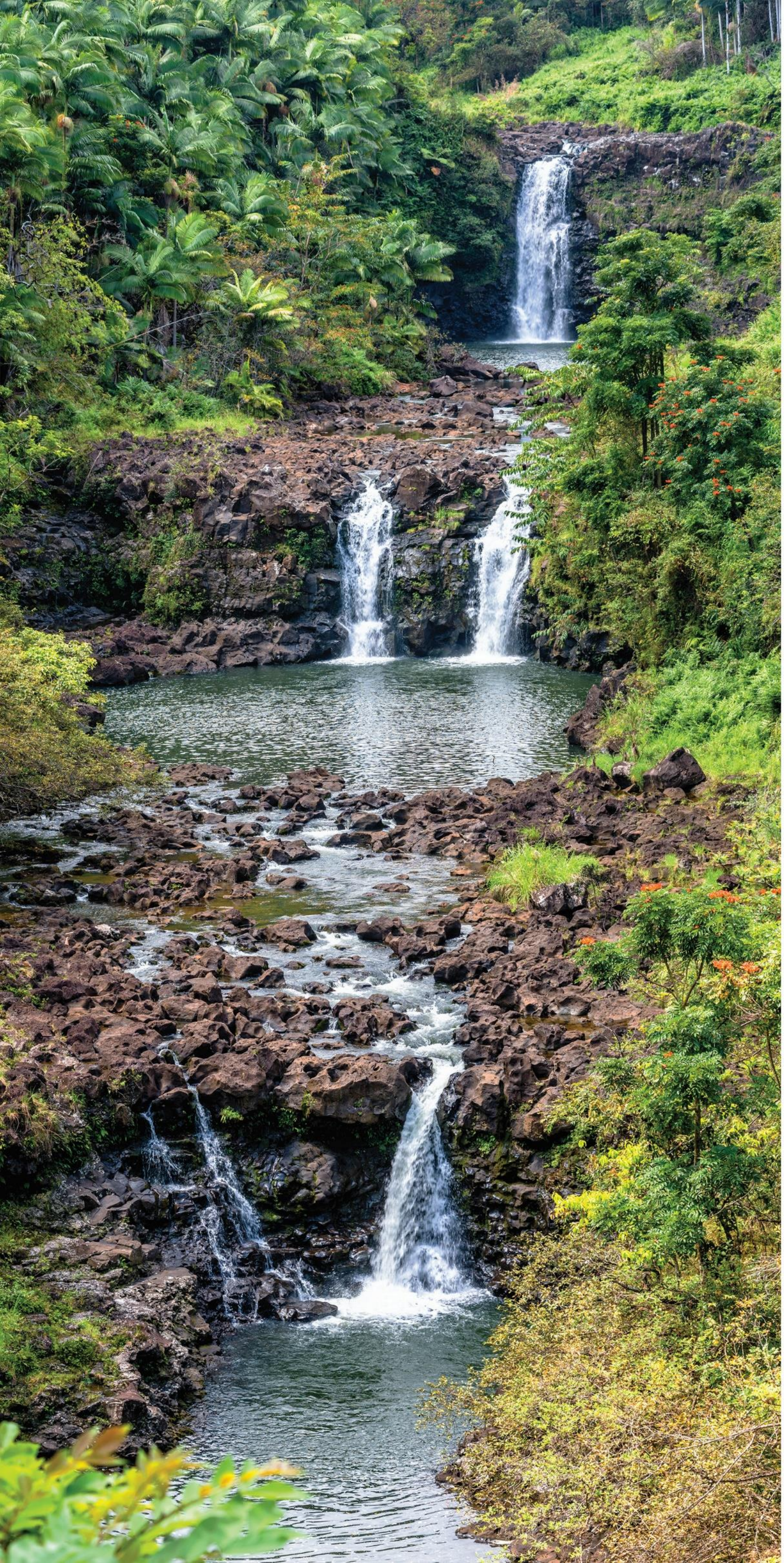

May 2023

Integrated Climate Action Plan for the Island of Hawai‘i

Greenhouse Gas Reduction and Climate Adaptation Actions to Build Local Resilience to Climate Change

(DRAFT)

COUNTY OF HAWAII
STATE OF HAWAII

FPS

TETRA TECH

LAND ACKNOWLEDGMENT

We wish to recognize and respect Kanaka Maoli people as the original and continuing stewards of the land known as Hawaiʻi County. Through the ahupuaʻa system, Kanaka Maoli people managed the island waters and land for over a thousand years. Acknowledging the land is an expression of gratitude to the territory that nurtures us and the host culture and people who have built a relationship with and understanding of the land. Climate change is inextricably linked to the exploitation of people, land, and nature. Land acknowledgements recognize that this exploitation is tied to colonialism as a current and ongoing process and that governments have played a significant role in facilitating colonization on this land. The pursuit of colonization has resulted in significant loss of traditional knowledge, cultural practices, and native ecosystems that are essential for stewarding nature and preventing climate change. While it is outside the scope of this document, it is essential that the restoration and conservation of these traditional systems of knowing and ecological stewardship guide climate change mitigation and adaptation.

Climate change is an existential threat to all life and natural systems globally and here in Hawaiʻi. The natural cycle of greenhouse gases flowing from land and water to air (the greenhouse gas effect) enables life as we know it to exist. However, human activities have created an enhanced greenhouse effect that causes unprecedented warming of the Earth's atmosphere and oceans. This warming triggers complex, cascading effects that jeopardize natural systems on Earth. To restore balance to our natural system, we need to reduce our greenhouse gas emissions at the local level. In order to prepare for the current and future effects of climate change, we need to weave climate adaptation into our efforts to build resilient communities. This Integrated Climate Action Plan (ICAP) for the Island of Hawaiʻi establishes a greenhouse gas emissions baseline for the County, describes the impacts of climate change on natural hazards and community systems, and identifies both climate mitigation and adaptation actions that Hawaiʻi County can take to reduce or minimize these effects.

ACKNOWLEDGMENTS

The ICAP was developed and reviewed with the assistance of consultants, a Climate Action Plan Working Group and Technical Reviewers. Bethany Morrison, County Planning, and Kendra Obermaier, County Research and Development, led the planning effort. Amy DeBay (Focused Planning Solutions) and Kitty Courtney (Tetra Tech, Inc.) provided technical support in developing the plan framework, risk and exposure analysis, and Climate Cascade Mapping Tool. The Climate Action Working Group contributed to development and review of the plan. Members of County departments reviewed the actions. The County would like to extend a mahalo to all the community partners and County staff who contributed to the ongoing feedback and development of the ICAP.

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Stakeholder Input

Working Group: In the summer of 2021, Hawaiʻi County hosted three Climate Action workshops in Hilo and Kona. The County produced a Hawaiʻi Island Climate Action simulation for the workshops. During the workshops, the County presented the proposed Climate Action Plan scope, goals, and development process and facilitated the simulation with the group. The County formed a Climate Action Plan Working Group with the workshop participants. The Working Group met monthly from July 2021 – December 2021. The group then met every 3 months from January – June 2022. The Working Group was re-convened to review the draft plan in 2023.

The Working Group advised the County on the focus of the Plan. They also helped develop and distribute a Climate Change Community Sentiment Survey with the County. The high-level results and recommendations from the survey informed the identification of co-benefits for actions and the stakeholder engagement outlined in the Implementation section. For more information on the survey results, see Appendix C. Initially, the County proposed a community-wide scope for the plan and co-developed a scope for community outreach that would feed into this plan. The scope of outreach necessary to produce a place-based, equitable Climate Action Plan was determined to be unrealistic with the County's plan budget and staff. Long-term climate action planning and implementation should include continued partnerships like those described in the Implementation section. Mahalo nui loa to the working group members listed above who have provided feedback throughout the ICAP process.

County Staff: The County Climate Action Team hosted a series of interdepartmental meetings from October 2022 – January 2023 to review the outline and technical analysis of the ICAP with department directors and deputy directors. The Team then met one-on-one with the departments that are leads for the actions in the plan to review and amend plan actions. The actions in this document are the finalized actions approved by the departments.

Technical Review: The County Climate Action Team reached out to academic researchers focused on climate adaptation and mitigation in Hawaiʻi to review the ICAP. The technical reviewers provided feedback on the scientific framework, analyses and references in the ICAP. The International Council for Local Environmental Initiatives (ICLEI) also provided technical feedback as part of the County's participation in the ICLEI Integrated Climate Action Planning Cohort.

EXECUTIVE SUMMARY

The United Nations Intergovernmental Panel on Climate Change has concluded in its most recent report that human activities have unequivocally caused global warming.[1] Climate change is already impacting the lands and waters on which we live and the health of our communities. The ICAP identifies actions the County government itself can take and is a first step for the County holding itself accountable for climate action. The actions outlined in the ICAP will help the County achieve the following vision and goals, in alignment with existing State and County priorities.

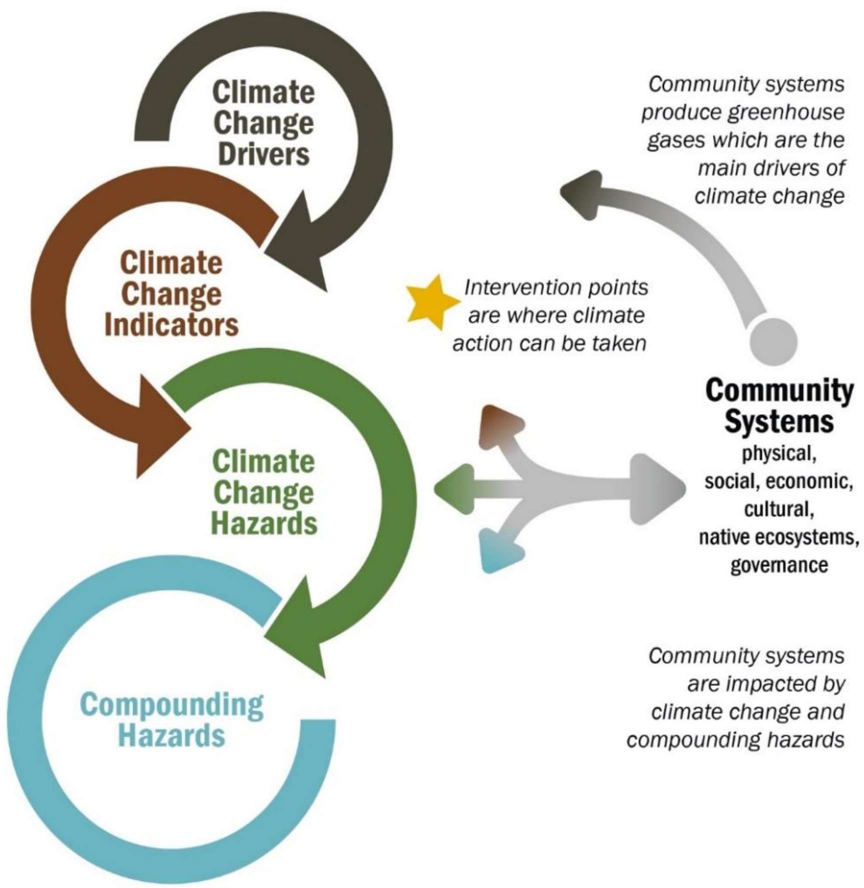
Vision: We ensure a just transition to a **climate resilient island** by addressing the causes and impacts of climate change through incorporating equitable climate mitigation and adaptation priorities into policies, programs, infrastructure, and decision making.

Goals:

1. Improve county capacity to implement climate action.
2. Reduce the County's contribution to global greenhouse gas emissions.
3. Increase the resilience of County infrastructure, assets, and services to climate change impacts.

Climate Action Framework

To accomplish these goals, the ICAP identifies climate mitigation and adaptation actions to be taken by Hawaiʻi County. Mitigation includes actions to reduce greenhouse gas emissions and adaptation actions include actions that build resilience to climate change impacts. A climate action framework was developed to describe the cascading effects of climate change and identify intervention points for County action (**see figure**). Exposure and risk analyses for the cascades were conducted using a geospatial overlay of climate hazards on maps of County assets.



