Hawai'i Climate Impacts and Costs

The climate crisis is accelerating in Hawaii, posing increased risks and burdening residents with the costs of adapting to a rapidly changing environment. Hawaii will experience increasing drought conditions, more intense tropical storms, rising sea level, and hotter temperatures in the coming years.[1] Even if fossil fuel emissions and atmospheric concentrations of greenhouse gasses eventually stabilize through climate action, the severity of these events will continue to rise as we adjust to the new reality of the climate crisis. Below we outline the impacts of climate change Hawaii faces and some of the potential costs associated with these impacts. This list is not exhaustive, other costs may be incurred as a result of climate change impacts.

Extreme Drought

Extreme drought due to climate change poses a significant threat to Hawaii. From 2010-2019, Hawaii experienced the least amount of rainfall for a consecutive 10 year period since 1900.[2] In other words, Hawaii has recently been experiencing extreme drought conditions. Both rainfall and streamflow have declined in Hawaii since the 1990's.[3] This has led to "browning" across Hawaii over the past four decades and can be seen by analyzing aerial imagery.[4] According to NOAA's National Centers for Environmental Information, drought was the second most expensive natural disaster — costing at least $249 billion — in the U.S. over the last three decades.[5]

Drought increases the risk of wildfires in Hawaii, which impacts human health and air quality. In recent years, the area burned by wildfires in Hawaii has increased fourfold, burning an average of 8,427 ha/yr.[6] Most recently, climate change exacerbated the Maui wildfires, which destroyed the town of Lahaina and killed at least 97 people.[7] The Environmental Protection Agency estimates the cost to treat long-term exposures to

1 "What Climate Change Means for Hawaii." https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-hi.pdf

2 Eischeid et al., "Diagnosing Hawaii's Recent Drought." https://journals.ametsoc.org/view/journals/clim/35/13/JCLI-D-21-0754.1.xml

3 State of Hawaii, "Less & Heavy Rain." https://climate.hawaii.gov/hi-facts/rain/

4 Madson et al., "A Near Four-Decade Time Series Shows the Hawaiian Islands Have Been Browning Since the 1980s." https://link.springer.com/article/10.1007/s00267-022-01749-x

5 Adam Smith, "2010-2019: A landmark decade of U.S. billion-dollar weather and climate disasters," 2020. http://www.climate.gov/news-features/blogs/beyond-data/2010-2019-landmark-decade-us-billion-dollar-weather-and-climate

6 Trauernicht et al., "The Contemporary Scale and Context of Wildfire in Hawai'i1." https://journals.ametsoc.org/view/journals/clim/35/13/JCLI-D-21-0754.1.xml

7 Hassan and Betts, "Maui Wildfires Latest." https://www.nytimes.com/article/maui-wildfires-hawaii.html

wildfire is $450 billion, while short-term exposure (2008-2012) leads to premature death and hospitalizations totaling $63 billion.[8] Wildfires are also costly to fight and control. Fire suppression — which includes expenditure on aviation, vehicles, and fire crew — cost the U.S. $3.7 billion in 2022.[9] On average, the cost of putting out a wildfire is $74,409.[10] Wildfires have become so severe in California that some major insurance companies have pulled out of the home insurance market,[11] which could become a reality in Hawaii as wildfire frequency and severity increase. Since 1980, the U.S. has experienced an increasing number of wildfires that cost over $1 billion per event. These large wildfires cost the U.S. $13.2 billion per year from 2018-2022, significantly more money than in the 1980's where there were no billion dollar wildfires in the U.S.[12]

Drought also causes water security issues, as climate change will impact the amount of water available for some Hawaiian islands.[13] For example, the amount of water available in the Nuuanu watershed located in Oahu is projected to decrease by as much as 27%.[14] Similarly, water availability is projected to decrease due to climate change in the Heeia watershed.[15] The Na Wai Eha watershed is also experiencing a decrease in rainfall, which threatens the groundwater supply from which 80% of Hawaii gets their drinking water.[16] The decrease in water availability is particularly troubling, as researchers estimate that water demand on the Hawaiian islands may increase up to 36% by the end of the century.[17]

8 Jesse Roman, Angelo Verzoni, and Scott Sutherland, "The Wildfire Crisis: Greetings from the 2020 Wildfire Season," *National Fire Protection Association Journal*, 2020. http://www.nfpa.org/News-and-Research/Publications-and-media/NFPA-Journal/2020/November-December-2020/Features/Wildfire

9 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/

10 Bishop, "Wildfire Statistics." https://www.valuepenguin.com/homeowners-insurance/wildfire-statistics

11 The Associated Press, "Surge in U.S. Thunderstorms" https://www.cbc.ca/news/business/swiss-re-insurance-damage-1.6932920

12 NOAA, "U.S. Billion-Dollar Weather and Climate Disasters" https://www.ncei.noaa.gov/access/billions/

13 "What Climate Change Means for Hawaii."

