level, it was first necessary to match each census tract to the municipality(s) that it intersects with and then determine the proportion of the census tract to be assigned to each intersecting municipality. First, we transform the coordinates for the municipal boundaries from World Geodetic System 84 (WGS84; decimal degrees) to North American Datum 83, Universal Transverse Mercator Zone 5 (NAD83, UTM Zone 5; US feet) to match the census tracts planar coordinate system. Then, we simply divide the area of a given municipality that intersects the given census tract by the total land area[141] of the given census tract. Assuming the population density in a given census tract is uniform, we estimate the population for each municipality by multiplying the fraction of the census tract that is in the municipality by the population of the census tract and round to the nearest whole number.[142] An example for census tract "400501" is shown below (Table G2).

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[136] The datasets for disability status, foreign born population, and health insurance contain information for one less census tract (990300) than the Census 2020 SRR and demographic characteristics dataset. Census tract 990300 has a population of 0, so this does not impact the equity analysis.

[137] County of Los Angeles, "Census 2020 SRR and Demographic Characteristics," 2023, https://data.lacounty.gov/maps/e137518f57cf4dbc96ac7139a224631e/about.

[138] County of Los Angeles, "Disability Status (Census Tract)," July 6, 2023, https://data.lacounty.gov/datasets/lacounty::disability-status-census-tract/about.

[139] County of Los Angeles, "Foreign Born Population (Census Tract)," February 14, 2023, https://egis-lacounty.hub.arcgis.com/datasets/lacounty::foreign-born-population-census-tract/about.

[140] County of Los Angeles, "Health Insurance (Census Tract)," https://egis-lacounty.hub.arcgis.com/datasets/lacounty::health-insurance-census-tract/about.

[141] The municipal boundary shapefile contains "holes" in the data due to water (e.g. harbors). The census tracts do not contain these holes, so we use the land area of a census tract instead of total area, so that the area of the given census tract matches the area of all municipalities in the census tract. We do this by taking the sum of the area of all municipalities in the given census tract.

[142] Due to rounding errors, we lose 25 residents or 0.00025% of the population of Los Angeles County.

Figure G1: Los Angeles County municipal boundaries (black outline) and census tract boundaries (gray outline).