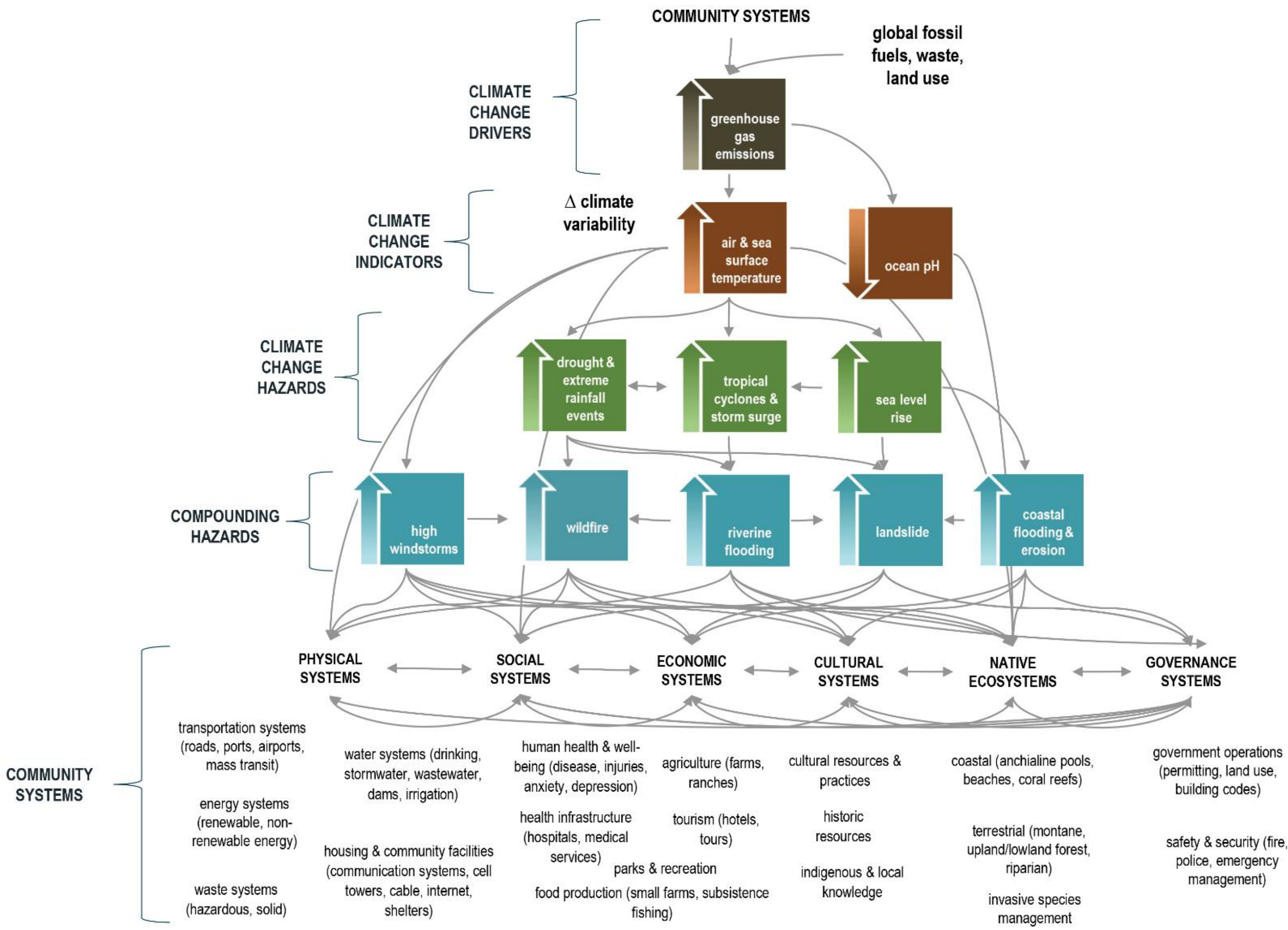
[1] United Nations, Intergovernmental Panel on Climate Change (IPCC) (2023) Synthesis Report of the IPCC Sixth Assessment (AR6), Summary for Policy Makers. https://report.ipcc.ch/ar6syr/pdf/IPCC_AR6_SYR_SPM.pdf

Five cascading areas of impact were identified. Key intervention points were determined under each cascade. County actions were identified within these key intervention points. Individual actions that can be taken and co-benefits of County actions were also highlighted for each cascade. The implementation section outlines the capacity and financing improvements required to execute the ICAP and the County's process for monitoring and evaluation. The five cascades are:

- **Climate Cascade 1 – Greenhouse Gas Emissions** caused by human activities are the key drivers of human-induced climate change. This climate cascade establishes a baseline for greenhouse gas emissions for the Island of Hawaiʻi from which to develop climate mitigation interventions to reduce Hawaiʻi County contributions to global climate change.
- **Climate Cascade 2 –Air and Sea Surface Temperature** are directly influenced by greenhouse gas emissions. These climate change indicators have direct impacts on human and native ecosystem health.
- **Climate Cascade 3 – Drought and Severe Rainfall Events** are among the climate hazards resulting from increasing air and sea surface temperature and climate variability. Drought and severe rainfall impacts to community systems are exacerbated by the compounding hazards of wildfire, landslides, windstorms, and riverine flooding.
- **Climate Cascade 4 – Sea Level Rise** is a climate hazard with slowly emerging impacts on community systems, compounded by coastal and riverine flooding and landslides.
- **Climate Cascade 5 – Tropical Cyclones and Storm Surge** are climate hazards with extreme impacts on community systems.

Although Hawaiʻi Island alone will not reverse the harmful impacts of climate change, we can lead by example and set precedent for other island-states to become more sustainable through energy conservation and efficiency, clean transportation, zero waste initiatives, and better management of water, land, and natural resources.

Climate Cascade Summary



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ACRONYMS

AFOLU	Agriculture, Forestry, and Other Land Use
CD	Hawaiʻi County Civil Defense
CO_2	Carbon Dioxide
DEM	Hawaiʻi County Department of Environmental Management
DFIRM	Digital Flood Insurance Rate Map
DPR	Hawaiʻi County Department of Parks and Recreation
DPW	Hawaiʻi County Department of Public Works
DWS	Hawaiʻi County Department of Water Supply
ENSO	El Niño-Southern Oscillation
EPA	Environmental Protection Agency
EV	Electric Vehicle
FD	Hawaiʻi County Fire Department
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
GHG	Greenhouse Gas
ICAP	Integrated Climate Action Plan
IPCC	Intergovernmental Panel on Climate Change
MTA	Mass Transit Agency
$MTCO_2e$	Metric Tons of Carbon Dioxide Equivalent
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
PD	Hawaiʻi County Planning Department
R&D	Hawaiʻi County Department of Research and Development
RCP	Representative Concentration Pathway
SLR	Sea Level Rise

KEY TERMS

Carbon sequestration refers to actions that remove carbon from the atmosphere.

Cascading effects refers to the network of interactions between human activities causing climate change and the impacts of climate change on community systems. These cascading effects are of greater magnitude than any individual element of the network.

Climate adaptation refers to actions that adjust to actual or expected future climate with the goal of reducing risks from the harmful effects of climate change and maximizing any potential benefit opportunities.[2]

Climate cascade summarizes the cascading effects between human activities causing climate change and the impacts of climate change on community systems.

Climate change refers to the long-term (usually at least 30 years) regional or even global average of temperature, humidity, and rainfall patterns over seasons, years, or decades.[3] Human-induced climate change is resulting in global warming, the long-term heating of Earth's surface.

Climate change drivers are greenhouse gases, primarily CO2, methane, and nitrous oxide, in the atmosphere resulting from human activities over the industrial era, that are the principal drivers of many changes observed across the atmosphere, ocean, cryosphere and biosphere.[4] Greenhouse gas emissions from building electricity, energy production, transportation, waste, and land use are considered climate change drivers of focus in the ICAP.

Climate change hazard refers to changes in a physical process or event (hydro-meteorological or oceanographic variables or phenomena) driven or amplified by human induced climate change that can harm human health, livelihoods, or natural resources. Drought, extreme rainfall events, sea level rise, and tropical cyclones and storm surge are considered climate change hazards of focus in the ICAP.

Climate change indicators are observed climate changes linked to rising levels of greenhouse gases in our atmosphere caused by human activities.[5] Increasing air and sea surface temperature and ocean acidification are considered climate change indicators of focus in the ICAP.

Climate mitigation refers to actions that reduce the flow of greenhouse gases into the atmosphere, either by reducing sources of these gases or enhancing the sinks that accumulate and store these gases. Climate mitigation and "GHG reduction" are used interchangeably throughout this document:[6]

- **GHG sources** refers to processes and behaviors that emit GHG, such as burning fossil fuels for electricity and transportation.
- **GHG sinks** refers to processes and behaviors that sequester and store GHG, such as forests, oceans, and soils.

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[2] NASA, Global Climate Change, https://climate.nasa.gov/solutions/adaptation-mitigation/
[3] NASA, Global Climate Change, https://climate.nasa.gov/global-warming-vs-climate-change/
[4] NASA, Global Climate Change, https://climate.nasa.gov/causes/
[5] EPA, Global Climate Change Program, https://www.epa.gov/climate-indicators
[6] NASA, Global Climate Change, https://climate.nasa.gov/solutions/adaptation-mitigation/

Climate resilience is the ability to anticipate, prepare for, and respond to hazardous events, trends, or disturbances related to climate change. Improving climate resilience involves assessing how climate change will create new, or alter current, climate-related risks, and taking steps to better cope with these risks.[7]

Climate risk occurs from the interaction of hazard, exposure, and vulnerability.[8]

Co-benefits refer to the potential for actions to achieve multiple positive impacts and reinforcing outcomes.[9]

Community systems are the diverse and interconnected physical, social, economic, ecological, cultural, and governance systems supporting the health and wellbeing of the people of Hawaiʻi Island.

Compounding hazards are hazards that are exacerbated by climate change indicators and hazards. Riverine flooding, landslides, wind storms, and coastal flooding and erosion are considered compounding hazards of focus in the ICAP.

Global warming is the long-term heating of Earth's surface observed since the pre-industrial period (between 1850 and 1900) due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth's atmosphere.[10]

Hazard mitigation is any sustainable action that reduces or eliminates long-term risk to people and property from future disasters.[11]

Intervention points refer to specific points where a climate cascade could be disrupted by an action to prevent cascading effects and negative impacts on community systems.

RCP 8.5 is the future greenhouse gas emissions scenario with the highest level of emissions of the standard scenarios in use for climate change projections. It assumes no measures will be taken to reduce emissions from current trends.

Risk is the potential for an unwanted outcome resulting from an event, as determined by the likelihood of the event and the associated consequences.[12]

Threat is a natural, technological, or human-caused occurrence, individual, entity, or action that has or indicates the potential to harm life, information, operations, the environment, and/or property (FEMA).

Vulnerability refers to the degree to which a community is susceptible to adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC).

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[7] Center for Climate and Energy Solutions, https://www.c2es.org/content/climate-resilience-overview/#:~:text=Climate%20resilience%20is%20the%20ability,better%20cope%20with%20these%20risks.

[8] International Atomic Energy Authority, https://www.iea.org/reports/climate-resilience-policy-indicator/climate-hazard-assessment

[9] Mayrhofer, J. P., & Gupta, J. (2016). The science and politics of co-benefits in climate policy. Environmental Science & Policy, 57, 22-30. doi:https://doi.org/10.1016/j.envsci.2015.11.005

[10] NASA, Global Climate Change, https://climate.nasa.gov/global-warming-vs-climate-change/

[11] FEMA, Hazard Mitigation Assistance Grants, https://www.fema.gov/grants/mitigation#:~:text=%22Hazard%20mitigation%22%20is%20any%20sustainable,damage%2C%20reconstruction%20and%20repeated%20damage.