14 Leta, El-Kadi, and Dulai, "Implications of Climate Change on Water Budgets and Reservoir Water Harvesting of Nuuanu Area Watersheds, Oahu, Hawaii." https://ascelibrary.org/doi/10.1061/%28ASCE%29WR.1943-5452.0000839

15 Leta et al., "Assessment of Climate Change Impacts on Water Balance Components of Heeia Watershed in Hawaii." https://www.sciencedirect.com/science/article/pii/S2214581816301215

16 State of Hawaii, "Less & Heavy Rain."

17 DeMaagd and Roberts, "How Will Climate Change Affect Residential Water Demand?" https://www.worldscientific.com/doi/10.1142/S2382624X21500053

Potential Costs Related to Extreme Drought

Water Management

- Purchase of water during water-scarce times.[18]
- Public health costs related to increased exposure to water-borne illnesses.[19]
- Replace old pipelines and related infrastructure that have water leak issues.[20]
- Building water conservation infrastructure.
- Upgrade water treatment, wastewater treatment, and other energy infrastructure.[21]
- Maintain and expand urban and community tree canopy.[22]

Wildfires

- Implement building standards to protect structures against wildfires.[23]
- Increase fire suppression, including staffing, equipment, 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.[24]
- 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).

18 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

19 Ibid.

20 CISA, "Drought and Infrastructure - A Planning Guide" https://www.cisa.gov/sites/default/files/publications/Drought_and_Infrastructure_A_Planning_Guide_508c.pdf

21 Ibid.

22 Gibson and Jones, "Clark County, Nevada: Climate Vulnerability Assessment." https://allinclarkcounty.com/resources/ID_59/Documents/CC_CVA_FINAL_LR.pdf

23 Flavelle, "Fire Exposes Flaws in Hawaii's Defenses Against Climate Shocks." https://www.nytimes.com/2023/08/17/climate/hawaii-climate-wildfire-prevention.html

24 Jennifer L, "Wildfires Cost Over $148B" https://carboncredits.com/wildfires-cost-emissions/

Local Planning and Regulation

- Organize public participation and staffing in the creation of water scarcity management plans.[25]
- Develop tools for monitoring ground and surface water resources for public use.[26]

Education and Awareness Programs

- Public education, outreach, and awareness campaigns about water conservation.[27]
- Increase public outreach to encourage wildfire risk management; educate residents in wildfire safety, technical assistance availability, funding sources, and best practices.

Summary of Costs from Drought

Fire prevention and recovery, water security and water treatment, infrastructure damages, public health, and education and awareness.

Tropical Storms and Flooding

Hawaii has also been experiencing more intense storms and hurricanes, where vast amounts of rain fall all at once. For example, in April 2018, 50 inches of rain fell in a period of 24-hours in Kauai.[28] This storm flooded over 500 homes and damage to public properties was estimated at $20 million. This storm also triggered many landslides, which cut off access to both Wainiha and Haena for over two weeks.[29] Precipitation-induced landslides further compound risk to people, homes, roads, and other infrastructure. In March 2021, a state of emergency was declared in Hawaii because of "extensive damage" caused by a severe storm and subsequent flooding. People in Maui and Oahu were even ordered to evacuate. In cases like these, state funds are used to help people in need.[30]

In 2014, Hawaii experienced an unusually active tropical cyclone season, which researchers found was made more likely by climate change.[31] In December 2021, major roads were shut down in Hawaii to remove rocks, trees, and downed power lines that