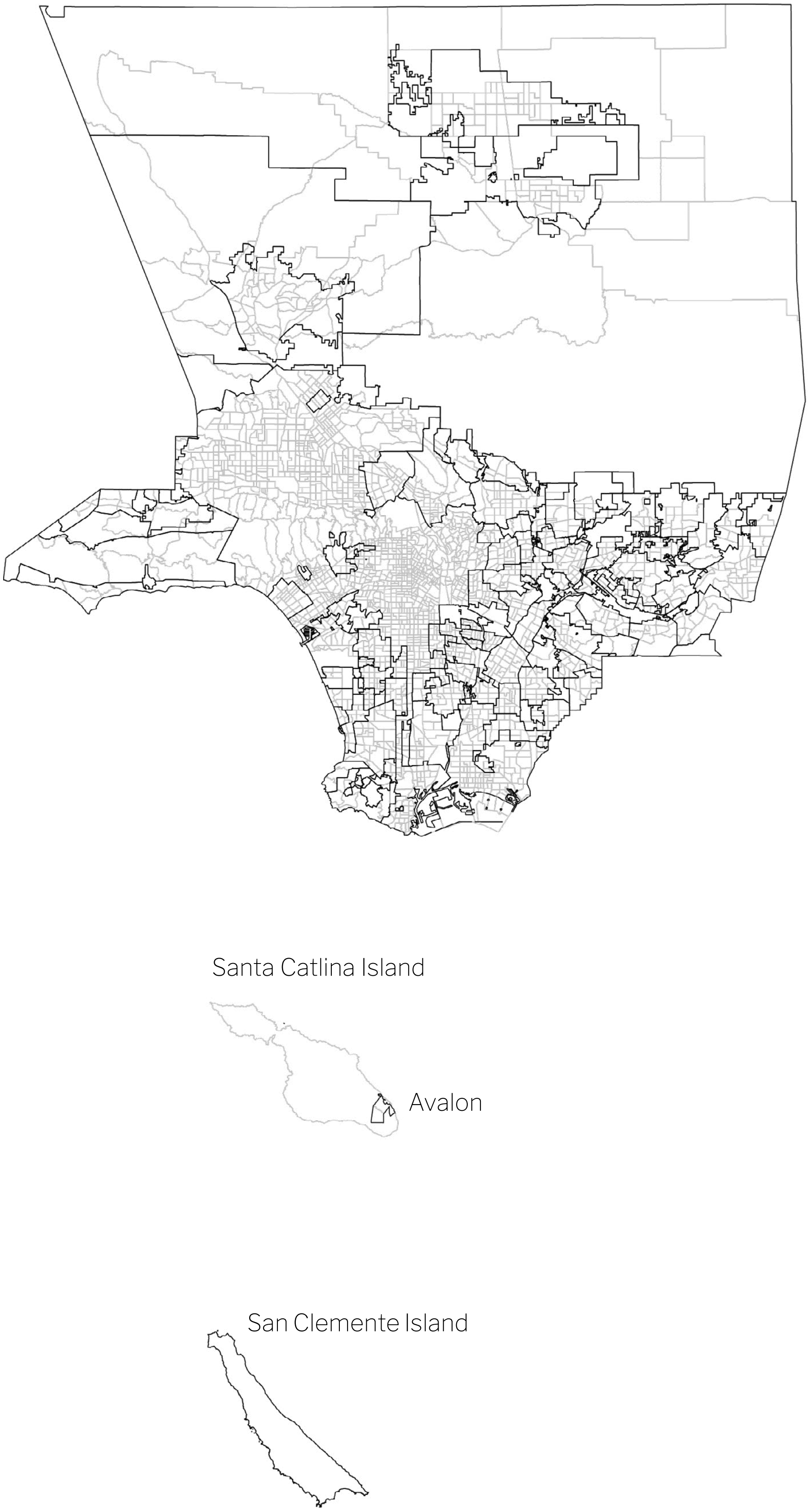

Table G2: An example of a population weighted estimate for census tract 400501, which exists within one incorporated municipality and three unincorporated areas.

Census Tract (CT20)	**Municipality (CITY_COMM_)**	**Jurisdiction (JURISDICTI)**	**Area in CT20 (sq. ft.)**	**Proportion of CT20 in City**	**Area Weighted Population**
400501	Antelope Valley	Unincorporated Area	22,032	0.0017	0
400501	Azusa	Incorporated City	1,806	0.000014	0
400501	East Azusa	Unincorporated Area	4,287,795	0.034	69
400501	Glendora	Incorporated City	118,637,700	0.94	1901
400501	Glendora Islands	Unincorporated Area	3,541,522	0.028	57
			Total Area	**Total Fraction**	**Total Population**
400501	–	–	126,490,830	1.00	2,027

We then take a population weighted average for each demographic dataset (Table G1) to determine an average characteristic for each municipality. The population (P) weighted average calculation for a given demographic characteristic in a given municipality is given by:

$$D_{muni} = \frac{(P_{CT1} * D_{CT1}) + (P_{CT2} * D_{CT2}) + (P_{CT3} * D_{CT3}) + \ldots + (P_{CTx} * D_{CTx})}{P_{Total}} , \qquad \text{(Eq. G1)}$$

where D_{muni} is the demographic characteristic in the city of interest, P_{CTx} is the area weighted population of the given census tract, D_{CTx} is the demographic characteristic in the given census tract, and P_{Total} is the total population in the given municipality. Table G3 outlines an example population (P) weighted average calculation (*Eq. G1*) for percent non-Hispanic white (NHW) residents in the City of Palos Verdes Estates following this logic.

Table G3: Non-Hispanic white population for each census tract (CT20) in Palos Verdes Estates and population weighted average non-Hispanic white population for the entire municipality.