[12] FEMA, https://emilms.fema.gov/is_0870a/groups/22.html

VISION, GOALS, AND ALIGNMENT

Hawaiʻi Island has long held a reciprocal relationship between land and people. As an island community, we can tangibly experience the cascading effects of our actions on the people and places surrounding us. Island communities such as Hawaiʻi Island are at the forefront of climate change, as we experience impacts such as sea level rise and coral bleaching. Our small population and island geography make us feel more deeply the cascading effects of any impact on the health and the land of the people.

The Integrated Climate Action Plan (ICAP) is a first step by Hawaiʻi County to address the causes and effects of climate change. The County has a dual role to play: reducing the County's contribution to global climate change; and building the resiliency of our programs, policies, and infrastructure to climate change. The actions outlined in the ICAP will help the County achieve the following vision and goals, in alignment with existing State and County priorities.

Vision

We ensure a just transition to a **climate resilient island** by addressing the causes and impacts of climate change through incorporating equitable climate mitigation and adaptation priorities into policies, programs, infrastructure, and decision making.

Goals

1. Improve County capacity to implement climate action.
2. Reduce the County's contribution to global greenhouse gas emissions.
3. Increase the resilience of County infrastructure, assets, and services to climate change impacts.

Alignment

Several commitments at the State and County level have set mandated and non-mandated greenhouse gas emissions goals for select industries (Figure 1). Targets have been set for greenhouse gas emissions, renewable energy standards, and transportation reform. However, clear and explicit goals codified at the County level are needed to emphasize the urgency and commitment this plan requires.

To demonstrate the County's commitment to climate action, the County should codify climate mitigation and adaptation goals. This plan recommends that the County codify mitigation goals in alignment with State renewable energy goals, County renewable energy for transportation goals, and the County's zero waste resolution. This plan recommends that the County codify adaptation goals in alignment with the Climate Adaptation Priority Guidelines defined in the State Planning Act.

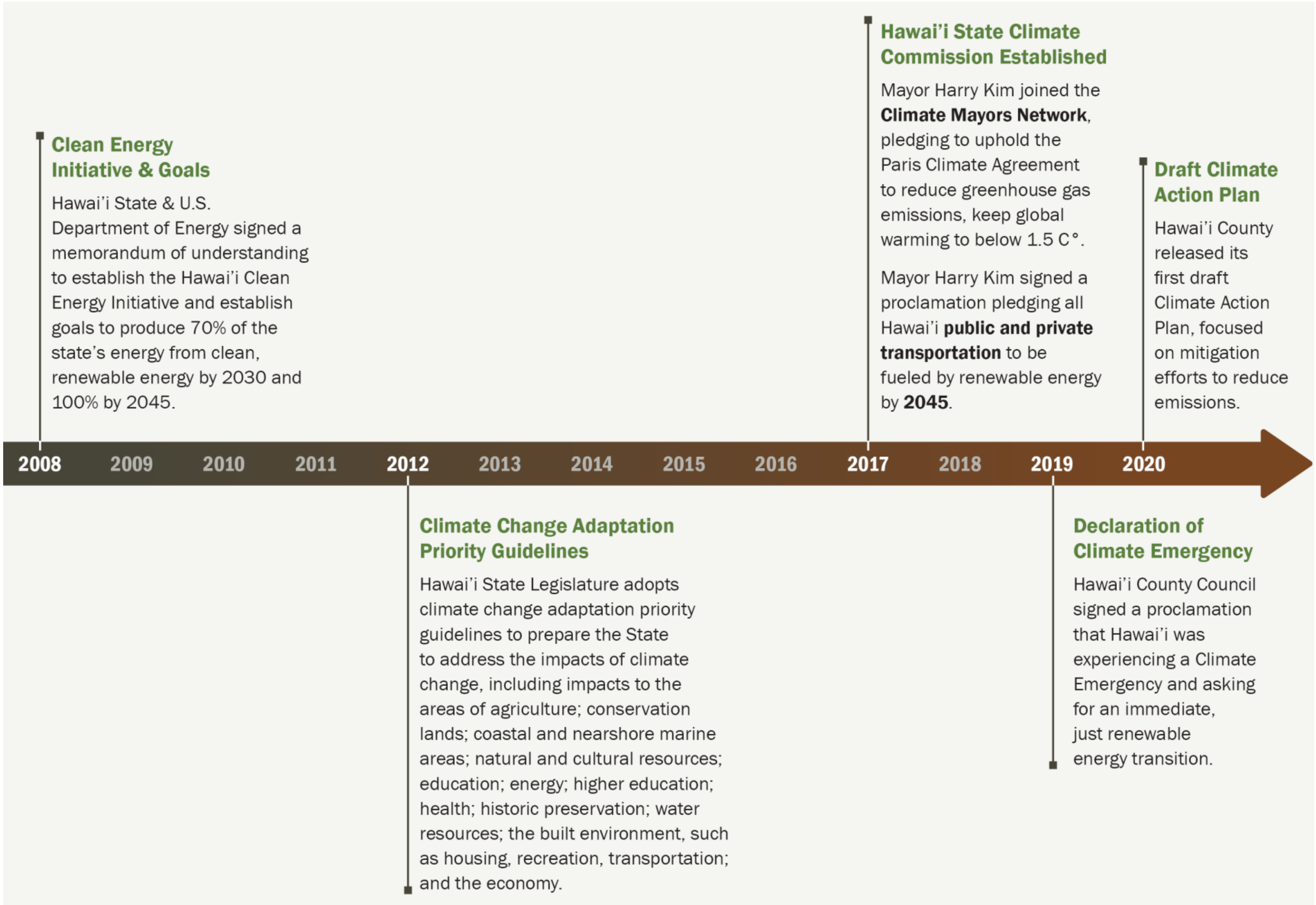

Figure 1. Timeline of State and County climate action commitments

CLIMATE ACTION FRAMEWORK

The climate action framework was developed to illustrate the cascading nature of climate change. Cascading effects result from interdependencies between natural and socioeconomic systems.[13] The term "cascading effects" has been increasingly used to describe the network of impacts across various systems that are of greater magnitude than any individual element of network.[14] The cascading effects of climate change represent extremely complex interactions between global climate change and local physical, ecological, social, and economic systems.

The framework captures how what we do as communities causes climate change, which in turn impacts our same communities. Increased use of fossil fuels is causing greenhouse gases in the atmosphere to rise. Greenhouse gases are causing global air and sea surface temperature to rise and oceans to become more acidic. These changes in temperature and ocean pH are the key indicators of climate change. They directly trigger climate hazards including sea level rise, drought, extreme rainfall events, and tropical cyclones. The impacts of those climate hazards can be heightened by compounding hazards such as landslides, wildfire, and flooding. Together, the impacts of these climate and compounding hazards cascade across multiple social, cultural, economic, ecological, and governance systems.[15] A climate action framework was developed to describe these cascading effects of climate change and to identify intervention points where both climate mitigation and adaptation actions can be implemented by the County (Figure 2).

Understanding the cascading impacts of climate change on human-environmental systems is a growing area of research.[16] Better accounting of these interactions is needed to identify potential feedback loops. The cascading effects of climate change on infrastructure and social-ecological systems related to extreme rainfall events,[17] sea level rise,[18] wildfires and other disasters,[19] wastewater systems,[20] electrical systems,[21] and fisheries and agriculture[22] are some emerging topics of new research.

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[13] Lawrence, J., Blackett, P., & Cradock-Henry, N. A. (2020). Cascading climate change impacts and implications. Climate Risk Management, 29, 100234. doi:https://doi.org/10.1016/j.crm.2020.100234
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[22] Thiault, L., Mora, C., Cinner, J. E., Cheung, W. W. L., Graham, N. A. J., Januchowski-Hartley, F. A., . . . Claudet, J. Escaping the perfect storm of simultaneous climate change impacts on agriculture and marine fisheries. Science Advances, 5(11), eaaw9976. doi:10.1126/sciadv.aaw9976

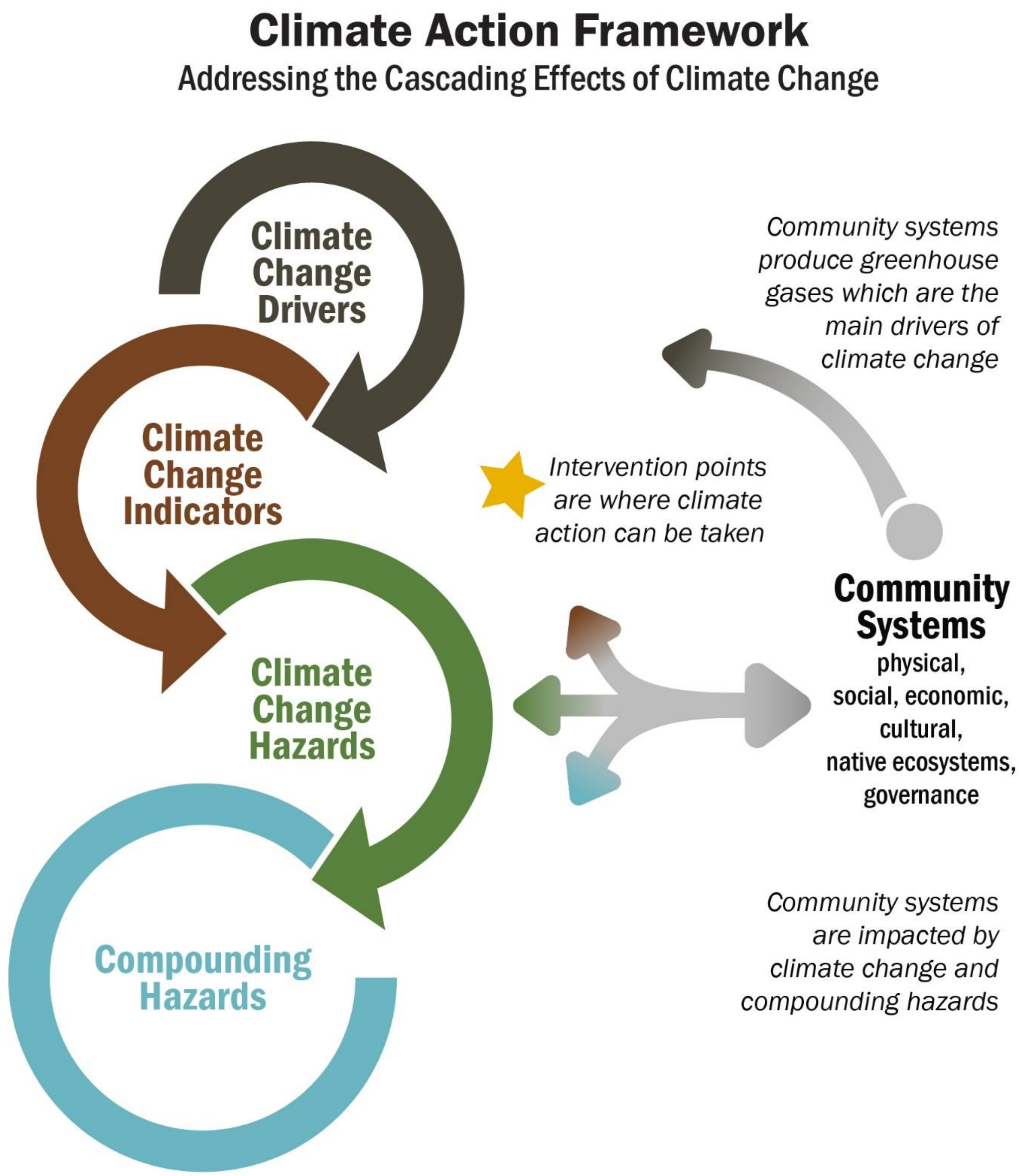

Figure 2. Climate action framework

The Natural Hazard Cascade of 1868

Hawaiʻi Island is no stranger to cascading effects. On April 2, 1868, a 7.9-magnitude earthquake, the largest in recorded history for Hawaiʻi Island, shook the island north of Pahala. The quake was preceded by hundreds of smaller tremors. This earthquake reactivated the Hilina Slump, which resulted in a tsunami that produced waves as high as 49 feet and killed 46 people. The quake also triggered numerous landslides, the largest of which was nearly 2 miles wide and as much as 30 feet thick, causing widespread damage and another 31 fatalities. Although not climate-related, this event exemplifies how cascading hazard events can affect people and property.