25 CISA, "Drought and Infrastructure - A Planning Guide"
26 Ibid.
27 Ibid.
28 State of Hawaii, "Less & Heavy Rain."
29 National Weather Service, "Record Kauai and Oahu Rainfall and Flooding - April 2018." https://www.weather.gov/hfo/RecordKauaiandOahuRainfallAndFlooding-April2018
30 Diaz, "Hawaii Governor Declares State of Emergency After Floods." https://www.nytimes.com/2021/03/09/us/maui-hawaii-dam-evacuation.html
31 Murakami et al., "Investigating the Influence of Anthropogenic Forcing and Natural Variability on the 2014 Hawaiian Hurricane Season." https://doi.org/10.1175/BAMS-D-15-00119.1

were caused by tropical cyclone induced flash floods.[32] Increased tropical cyclone activity is likely to persist as the climate warms.[33] According to NOAA, tropical cyclones are the costliest billion-dollar natural disaster in the United States. Since 1980, billion-dollar tropical cyclones have cost the U.S. $1.3 trillion, which is about $22.8 billion per event.[34] As such, tropical cyclones pose an immense economic threat to Hawaiian residents.

Potential Costs Related to Tropical Storms

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)[35] 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.

32 Medina and Lukpat, “Flash Floods Hit Parts of Hawaii as Storm Lashes Region.” https://www.nytimes.com/2021/12/06/us/hawaii-flooding.html

33 Murakami et al., “Projected Increase in Tropical Cyclones near Hawaii.” https://www.nature.com/articles/nclimate1890

34 “NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters.” https://www.ncei.noaa.gov/access/billions/summary-stats

35 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.”

- 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).[36]
- 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.

Local Planning and Regulation

- 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). [37]
- 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.

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

37 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 October 18, 2023; Hawaii has over 55,000 policies in place covering almost $14 billion.

Summary of Costs from Tropical Storms

Floodproof buildings, relocate infrastructure in especially flood prone areas, improve drainage systems and flood control structures, elevate infrastructure (buildings, roads, and bridges) where needed, restore natural flood protection, develop and implement comprehensive flood management plans, preserve floodplains, and increase public awareness of flooding.

Sea Level Rise

As sea level rise continues to accelerate due to climate change, Hawaii will face many serious associated impacts. While sea level rise rates vary across the Hawaiian islands due to various geological processes, according to NOAA sea level has risen 10 inches on average in Hawaii as compared to 1950.[38] Sea level rise has and will continue to cause coastal inundation and flooding.[39] For example, the mean number of days that cause high tide flooding in Honolulu has almost doubled from 6 to 11 days per year since the 1960's.[40] High tide flooding impacts infrastructure throughout Hawaii.[41]

Increased coastal erosion and shoreline retreat has also been linked to sea level rise in Hawaii.[42] Almost all the shorelines in Hawaii (~92%) are predicted to retreat between 1-24 m, depending on location, by 2050.[43] The researchers predict shoreline retreat rates that are twice that of the historical rate due to sea level rise.[44] To combat sea level rise in Hawaii, the state has $6 billion in planned solutions, such as dredging and restoring wetlands.[45]

38 SeaLevelRise.org, "Hawaii's Sea Level Has Is Rising." https://sealevelrise.org/states/hawaii/#:~:text=The%20sea%20level%20off%20Hawaii's,and%20it's%20causing%20major%20issues

39 Hawai'i Climate Change Mitigation and Adaption Commission, "Hawai'i Sea Level Rise Vulnerability and Adaptation Report." https://sealevelrise.org/states/hawaii/#:~:text=collectively.-,4,-The%20state%20is

40 Marra and Kruk, "State of Environmental Conditions in Hawaii and the U.S. Affiliated Pacific Islands under a Changing Climate: 2017." https://coralreefwatch.noaa.gov/satellite/publications/state_of_the_environment_2017_hawaii-usapi_noaa-nesdis-ncei_oct2017.pdf

41 Habel et al., "Sea-Level Rise Induced Multi-Mechanism Flooding and Contribution to Urban Infrastructure Failure." https://www.nature.com/articles/s41598-020-60762-4

42 Romine et al., "Are Beach Erosion Rates and Sea-Level Rise Related in Hawaii?" https://www.sciencedirect.com/science/article/pii/S0921818113001513

43 Anderson et al., "Doubling of Coastal Erosion under Rising Sea Level by Mid-Century in Hawaii." https://link.springer.com/article/10.1007/s11069-015-1698-6

44 Ibid.

45 SeaLevelRise.org, "Hawaii's Sea Level Has Is Rising."

Potential Costs Related to Rising Sea Level

Structure and Infrastructure Projects

- Stabilize susceptible coastal slopes and cliffs and shorelines using grading techniques, planting vegetation, riprap or geotextile fabric, or bioengineering.
- Maintenance of canals and ports through dredging.[46]
- Refer to "Structure and infrastructure projects" from "Potential costs related to tropical storms," 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.[47]

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.