City	**CT20**	**Population (P)**	**Non-Hispanic White (D)**
Palos Verdes Estates	651302	4	62.20%
Palos Verdes Estates	651304	1	63.25%
Palos Verdes Estates	670324	5117	74.59%
Palos Verdes Estates	670326	3706	63.73%
Palos Verdes Estates	670328	4500	55.76%
Palos Verdes Estates	670413	0[143]	39.55%
Palos Verdes Estates	670418	20	58.18%
Total: Palos Verdes Estates	**–**	**13,348**	**65.20%**

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[143] In some instances, a given census tract intersects such a small area of a municipality, that no population is assigned to the given municipality (see Table G3, census tract 670413). Note that the population of the census tract will be assigned proportionally to another municipality(s). We also note that the county has a "Split Tracts" dataset, which assigns census tracts to either incorporated municipalities or unincorporated Countywide Statistical Areas. Their method eliminates census tracts from a given municipality that intersect a negligible area of that given municipality (example census tracts 651302, 651304, 670413, 670418 in Palos Verdes Estates; Table G3).

We now have a dataset of all 11 population weighted demographic characteristics for all 162 municipalities in Los Angeles County. We use these data to assess how municipal per capita climate costs will impact residents across Los Angeles County. We define areas that are above or below, depending on the equity category, the Los Angeles County average statistic for that equity category (Table G4) as high priority equity areas.

Table G4: Los Angeles County mean demographic characteristics from the 2020 ACS-5 survey that are used to define the threshold for our equity categories.

Demographic Characteristic	Mean Characteristic for Los Angeles County[144]	Threshold	Number of Municipalities	Percentage of Municipalities
Median Household Income	$82,516	Low income if **below** $82,516	80	49%
Poverty Rate	13.9%	High poverty if **above** 13.9%	31	19%
Percent Non-Hispanic white	32.5%	Low white if **below** 32.5%	91	56%
Percent Non-Hispanic Black	7.9%	High Black if **above** 7.9%	32	20%
Percent Non-Hispanic Asian	15.0%	High Asian if **above** 15.0%	62	38%
Percent Hispanic	48.0%	High Hispanic if **above** 48.0%	66	41%
Percent Less Than High School Education	19.5%	Low education if **above** 19.5%	58	36%
Percent without Internet	7.4%	High if **above** 7.4%	94	58%
Percent Disabled	11.6%	High disability if **above** 11.6%	32	20%
Percent Uninsured	8.2%	High if **above** 8.2%	53	33%
Percent Foreign Born	33.1%	High foreign born if **above** 33.1%	63	39%

We note that municipalities can fall within multiple racial and ethnic demographic groups. For example, two municipalities fall within both the high white and high Hispanic groups,[145] 10 municipalities fall within both the high white and high non-Hispanic Black groups,[146] and 29 municipalities fall within the high white and high non-Hispanic Asian groups.[147]

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[144] U.S. Census Bureau, "Los Angeles County, California - Census Bureau Profile," Government, 2024, https://data.census.gov/profile/Los_Angeles_County,_California?g=050XX00US06037.

[145] Avalon and Sylmar Island fall in both groups.

[146] Altadena, Ballona Wetlands, Culver City, Lakewood, Marina del Ray, North Claremont, Northeast La Verne, Rolling Hills, West Fox Hills, and West Los Angeles fall in both groups.

[147] Bradbury, Culver City, East Azusa, Gilmore Island, Kinneloa Mesa, La Canada Flintridge, La Crescenta - Montrose, La Habra Heights, La Habra Heights Islands, La Mirada, Lakewood, Lomita, North Claremont, Northeast La Verne, Oat Mountain, Palos Verdes Estates, Pasadena, Rancho Palos Verdes, Rolling Hills, Rolling Hills Estates, San Dimas, San Pasqual, Sierra Madre, South Pasadena, Torrance, Twin Lakes, West Fox Hills, West San Dimas, and Westfield fall in both groups.

Appendix G.2: Budget Analysis

As reported herein, communities in Los Angeles County face around $12.5 billion ($735 million per year) from 2024 through 2040 in adaptation costs to combat just 14 climate impacts. Using the adopted, appropriated budget for Los Angeles County for fiscal year 2023,[148] we examine how the 14 climate adaptation costs might stress the Los Angeles County departmental budgets (Table G5).