Source: "*The Great Kaʻū Earthquake of 1868." Hawaiian Volcano Observatory. April 1, 1994*

CLIMATE CASCADES

A ***climate cascade*** represents one component of the cascading effects and interactions of climate change. Using the climate action framework, five climate cascades were developed to address the three goals of the ICAP. All actions and plan implementation seek to address Goal 1, to increase the County capacity to address climate change. Actions in Cascades 1 and 2 address Goal 2, to reduce GHG emissions. Actions in Cascades 3, 4 and 5 address Goal 3 to increase resilience of County infrastructure and services to climate change impacts.

- **Climate Cascade 1 – Greenhouse Gas Emissions** caused by human activities are the key drivers of human-induced climate change. This climate cascade establishes a baseline for greenhouse gas emissions for the Island of Hawaiʻi from which to develop climate mitigation interventions to reduce Hawaiʻi County contributions to global climate change.
- **Climate Cascade 2 –Air and Sea Surface Temperature** are directly influenced by greenhouse gas emissions. These climate change indicators have direct impacts on human and native ecosystem health.
- **Climate Cascade 3 – Drought and Severe Rainfall Events** are among the climate hazards resulting from increasing air and sea surface temperature and climate variability. Drought and severe rainfall impacts to community systems are exacerbated by the compounding hazards of wildfire, landslides, windstorms, and riverine flooding.
- **Climate Cascade 4 – Sea Level Rise** is a climate hazard with slowly emerging impacts on community systems, compounded by coastal and riverine flooding and landslides.
- **Climate Cascade 5 – Tropical Cyclones and Storm Surge** are climate hazards with extreme impacts on community systems.

A graphic and narratives were developed for each cascade based on the current state of knowledge and experience gleaned from global, regional, and local information and data. The ICAP analyzes exposure and risk associated with each climate cascade using a geospatial overlay of climate hazards on County assets and a social vulnerability analysis of the population. County actions for climate change mitigation and adaptation were identified for key intervention points within each climate cascade. Co-benefits of climate action were identified to highlight opportunities to build climate resilience action by action. A summary of the cascading effects is depicted in Figure 3.

Key climate change drivers, indicators, climate hazards, and compounding hazards used to develop the climate cascades were identified from the County of Hawaiʻi Hazard Mitigation Plan 2020, the Hawaiʻi State Climate Summary, the 4th National Climate Assessment, and other relevant literature. A closer look at the climate hazards can be found in Appendix A. Community systems were defined as physical, social, economic, cultural, native ecosystem, and governance assets and services. County assets and services were identified within these community systems as the focus for action in this plan.

Climate cascades are intended as a starting point in describing the complexities of climate change impacts in order to better anticipate feedback loops and avoid maladaptation. These cascades will be reviewed, revised, and expanded as new research becomes available and conditions change.

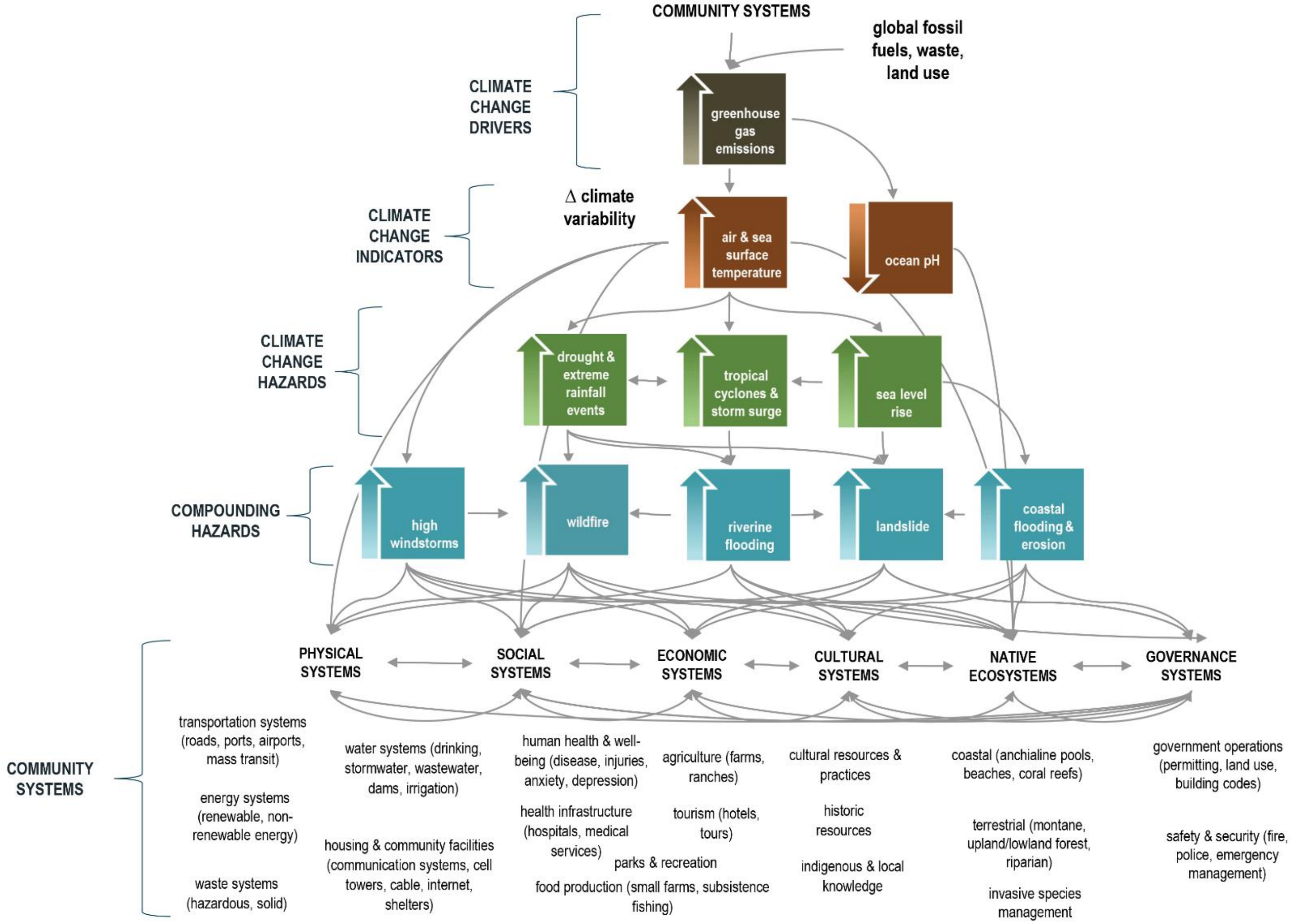

Figure 3. Climate cascade summary

Climate Cascade Exposure Analysis

Exposure analysis is the process of identifying assets that may experience each hazard associated with a climate cascade. Exposure analysis for Climate Cascades 3, 4, and 5 is based on the climate hazards and compounding hazards associated with each climate cascade. For each of these climate cascades, County assets exposed to these multiple hazards were identified using geospatial mapping to determine:

- Areas in Hawaiʻi County where each hazard may occur (this mapping is specific to each analyzed climate cascade)
- Locations of the County's assets (this mapping is the same for all analyzed climate cascades)

Climate Cascade 1 does not include hazard exposure, so no analysis was conducted. Cascade 2 was limited by data availability. Exposure analysis was not conducted but could be in the future.

The components of the **exposure analysis** are shown in Figure 4.

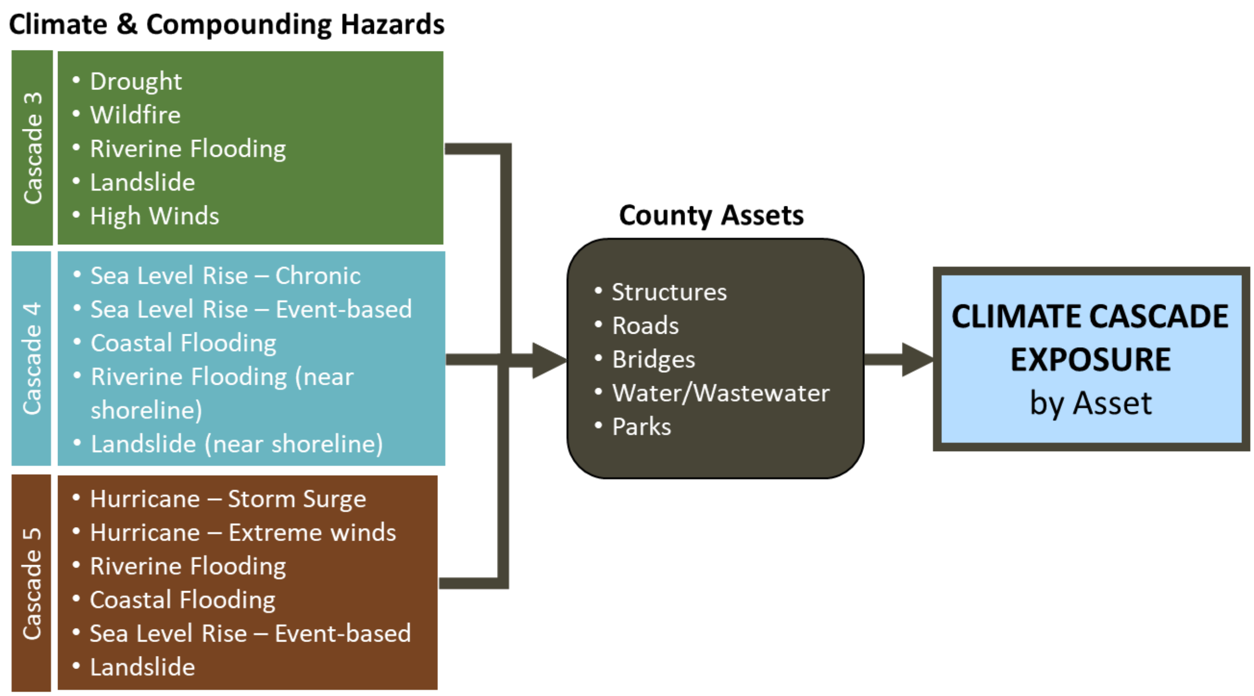

Figure 4. Exposure analysis components for Climate Cascades 3, 4, and 5

Hazard Mapping

Climate Cascades 3 and 4 are characterized by five hazards each, and Climate Cascade 5 is characterized by six hazards. The datasets used to map hazard areas for each cascade are listed in Table 1 and described in more detail in Appendix A.

Table 1. Cascade exposure analysis: hazards analyzed by cascade

Hazard	CASCADE 3 Drought and Extreme Rainfall	CASCADE 4 Sea Level Rise	CASCADE 5 Tropical Cyclones and Storm Surge
Drought (93-year drought trends)	●		
Wildfire communities at risk rating (high)	●		
Riverine flooding (FEMA FIRM A/AE Zones)	●	●	●
High winds (Average wind speeds at 50m above ground: moderate (greater the 5 meters/second) and high (greater than 8.5 meters/second) severity)	●		
Landslides (medium/high susceptibility)	●	●	●
Chronic coastal flooding with 3.2 feet of sea level rise (passive inundation only, SLRXA-3.2)		●	
Event-based coastal flooding with 3.2 feet of sea level rise (projected future, 1% Annual Chance Coastal Flood Zone, 1%CFZ-3.2)		●	●
Event-based coastal flooding (historical; FEMA DFIRM V/VE Zone)		●	●
Hurricane – Wind (Category 4 with peak gusts greater than 125 miles per hour.)			●
Hurricane – Storm surge (Category 4)			●
Total Number of Hazards	**5**	**5**	**6**

By mapping all relevant hazards, this analysis was able to identify the number of hazards with the potential to occur at any location in the County for each climate cascade. A given location might be susceptible to multiple hazards. An example of the cascade exposure levels for a cascade with five hazards is shown in Figure 5.