Summary of Costs from Sea Level Rise:

Implement flood management infrastructure and structure projects in coastal areas, install coastal protection, restore natural flood protection, develop and implement a comprehensive coastal zone management plan, and increase public awareness of sea level rise risks.

46 City & County of Honolulu, "Climate Adaptation Design Principles for Urban Development." https://www.honolulu.gov/rep/site/dpptod/dpptod_docs2/Climate_Adaptation_Principles.pdf

47 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

Increasing Temperatures

Climate change will cause more extreme temperatures in Hawaii. The average annual temperature in Hawaii in 2016 was about 1.7°F warmer than the 100-year mean from 1917 to 2016.[48] Similarly, global mean sea surface temperature has increased by about 1.8°F over the past century and waters around Hawaii have followed this trend.[49]

Increasing atmospheric temperatures are a public health threat. Heat illness is already a common health problem in the Hawaii Islands due to its tropical climate,[50] but heat illness will become more frequent and severe as temperatures continue to increase. The city of Honolulu has plans to mitigate extreme heat as the atmosphere warms, by planting trees and increasing shade, among other things.[51] Increasing sea surface temperatures also pose great risk to Hawaii, as warmer ocean temperatures kill coral reefs and other marine life.[52] This is devastating to Hawaii, as NOAA estimates that Hawaiian coral reefs bring in 60% of Hawaii's tourism income.[53] Coral reefs also provide protection to the coastline during storms and help decrease flooding.[54] Without coral reefs, both high tide and storm surge flooding will likely be worse.

Potential Costs Related to Increasing Temperatures

Structure and Infrastructure Projects

- Energy efficiency retrofits in public and private buildings and housing, including costs for the design and development of energy efficiency 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 temperatures.

48 McKenzie, Giambelluca, and Diaz, "Temperature Trends in Hawai'i." https://rmets.onlinelibrary.wiley.com/doi/abs/10.1002/joc.6053

49 Marra and Kruk, "State of Environmental Conditions in Hawaii and the U.S. Affiliated Pacific Islands under a Changing Climate: 2017."

50 Gordon, "Heat Illness in Hawai'i." https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4244899/

51 City & County of Honolulu, "Climate Adaptation Design Principles for Urban Development." https://www.honolulu.gov/rep/site/dpptod/dpptod_docs2/Climate_Adaptation_Principles.pdf

52 Pierre-Louis, "The Return of the 'Blob.'" https://www.nytimes.com/interactive/2019/10/21/climate/hawaii-coral-bleaching.html

53 NOAA, "Shallow Coral Reef Habitat." https://www.fisheries.noaa.gov/national/habitat-conservation/shallow-coral-reef-habitat#:~:text=and%20fisheries%20activity.-,Tourism,income%20comes%20from%20reef%20visitors

54 "How the Climate Crisis Is Affecting Hawaii." https://www.climaterealityproject.org/blog/how-climate-crisis-affecting-hawaii

- Increase high-albedo surfaces on buildings, roads, or where feasible.
- "Promote landscaping on rooftops and around buildings for cooling."[55]
- "Provide shade through trees, awnings, or canopies."[56]

Public Health Projects

- Build and manage more cooling centers, including staffing and tracking of high-risk individuals.
- "Formalize a network of well-resourced mobile crisis intervention services to engage communities of concern during emergency and non-emergency situations."[57]
- 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 mosquitos.
- Treat victims of vector borne illness.
- Treat victims of heat induced 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.

Summary of Costs from Temperature Extremes:

Public health costs (e.g., medicare/medicaid), AC installation and improvement where needed, establishing new cooling centers, planting trees to reduce urban heat islands, and protecting drinking water supplies.

55 City & County of Honolulu, "Climate Adaptation Design Principles for Urban Development."

56 Ibid.

57 Gibson and Jones, "Clark County, Nevada: Climate Vulnerability Assessment." https://allinclarkcounty.com/resources/ID_59/Documents/CC_CVA_FINAL_LR.pdf

Other Extreme Weather

Other extreme weather includes: increased El Niño years, hailstorms, tsunamis, and big waves.

Potential Costs Related to 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.

Other Public Health Costs

Other plausible impacts from climate change that would incur public health costs are increased allergen levels, food- and waterborne infections, and zoonotic diseases.