Table G5: Targeted county budget analysis for the Beaches & Harbors and Public Works (Water Resources, Transportation, Municipal Services) departments. Climate adaptations are assigned to each department of interest.

Fiscal Year	Department	Adopted Budget – Appropriated	Climate Adaptation
2023	Beaches & Harbors	$99,433,000	Coastal protection
	Public Works[149] – Water Resources	$1,836,914,000	Stormwater drainage and drinking water
	Public Works – Transportation	$882,475,000	Cool pavements, metro rail, road maintenance, bridge stabilization
	Public Works – Municipal Services[150]	$140,504,000	All services for unincorporated areas

We separate the adaptation strategies into the various departments based on publicly available information about which programs each department in Los Angeles County is responsible for. Since most of the adaptations are assigned to the Public Works Department, we separate the adaptations into different core service areas of the Public Works Department to better understand how implementing these climate change adaptations will stress the department.[151]

We also look at how the costs will stress municipal budgets within Los Angeles County. We use the publicly available budgets for the City of Los Angeles, the City of Long Beach, and the City of Santa Clarita, as those cities have some of the highest adaptation costs in the county (Table G6). Similar to our county budget analysis, we separate adaptation strategies into various departments based on publicly available information about which programs those departments are responsible for. We then compare the annual climate adaptation cost to the most recent annual budget for that department. We note that this can be done for any cost for any municipality estimated in this study.

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[148] LA County, "LA County Open Budget Appropriation (Auditor-Controller)," January 3, 2024, https://data.lacounty.gov/datasets/lacounty::la-county-open-budget-appropriation-auditor-controller/explore.

[149] Public Works Los Angeles County, "FY2023-24 Core Services Areas Final Adopted Budget," https://content.pw.lacounty.gov/explore-public-works/budget/core-services-areas/.

[150] Public Works Los Angeles County, "Municipal Services," LA County Public Works, 2024, https://content.pw.lacounty.gov/core-service-areas/municipal-services/.

[151] Public Works Los Angeles County, "FY2023-24 Core Services Areas Final Adopted Budget."

Table G6: Targeted budget analysis for municipal climate adaptations are assigned to each department or budget line item of interest.

Fiscal Year	City	Department/Item	Budget	Climate Adaptation
2023	City of Long Beach	5-Year Climate Adaptation and Action Plan [152]	$16,350,000	Cool pavements
2024	City of Los Angeles	Street Tree and Parkway Maintenance[153]	$27,890,000	Urban canopy
2023	City of Santa Clarita	Stormwater Utility[154]	$4,802,000	Stormwater and drainage capacity
2024	City of Los Angeles	Capital Improvements - Flood Control[155]	$31,550,000	Stormwater and drainage capacity
2024	City of Los Angeles	Pavement Preservation[156]	$111,840,000	Proactive road maintenance

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152 The City of Long Beach, "Innovation & Efficiency," 2023, https://longbeach.gov/globalassets/finance/media-library/documents/city-budget-and-finances/budget/budget-documents/fy-24-proposed-budget/fy-24-innovation-and-efficiency.

153 City of Los Angeles, "LA City Open Budget: Bureau of Street Services," 2024, https://openbudget.lacity.org/#!/year/2024/operating/0/department_name/Bureau+of+Street+Services/0/program_name.

154 City of Santa Clarita, "Annual Operating Budget & Capital Improvement Program: FY2023-2024," 2023, https://filecenter.santa-clarita.com/cmo/FY%202023-24%20Budget%20-%20opt.pdf.

155 City of Los Angeles, "LA City Open Budget: Capital Improvements - Flood Control," 2024, https://openbudget.lacity.org/#!/year/2024/operating/0/program_name/Capital+Improvements+-+Flood+Control/0/department_name.

156 City of Los Angeles, "LA City Open Budget: Pavement Preservation," 2024, https://openbudget.lacity.org/#!/year/2024/operating/0/department_name/Bureau+of+Street+Services/0/program_name/Pavement+Preservation/0/source_fund_name.