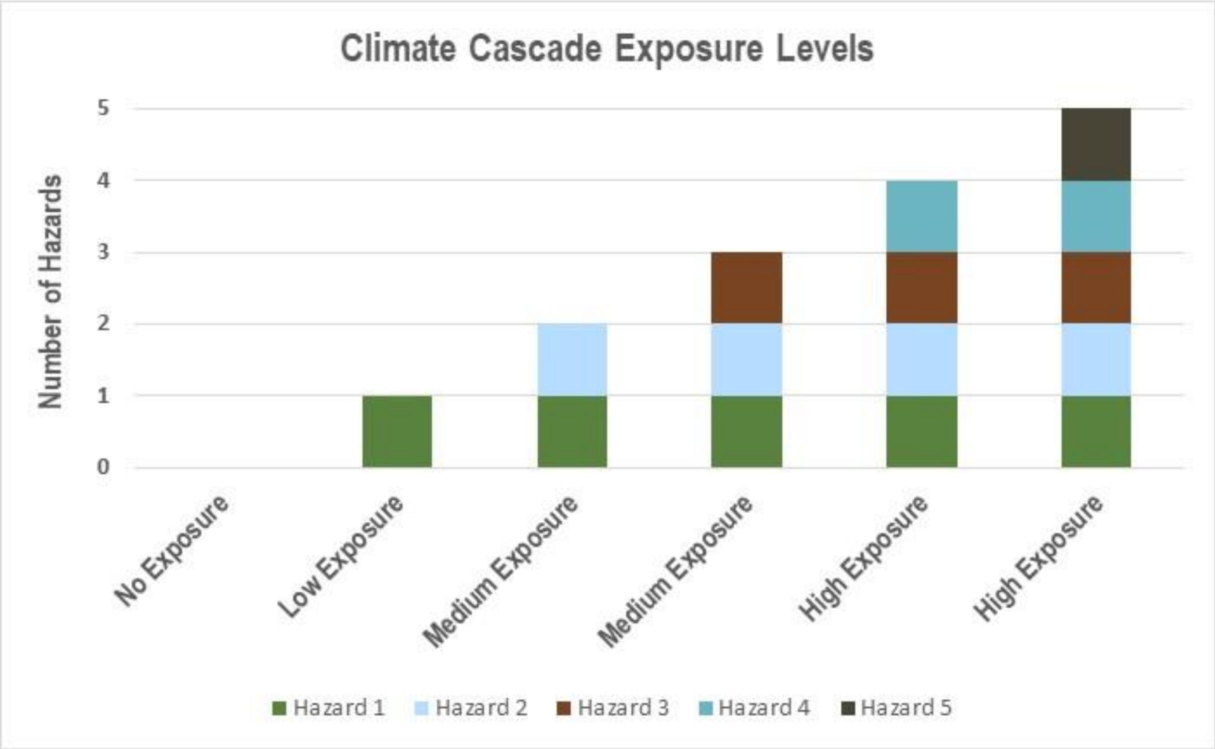

Figure 5. Example of cascade exposure levels

Asset Mapping

Asset data was compiled from all County departments. This included County structures, water and wastewater lines, on-site disposal systems, roads, bridges, and parks, as well as proposed and planned capital improvement projects. Interviews were conducted with each County department to review existing County assets and existing departmental priorities for proposed and in progress projects. A map of asset locations was generated from the information collected. More details on assets and projects are available on the **County Climate Cascade Exposure Tool**.

Exposure Analysis

The exposure analysis overlaid the hazard area mapping on top of the asset location map. This allowed assets to be tallied by number of potential hazards at the asset location for each climate cascade. County assets exposed to the greatest number of hazards could be candidates for interventions. The County Climate Cascade Exposure Tool can help County staff better understand climate-related hazards potentially impacting County-managed assets and projects.

The Cascade Exposure Tool also contains the results of a risk analysis conducted based on the distribution of socially vulnerable populations. The description of the risk assessment methodology and results are provided in Appendix B.

Intervention Points and Actions

Intervention points were identified for each climate cascade. These are points where the cascading effects of climate change could be disrupted by a project or action to reduce greenhouse gas emissions or impacts on community systems. An intervention early in the sequence that makes up a cascade is considered more effective as it can address multiple cascading effects and thereby enhance community resilience and save money, time, and effort.

This ICAP focuses on actions that County departments can take to improve climate resilience based on areas of responsibility as listed in Table 2. For each cascade, actions were identified at each intervention point based on County assets exposed and population at risk. An estimate for the cost of each action is noted as follows:

$ - action can be accomplished within the current County budget and staff

$$ - action requires additional funding for consultants or studies

$$$ - action requires major investment for infrastructure design and implementation

Projects proposed or recently completed under the County's capital improvement program and Multi-Hazard Mitigation Plan were reviewed for inclusion in this plan.

Table 2. Hawaiʻi County departments with primary responsibilities in the ICAP

County Department	Primary Area of ICAP Responsibility
Civil Defense	Disaster response
Finance	Financing for capital improvement, open spaces management
Environmental Management	Solid waste and wastewater systems
Fire Department	Emergency response
Mass Transit Agency	Public transportation
Parks and Recreation	Beach parks, senior centers, and sports centers
Planning	Land use and coastal zone management
Public Works	Roads, bridges, floodplain management, energy efficiency, County fleet maintenance, building and energy codes, and building permits
Research and Development	Emissions data and reporting, agriculture and tourism industry support, energy transformation, and grants
Water Supply	Water tanks, reservoirs, and water lines

Individual actions were also included for every cascade after the County actions and co-benefits. These are actions that members of the community, homeowners, and businesses can take to contribute to climate action.

Climate Action Co-Benefits

Co-benefits refer to the potential for actions to achieve multiple positive impacts and reinforcing outcomes. The concept of co-benefits implies a 'win–win' strategy where a single policy or action can address two or more goals.[23] The term co-benefits is also referred to as "multiple benefits" or "synergies." Table 3 describes the co-benefits that may come with climate actions. The evaluation of co-benefits for each action is a key activity in monitoring and evaluation (see the section on Plan Implementation).

Table 3. Climate action co-benefits considered in evaluating climate actions

Action	Primary Purpose	Co-Benefits
Greenhouse Gas Reduction	Actions that reduce greenhouse gas emissions through using technology that does not burn materials, especially imported fossil fuels, or through reducing the amount of energy or fuel needed.	• Improved public health through reducing local co-pollutants to improve air quality • Increased economic independence from international markets for fossil fuels • Decreased cost of living through lowering electricity and gas bills
Climate Risk Reduction	Actions that reduce cascading effects of climate change and increase the resilience of communities, infrastructure, and ecosystems to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events and changing conditions.	• Reduced disruptions to government operations and the economy • Faster recovery from disaster events • Safer communities due to reduced loss of life and property damage • Reduced financial impact of climate change on individuals, communities, and society as a whole
Social-Cultural Equity	Actions that prioritize historically marginalized peoples and disproportionally impacted communities in receiving support for community services at greatest risk to climate change, reduce barriers, and increase opportunities so all people can get help when they need it.	• Conserving native ecosystems that are fundamental to cultural practices • Decreasing pollution and corresponding public health risks in historically marginalized and underserved communities • Improving access to land and water for recreation, cultural practice, and self-sufficient practices like farming • Reducing cost of living
Environmental Protection	Actions that result in positive impacts on the environment beyond mitigating or adapting to climate change.	• Reducing air and water pollution • Removing invasive species • Restoring ecosystems • Protecting soil to reduce erosion and nutrient loss
Economic Resilience	Actions that result in positive impacts on the economy.	• Job creation • Industry advancement • Workforce training • Reduced financial impact of climate change on businesses and residents
Plan Integration	Actions that align priorities and investment toward climate risk reduction with existing policies across County, State, and federal plans.	• General Plan • Multi-Modal Transportation Plan • Multi-Hazard Mitigation Plan • Integrated Solid Waste Plan

[23] Mayrhofer, J. P., & Gupta, J. (2016). The science and politics of co-benefits in climate policy. Environmental Science & Policy, 57, 22-30. doi:https://doi.org/10.1016/j.envsci.2015.11.005

Limitations and Future Data Needs

Framework: The climate action framework was developed to illustrate the cascading nature of climate change. The framework is intended to show Hawaiʻi County's role in reducing our contribution to global climate change while preparing for the local effects. The cascading effects of climate change represent extremely complex interactions between global climate change and local physical, ecological, social, and economic systems. The framework captures how what we do as communities causes climate change, which in turn impacts our same communities. The framework simplifies this relationship and is intended to be improved over time as new knowledge, studies, and data emerge.

Exposure and Data Availability: The climate cascade exposure analysis presents a limited view of the cascading effects of climate change, focusing on exposure associated with climate hazards and compounding hazards. Geospatial analysis of exposure is constrained by data availability. Greater investment in monitoring and analyzing climate hazards and impacts is needed to document observed impacts of climate change on community systems, especially native ecosystems. The analysis of overlaps among the various hazards used in the exposure analysis was limited by the following:

- **Air and Sea Surface Temperature Change**. No geospatial analysis of climate exposure was conducted for air and sea surface temperature change (Climate Cascade 2). Literature was reviewed to describe cascading effects. An assessment of exposure and vulnerability of parcels and County infrastructure to increased temperature is needed, including parcels on which the County provides community services (activity type, vulnerable populations (i.e., keiki, kupuna), number of people served) and facilities with high levels of technology use that may need extra cooling infrastructure. To accomplish this, the assessment should follow a similar structure to the analyses for Climate Cascades 3, 4, and 5. The County should gather datasets on air temperature on Hawaiʻi Island and stack the datasets to determine the vulnerability of County assets and sites where services are provided to determine the effects of increased air and sea surface temperature. Notably, projected changes to air temperature are not measured just by air temperature data, but also by surface temperature, land cover type, and potential evapotranspiration. These variables will need to be included in the stacking process to accurately capture air temperature trends and potential solutions, such as planting more trees in an exposed area (not something that we could do in an area that already has vegetation). As part of this project, the County should partner with the University of Hawaiʻi-Hilo to utilize the Mesonet data to map ambient air temperature over time.
- **Drought.** Drought trends were based on data for the period 1920 to 2012[8]. Incorporating the most current decade into the trend analysis is recommended to build on that dataset moving forward.
- **Sea Level Rise.** The Sea Level Rise Exposure Area with 3.2 feet of sea level rise (SLRXA-3.2) is the best available projection for the end of the century available at this time. Local projections from NOAA point to closer to 4 ft of SLR by 2100 in an Intermediate scenario. In addition, SLRXA-3.2 for Hawaiʻi Island is based solely on passive inundation. New wave modeling with sea level rise conducted by the University of Hawaiʻi is anticipated over the next 5 years.
- **Extreme Rainfall Events.** Riverine flood zones (FEMA Flood Insurance Rate Map (FIRM) A/AE zones), mapped based on modeling historical floods, were used as a proxy for extreme rainfall events. In a changing climate, extreme rainfall events will not be confined to these zones. Further,

riverine flood zones do not overlap with coastal flood zones (FEMA FIRM V/VE zones). This results in an underestimation of the hazard risk in areas where a river meets the sea. Finally, the riverine flood zones have not been mapped everywhere in the County, creating gaps in the data, especially in Hāmākua, and therefore underestimating the number of overlapping climate hazards.

- **Wildfire.** Wildfire mapping differs from the other hazard mapping used in the exposure analysis as it does not show wildfire risk over the entire island, but only the risk in populated areas.
- **Coastal Flooding and Erosion with Sea level Rise.** For Hawaiʻi Island, coastal flooding with sea level rise was modeled only for passive inundation, with the highest sea level rise scenario at 3.2 feet by 2100. Without considering coastal erosion and wave runup with sea level rise, the Sea Level Rise Exposure Area with 3.2 feet of sea level rise (SLRXA-3.2) for Hawaiʻi Island underestimates the total land area exposed by 35 to 54 percent, depending on location and sea level rise scenario.[24] Shoreline change rate studies are being conducted by the University of Hawaiʻi for two pilot sites.
- **Landslides.** Geological studies are needed to better understand the conditions for cliff erosion and failure, especially along the Hāmākua coast.
- **Tropical Cyclones and Storm Surge.** Tropical cyclones may make landfall anywhere on Hawaiʻi Island or just come near enough to cause storm surge and high winds. A Category 4 tropical cyclone, modeled to make landfall in Kona and travel northeast, was used in the cascade exposure analysis. Overall, exposure to climate hazards in Cascade 5 should be considered island wide.

Focus on Hazards: The cascade exposure and risk analyses completed for this plan focus on climate change related hazards and social vulnerability. A more complete analysis would need to include more detailed data and socioeconomic and environmental indicators. Future cascades should include more detailed analyses of critical infrastructure and hubs beyond County assets, environmental pollution, and historical marginalization.

Vulnerability Analysis: This analysis was limited to the variables considered and does not fully capture the complex, multidimensional aspects of social vulnerability, such as social networks, self-sufficiency, and neighborhood conditions. These variables are also subjective to different contexts and cultures. What is considered “vulnerable” to some may be a strength or may be unimportant to others. Census data is limited by time lags, spatial scale, and missing or inaccurate information, specifically from hard-to-reach populations such as rural communities and non-English speakers. A more complete analysis would need to include a more comprehensive set of factors and qualitative, place-based community engagement and research to supplement the data and better define “social vulnerability” for communities on Hawaiʻi Island. A future analysis could also cross-reference the EPA’s Environmental Justice Screening and Mapping Tool or other such tools to include the impact of historic marginalization and disproportionate effects from pollution or other environmental hazards.

[24] Anderson, T. R., Fletcher, C. H., Barbee, M. M., Romine, B. M., Lemmo, S., & Delevaux, J. M. S. (2018). Modeling multiple sea level rise stresses reveals up to twice the land at risk compared to strictly passive flooding methods. Scientific reports, 8(1), 14484. doi:10.1038/s41598-018-32658-x

CLIMATE CASCADE I: GREENHOUSE GAS EMISSIONS

Climate Cascade 1 focuses on the primary drivers of climate change - anthropogenic greenhouse gas emissions (GHGs) - and the community systems on Hawaiʻi Island that emit GHGs (Figure 6). This section describes and evaluates this climate cascade and identifies intervention points for County actions and the potential co-benefits of such actions. The County of Hawaiʻi Greenhouse Gas Inventory, summarizing island-wide emission sources and sinks, provides a baseline for the intervention points and informs the cascade narrative. Intervention points for County actions are identified along with climate co-benefits.

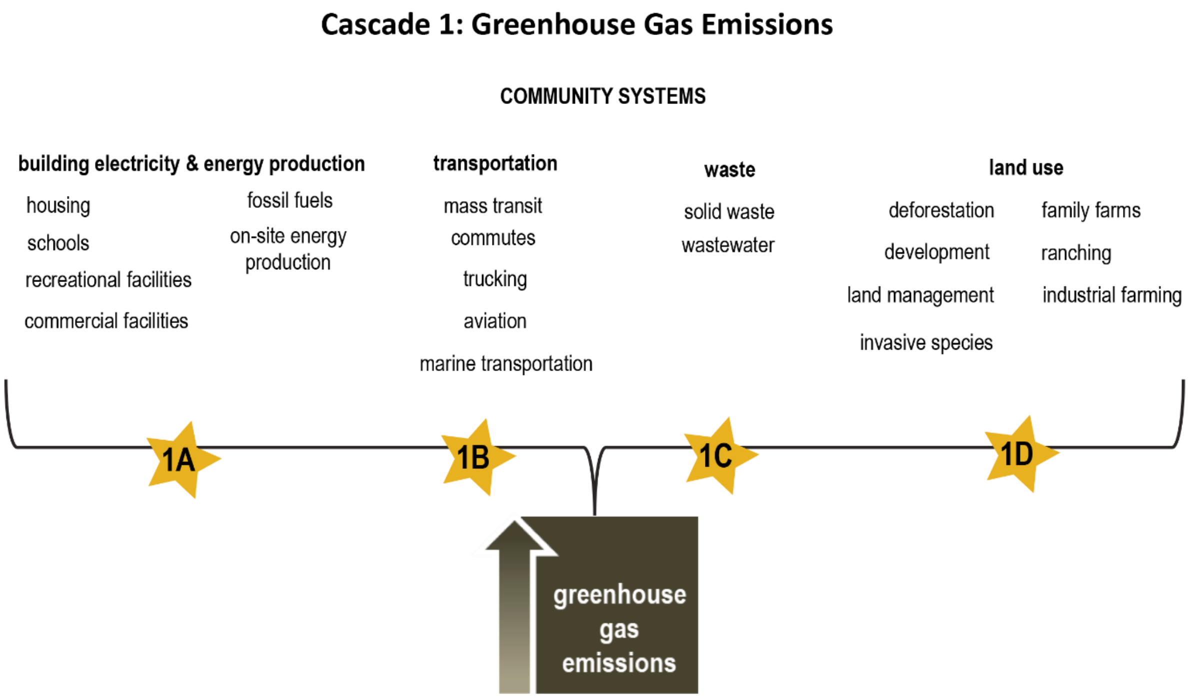

Figure 6. Climate Cascade 1. Greenhouse gas emissions

Cascade Narrative

Human activities are increasing greenhouse gas emissions globally to levels that are changing the climate and the Earth's ecosystem.

The natural carbon cycle includes sources that emit GHGs and sinks that sequester GHGs. Greenhouse gases include carbon dioxide, methane, nitrous oxide, and fluorinated gases. The "greenhouse gas effect" occurs when GHGs trap heat by impeding the release of infrared light waves back into the atmosphere. Before 1850, global sources and sinks maintained a stable cycle of GHGs and therefore stable temperature patterns. Since 1850, GHGs have been released at unprecedented levels, creating today's climate crisis. In 2021, the Intergovernmental Panel on Climate Change (IPCC) reported that anthropogenic (human-originated) emissions are the cause of global climate change.[25]

Hawaiʻi County is responsible for 0.00081 percent of global emissions, even though we are only 0.000023 percent of the global population. GHG sources in Hawaiʻi County include emissions from the burning of fossil fuels for energy and transportation and from the decomposition of organic and inorganic waste. These GHGs are emitted to support community systems such as building electricity, transportation, waste, and industries from agriculture to healthcare to tourism. Simultaneously, the cycle of land development and underdevelopment has led to deforestation and biodiversity loss, decreasing natural carbon sinks on Hawaiʻi Island. The early 20th century expansion of plantation and cattle industries followed by the contraction of farming and ranching in the 21st century were major drivers of these impacts. Deforestation and biodiversity loss will continue without increased investment in appropriately managing our open spaces.

As the effects of climate change emerge, so does the urgency to understand how to reduce emissions and ensure equity while pursuing solutions. While Hawaiʻi County's contribution to global emissions may be small by proportion, it's essential that we take responsibility for our contribution to global climate change and reduce our sources of emissions alongside the rest of the world.

Increasing use of fossil fuels to generate electricity for commercial, industrial, and residential activity emits increasing amounts of greenhouse gases.

Hawaiʻi Island has a long history of utilizing renewable energy. In 1888, Hilo was the site of one of the first hydropower projects in the state. Hawaiʻi Island also has the state's only geothermal plan, Puna Geothermal Ventures, founded in 1993.[26] Since then, Hawaiian Electric has made a commitment to cut its carbon emissions by 70 percent by 2030.

[25] IPCC (2021) Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change[Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, In press, doi:10.1017/9781009157896.
[26] Hawaii Energy Facts & Figures (2020). *Hawaii State Energy Office*. https://energy.hawaii.gov/wp-content/uploads/2020/11/HSEO_FactsAndFigures-2020.pdf

On and off-grid energy production and electricity use is the second-largest source of emissions on Hawaiʻi Island, with a total of 959,900 metric tons of carbon dioxide equivalent ($MTCO_2e$) released per year.[27] Energy production provides electricity, air conditioning, and heat that support commercial, industrial, and residential activity. The population of Hawaiʻi County is projected to increase a little over 1 percent annually between now and 2045.[28] As the population grows, additional building infrastructure and electricity will be necessary for housing and social services such as schools, grocery stores, and medical care. The rise in technology use places an additional burden on electricity needs, as devices such as computers, televisions, and cellphones require immense amounts of electricity to run. Despite potential increase in energy efficiency from digitalization, the greenhouse gas emissions and toxic waste associated with usage and disposal of technologies outweigh the reduction in greenhouse gas emissions from energy efficiency.[29] Increased infrastructure will augment energy demand and the resulting carbon footprint.

Solar-paneled parking lot in the West Hawaiʻi Civic Center

[27] County of Hawaiʻi Department of Research and Development. (2021). *Greenhouse Gas Emissions Inventory for 2017*. County of Hawaiʻi.https://www.hawaiicounty.gov/home/showpublisheddocument/304504/637834584810900000
[28] State of Hawaiʻi Department of Business, Economic Development, and Tourism. (2018). Population and Economic Projections for the State of Hawaii to 2045. https://files.hawaii.gov/dbedt/economic/data_reports/2045-long-range-forecast/2045-long-range-forecast.pdf
[29]Steffen Lange, Johanna Pohl, Tilman Santarius (2020) Digitalization and energy consumption. Does ICT reduce energy demand?, Ecological Economics, Volume 176, 106760, ISSN 0921-8009, https://doi.org/10.1016/j.ecolecon.2020.106760.

Hawaiʻi homes use 40 percent less electricity on average than the national average.[30] However, Hawaiʻi has the highest energy cost of any state in the United States, at 42.37 cents per kWh compared to the national average of 12.52 cents.[31] These high prices stem from Hawaii's dependence on energy importation, as Hawaiʻi uses 12 times more energy than it produces and pricing structures are dependent on the cost of foreign oil, even for renewable energy generation. Foreign oil generates 60 percent of the State of Hawaii's energy. Hawaiʻi Island's electric grid is only 40 percent dependent on foreign oil when all its renewable power plants are running.[32] However, the grid does not account for propane use, meaning Hawaiʻi Island is more dependent on foreign fuel than reflected by the grid. Therefore, operations cost is higher for businesses in Hawaiʻi, even when using less energy than comparable businesses on the continent. In the face of international oil shortages or economic disruptions, the dependence on foreign oil will continue to increase the costs of living and operating businesses on the island. Hawaiʻi residents have already experienced increased cost of electricity as a result of the Ukraine-Russia war.

Hawaiʻi Island has a long history of utilizing renewable energy. In 1888, Hilo was the site of one of the first hydropower projects in the state. Hawaiʻi Island also has the state's only geothermal plan, Puna Geothermal Ventures, founded in 1993.[33] Since then, Hawaiian Electric has made a commitment to cut its carbon emissions by 70 percent by 2030.

Inefficient energy use in existing and new buildings emits increasing amounts of greenhouse gases.

Building energy efficiency refers to how effectively infrastructure uses energy generated. Building design determines energy efficiency. For example, buildings that are designed with natural cooling systems (such as windows and doors that allow for cross-ventilation or siding that better reflects sunlight) require fewer fans or small air conditioning units. Upgrading appliances such as light bulbs, refrigerators, and washing machines also reduces electricity usage. New building development inevitably increases greenhouse gas emissions by adding an additional load on or off grid. New development also includes embodied emissions from harvesting, transportation, and construction of materials. However, buildings that are developed efficiently emit less than those that are not. Retrofitting older buildings can also decrease electricity use and therefore greenhouse gas emissions. This is one of the most cost-effective ways to reduce emissions, as improving energy standards costs less than 1 cent per kWh saved.[34]

[30] Hawaii State Energy Profile. U.S. Energy Information Administration. https://www.eia.gov/state/print.php?sid=HI. 1 Nov. 2022.
[31] Average Price of Electricity to Ultimate Customers by End-Use Sector. U.S. Energy Information Administration. https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a. 1 Mar. 2023.
[32] Hawaii State Energy Profile. U.S. Energy Information Administration. https://www.eia.gov/state/print.php?sid=HI. 1 Nov. 2022.
[33] Hawaii Energy Facts & Figures (2020). *Hawaii State Energy Office*. https://energy.hawaii.gov/wp-content/uploads/2020/11/HSEO_FactsAndFigures-2020.pdf
[34] Hawaii Energy Facts & Figures (2020). Hawaii State Energy Office. https://energy.hawaii.gov/wp-content/uploads/2020/11/HSEO_FactsAndFigures-2020.pdf

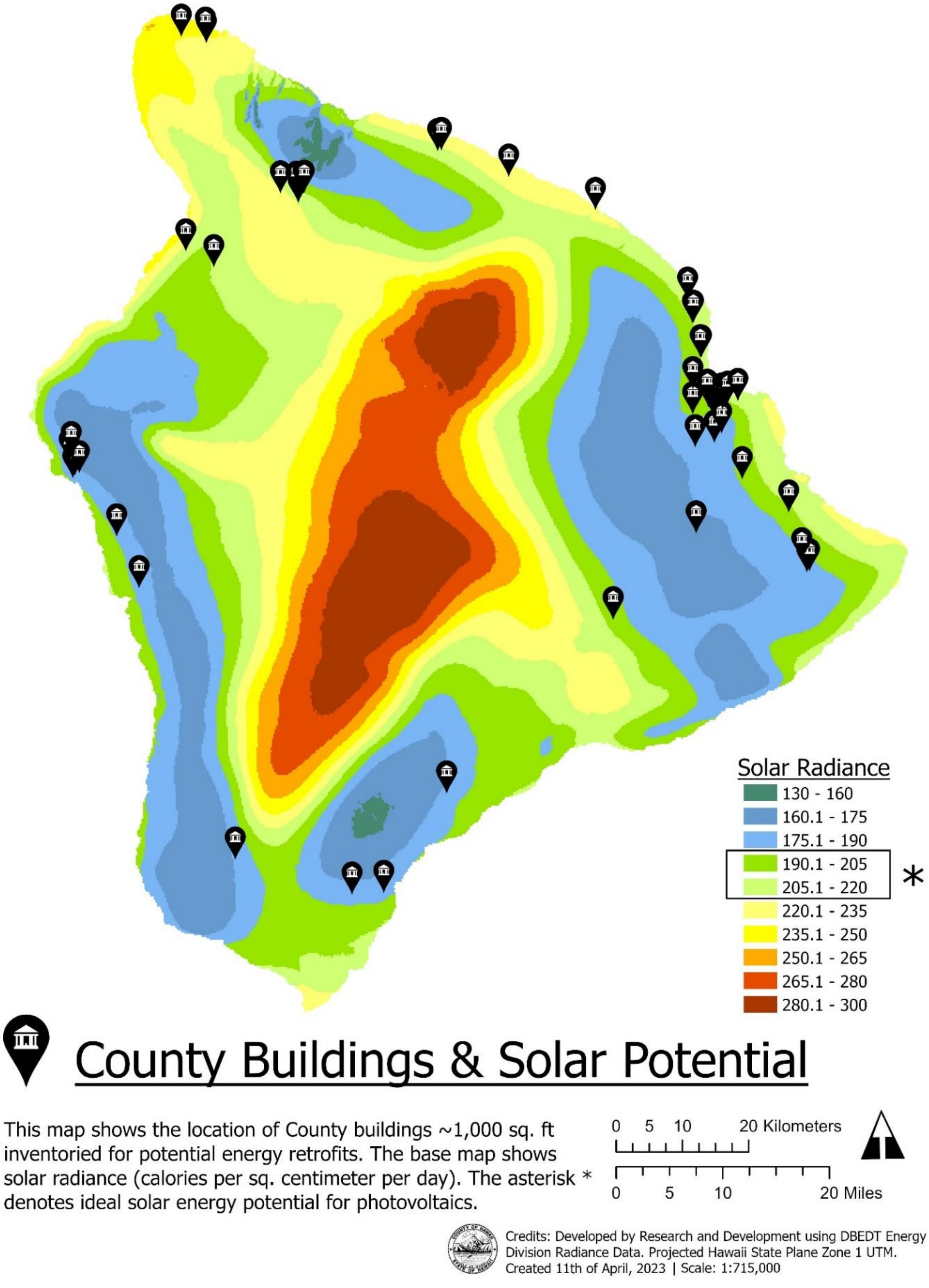

Figure 7. Locations of County buildings for potential energy retrofits

Increasing ground, air, and marine transportation for commercial, industrial, and residential activity emits increasing greenhouse gases.

Transportation is a key facet of residential, commercial, and industrial activity. Transportation is the largest source of emissions for Hawaiʻi County, with a total of 1,742,191 $MTCO_2e$ released per year. In Hawaiʻi, transportation emissions are generated from ground, air, and marine transportation. Ground transportation contributes 16.8 percent of emissions annually on Hawaiʻi Island.[35] Ground transportation includes individual and public vehicles used by residents and visitors for all purposes from daily life to construction, trucking, and agriculture. The visitor industry adds significantly to the use of cars on the island. Visitors often rent cars and drive to "hot spot" attractions around the island, putting extra stress on the community members and ecosystems of those places.[36] With increasing population and commercial activity, ground transportation emissions increased 17.31 percent from 2015 to 2017 and are expected to continue to increase.[37] More people will be commuting and recreating, and more businesses will need to transport goods around the island to service them.

On Hawaiʻi Island, 71.4 percent of workers rely on individual modes of transportation. In Hawaiʻi, the cost of gas is higher than any state except Alaska and is almost double the cost of states with the cheapest gas. The Ulupono Initiative estimates that the public costs of the vehicle economy, including roadway and bridge maintenance and public transportation, are around $15,000 per taxpayer with an additional $8,100 annual cost per vehicle. Therefore, 71.4 percent of workers are paying at least $8,100 per year to cover their transportation needs before taxes.[38] Forty-eight percent of people on Hawaiʻi Island are living below the ALICE (Asset Limited, Income Constrained, Employed) threshold.[39] The annual cost of vehicle ownership is 33 percent of the annual total income of an ALICE-qualified single adult households.

Airline transportation emissions are the dominant source of transportation emissions, accounting for 54 percent of total annual emissions. Airline emissions include all flights that originate from Hawaiʻi Island. Airline travel is an essential part of residential and commercial activity on island. Interisland commutes are a standard part of many industries, including construction. The visitor industry places a burden on air travel, as every visitor arrives by plane. Airlines are also an essential means of importing goods to the island. Increasing population and commercial activity augment the need for flights and imported goods, so airline emissions are expected to increase.

[35] County of Hawaiʻi Department of Research and Development (2021). *Greenhouse Gas Emissions Inventory for 2017*. County of Hawaiʻi.https://www.hawaiicounty.gov/home/showpublisheddocument/304504/637834584810900000
[36] Hawaii Tourism Authority (2021). "Hawaiʻi Island Destination Management Action Plan."
https://www.hawaiitourismauthority.org/media/7040/hta-hawaii-island-action-plan.pdf
[37] County of Hawaiʻi Department of Research and Development. (2021). *Greenhouse Gas Emissions Inventory for 2017*. County of Hawaiʻi.https://www.hawaiicounty.gov/home/showpublisheddocument/304504/637834584810900000
[38] Ulupono Initiative. (2022). *The Costs of the Vehicle Economy in Hawaii.* https://ulupono.com/project-list/the-costs-of-the-vehicle-economy-in-hawaii/
[39] ALICE Threshold, 2007-2018. American Community Survey, 2007-2018.

Increasing waste and wastewater production from commercial, industrial, and residential activity emits increasing amounts of greenhouse gases.

Waste emissions account for 8.79 percent of Hawaiʻi Island emissions.[40] Hawaiʻi County collected 203,872 tons of waste in its landfill in 2022. Solid waste produces emissions through the process of decomposition, which releases nitrogen gases and methane. The process of transporting waste to transfer stations and from transfer stations to the landfill produces additional emissions.

Wastewater (sewage) produces emissions during treatment processes, including nitrification and denitrification. Managing waste is especially important for an island community, which has limited land for waste disposal and watersheds that are easily polluted. Residential, commercial, and industrial activity add to waste production on the island through materials used in construction, agriculture, and the visitor industry. Without finding ways to repurpose and reduce waste, waste production will continue to grow as population expands and economic activity increases.

Historical deforestation and degradation of native ecosystems and open spaces reduce carbon sinks.

Hawaiʻi Island forests are the largest source of carbon sequestration in the state.[41] Pre-Western-contact, native habitat made up 85 percent of Hawaii's landscape. Post-contact, it fell to a little more than 40 percent of Hawaii's landscape.[42] Most deforestation in Hawaiʻi occurred in the late 1800s and early 1900s. Recent analysis indicates that forest cover is increasing.[43] As forest or shrubland is repurposed for commercial and residential activities, ranching, and agriculture, natural carbon sinks and vital cultural resources vanish. Additionally, land management practices, such as outplanting non-native species, have further reduced the prevalence of native ecosystems.[44]

Forests are also essential pieces of the watershed. Forested lands at higher elevation catch and collect water that then travels down to lower elevation zones, providing fresh water from mauka to makai. Deforestation and degradation of native forests can decrease the availability of fresh water, affecting potable water supply, agriculture, and ecosystem health. Forest composition is changing due to invasive trees and shrubs[45] which decreases groundwater recharge.[46] Improved watershed management is needed to improve groundwater recharge and protect drinking water.[47] Declines in forest cover have also been found to increase fecal bacteria in Hawaiʻi Island soil and nearby streams,

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[40] County of Hawaiʻi Department of Research and Development.(2021). *Greenhouse Gas Emissions Inventory for 2017*. County of Hawaiʻi.https://www.hawaiicounty.gov/home/showpublisheddocument/304504/637834584810900000
[41] Hawaii State Department of Health (2021). *Hawaii Greenhouse Gas Emissions Report for 2017.* https://health.hawaii.gov/cab/files/2021/04/2017-Inventory_Final-Report_April-2021.pdf
[42] Gon, S.M.; Tom, S.L.; Woodside, U. Āina Momona, Honua Au Loli—Productive Lands, Changing World: Using the Hawaiian Footprint to Inform Biocultural Restoration and Future Sustainability in Hawaiʻi. Sustainability 2018, 10, 3420.
[43] Lucas, M. (2017). Spatially quantifying and attributing 17 years of vegetation and land cover transitions across Hawai`i. MSc Thesis. University of Hawaii at Manoa
[44] A. C. Medeiros, E. I. von Allmen, C. G. Chimera. (2014). "Dry Forest Restoration and Unassisted Native Tree Seedling Recruitment at Auwahi, Maui," Pacific Science, 68(1), 33-45.
[45] Weller, S.G., Cabin, R.J., Lorence, D.H., Perlman, S., Wood, K., Flynn, T. and Sakai, A.K. (2011). Alien plant invasions, introduced ungulates, and alternative states in a mesic forest in Hawaii. Restoration Ecology, 19(5), pp.671-680.
[46] Kagawa, A., Sack, L., Duarte, K.E. and James, S. (2009). Hawaiian native forest conserves water relative to timber plantation: species and stand traits influence water use. Ecological Applications, 19(6), pp.1429-1443.
[47] Bremer, L.L., DeMaagd, N., Wada, C.A. and Burnett, K.M. (2021). Priority watershed management areas for groundwater recharge and drinking water protection: A case study from Hawaiʻi Island. Journal of Environmental Management, 286, p.111622.

compromising the health of the ecosystems dependent on affected watersheds.[48] Urban soils on Hawaiʻi Island are at most risk for potentially damaging fecal indicator bacteria and the staph bacteria MRSA.[49] Moreover, urban runoff carried by polluted water upstream impacts the health of coral reefs, increasing coral bleaching and reducing coral spawning and fish nurseries.[50]

Reduction in fresh water and the proliferation of invasive species contribute to biodiversity loss.[51] Over 90 percent of the species in Hawaiʻi are found nowhere else in the world.[52] Approximately half the species that have gone extinct in the world are island species, and over one-third of the plant species on Hawaiʻi Island are categorized as endangered or threatened by the U.S. Fish and Wildlife Service. Invasive species, such as coqui frogs, gorse, and albizia, reduce the ability of native ecosystems to support biomass and sequester carbon. Native species also increase the resilience of watersheds to extreme precipitation and warming temperatures.[53] The effect of urban runoff on groundwater discharge also feeds the growth of invasive algae species while decreasing the prevalence of native algae species, affecting the health of coastal waters.[54] On Hawaiʻi Island, there have already been extensive efforts to combat the reduction of ʻōhiʻa and nēnē species. However, not all native plants and animals have been able to survive the impacts of invasive species and biodiversity loss.

Native species carry immense cultural significance. ʻAhuʻula feather capes were traditionally made from feathers of birds, some of which are now endangered like ʻiʻiwi.[55] ʻUala has long been a staple food. Already, the ʻuala season in Maui has been affected by decreases in annual precipitation associated with climate change, as the amount of precipitation changes the zones in which ʻuala can be grown.[56] Traditional agriculture is a crucial piece of culture and food security in Hawaiʻi. Continued deforestation will only decrease the prevalence of native species. Kumu Hula Pua Kanahele said, "If we cut down the forests, we cut down ourselves." [57]

[48] Strauch, A.M.; MacKenzie, R.A.; Bruland, G.L.; Tingley, R.; Giardina, C.P. (2014). Climate Change and Land Use Drivers of Fecal Bacteria in Tropical Hawaiian Rivers. *J. Environ. Qual.* 2014, *43*, 1475

[49] Tyler Gerken, Tracy N. Wiegner, Louise M. Economy. (2022). "A comparison of soil Staphylococcus aureus and fecal indicator bacteria concentrations across land uses in a Hawaiian watershed." Journal of Environmental Quality, 10.1002/jeq2.20380, 51, 5, (916-929).

[50] Stender, Y.; Jokiel, P.L.; Rodgers, K.S. (2014). "Thirty Years of Coral Reef Change in Relation to Coastal Construction and Increased Sedimentation at Pelekane Bay, Hawaiʻi." *PeerJ* 2014, *2*, e300.

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Greenhouse Gas Inventory

Sources of emissions for Hawaiʻi County are documented by the County of Hawaiʻi 2017 Greenhouse Gas (GHG) Inventory. This inventory informs key intervention points; helps identify and prioritize sector-specific carbon mitigation and reduction strategies, and aids as a benchmark to gauge progress. Data for this report was collected from seven GHG-producing sectors made up of 42 sources, for the years 2005, 2015, and 2017 (Figure 8). These sectors and sources correspond with the State's GHG inventory, which was developed in accordance with the 2006 IPCC Guidelines for National GHG Inventories.

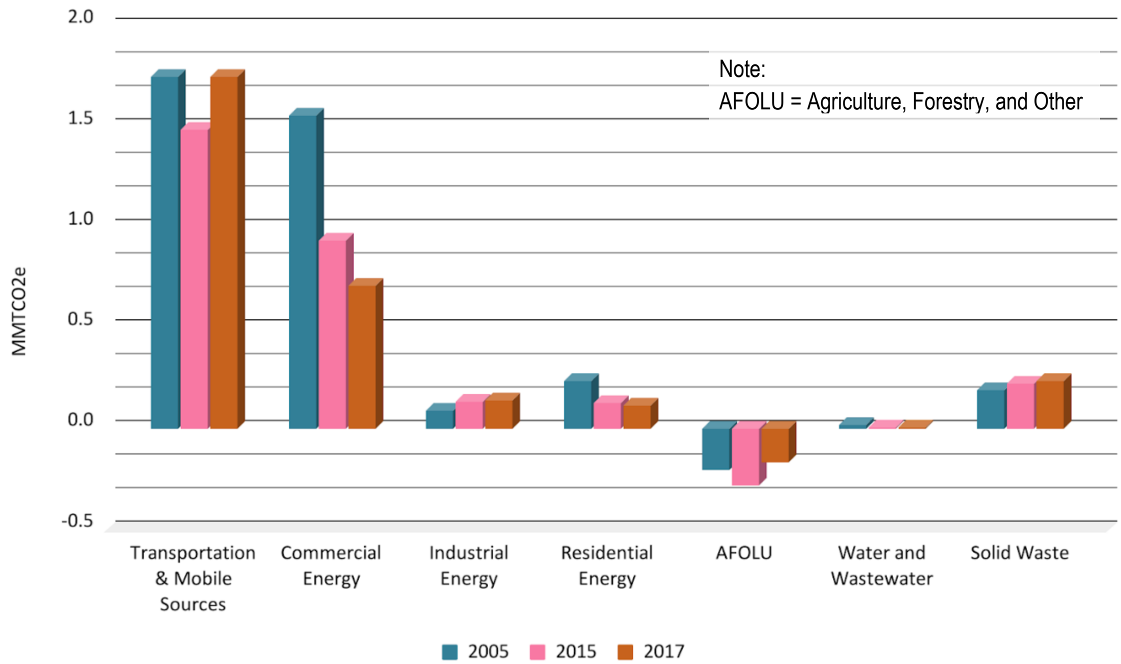

Figure 8. Hawaiʻi County sector overview of MTCO2e emissions for years 2005, 2015, and 2017

The County of Hawaiʻi GHG Inventory is guided by the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories and estimates GHG emissions that occur in the County's jurisdiction encompassing the entire island of Hawaiʻi. The Global Protocol is a carbon emissions accounting and reporting standard for cities and municipalities developed by the World Resources Institute, C40 Cities Climate Leadership Group, and the International Council for Local Environmental Initiatives Local Governments for Sustainability.

In 2017, overall emissions had decreased by 23 percent since 2005. The Transportation and Mobile Sources sector remained relatively stagnant over the years and remained the largest contributor to greenhouse gas emissions. Notably, Aviation accounted for 51 percent of total transportation emissions, compared to 32 percent from On-Road Motor Gasoline. The second largest contributor was Commercial Energy, but emissions from this sector decreased by approximately half between 2005 and 2017. The Residential Energy sector was the third largest contributing sector in 2005, but emissions from residential energy steadily declined due to ~28 percent increase in renewable energy capacity. By 2017, Solid Waste became the third largest source of emissions.

Intervention Points and Actions

Actions are associated with four intervention points (1A – 1D) within the greenhouse gas emissions cascade (Figure 6). Entities responsible for implementing these actions are mostly County departments but also include the private sector and individuals. Lead County departments for this cascade are as follows:

- Research and Development Department (R&D)
- Planning Department (DP)
- Department of Human Resources (HR)
- Department of Public Works (DPW)
- Department of Finance (DF)
- Department of Parks and Recreation (DPR)
- Mass Transit Agency (MTA)
- Department of Environmental Management (DEM)

1A. Energy and Electricity Use

Recommended actions at this intervention point fall under seven strategies, with a total of thirty-four actions, as presented in the sections and tables below.

1A1. Develop energy benchmarking standards for Hawaiʻi County buildings

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1A1.1	Aggregate all County meter data to create a baseline portfolio in Energy Star	R&D	$	2023	●		
1A1.2	Establish an online platform to streamline gathering and reporting of monthly County meter data	R&D, DPW, DF	$	2023	●		
1A1.3	Create an energy benchmarking dashboard and update monthly	R&D	$	2024	●		
1A1.4	Publish an annual report on County energy use and energy efficiency improvements	R&D	$	2025	●		
1A1.5	Hire or contract a certified energy manager to manage Energy Star portfolio and building energy contracts	DPW	$	2025	●		
1A1.6	Develop an Energy Management Plan for County owned facilities	DPW	$$	2025	●		
1A1.7	Purchase an Energy Management System for County buildings	DPW	$$	2025	●		

1A2. Transition Hawaiʻi County buildings to net zero emissions

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1A2.1	Screen all capital improvement projects (CIP) and maintenance projects for eligibility for energy rebates as part of the CIP project proposal checklist.	DF, DP	$	2024		●	
	– *Create a list of eligible rebates and specs necessary for rebate eligibility*	R&D	$	2023	●		
1A2.2	Conduct a cost-benefit analysis to determine the benefit of establishing an energy projects revolving fund to utilize rebates and electricity savings for future energy investments.	DF	$	2023	●		
1A2.3	Capture methane from County facilities to replace and reduce propane sources	DEM	$$$	2025			●
	– *Conduct a feasibility assessment*						
1A2.4	Apply for Energy Efficiency and Conservation Block Grants annually.	R&D	$	2023			●

1A3. Implement renewable and energy efficient purchasing policies

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1A3.1	Establish an energy efficiency standard checklist for all new County equipment and building purchases	DF, R&D	$				
	– *Create a cost-benefit analysis and specifications list that can be used by depts. to determine if there is a cost-appropriate energy efficient option for County equipment and building purchases*			2024	●		

1A4. Inventory greenhouse gas emissions at the municipal and County level

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1A4.1	Continue to publish a municipal greenhouse gas inventory for County buildings, transportation, waste, wastewater, and land use.	R&D	$	2024	●		
1A4.2	Publish a county-wide greenhouse gas inventory every 3 years.	R&D	$	2024	●		
1A4.3	Develop an embodied carbon baseline for County buildings, transportation, and waste.	R&D	$	2024	●		

1A5. Revise building and energy codes to incentivize energy efficiency measures for buildings, electric vehicle (EV) use, low-cost sustainable materials, and enerfy efficiency standards

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1A5.1	Amend Chapter 5 of the Hawaiʻi County Code to adopt the 2021 IECC energy code with modifications specific to Hawaiʻi County.	DPW	$	2024	●		
1A5.2	Create a dependable permitting system for developers by identifying and addressing inefficiencies in County permitting process.	DPW	$	2023	●		
1A5.3	Incentivize developments that align with County sustainability goals and plans.	DPW	$	2026		●	
	– Partner with on-island developers to identify ways to offset development costs associated with green infrastructure						
1A5.4	Amend Chapter 25 of the Hawaiʻi County Code to require all public and private parking lots to maintain a 25% parking stall minimum to be EV-charger ready by 2035.	Council, DP	$	2023	●		
1A5.5	Conduct a study to determine financial impact of waiving all permitting and review fees for development projects that have a minimum LEED certified credential or similar credential.	DPW	$$	2026	●		
1A5.6	Pilot low-emissions landscaping equipment and landscaping practices to determine effectiveness of equipment and practices.	DPW	$	2025	●		
	– Identify on-island partner organizations that can guide pilots						

1A6. Support residents and businesses in producing environmentally friendly on-site energy and implementing energy efficient cooling technologies

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1A6.1	Expand outreach for community rebate incentives by pursuing more public-private partnerships with Hawaiʻi Energy	R&D	$	2023			●
1A6.2	Advocate to the PUC in support of renewable energy sources and social equity in regard to rates, grid planning, and energy project siting	R&D	$	2023			●
1A6.3	Create educational workshops and an online-web series with partners to increase awareness of and access to rebates, tax credits, and energy conservation technology.	R&D	$	2023	●		
1A6.4	Release grants to encourage development and implementation of new on-site energy construction and energy efficiency measures on island	R&D	$$	2024			●
1A6.5	Conduct a study to evaluate the environmental impact of hydrogen energy production on-island.	R&D	$	2024	●		

1A7. Reduce the energy cost of the municipal water supply

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1A7.1	Replace old pumps with higher efficiency pumps for energy savings.	DWS	$$	2023			●
	– Prioritize based on payback period analysis						
1A7.2	Install new Hydro-turbine at Waimea Water Treatment Plant.	DWS	$$	2024		●	
1A7.3	Pursue additional renewable energy projects.	DWS	$$	2025		●	
1A7.4	Install power factor correction equipment at large facilities to increase power factor.	DWS	$$	2024		●	
1A7.5	Conduct energy study to establish baseline and detail power and energy savings opportunities.	DWS	$	2023	●		
1A7.6	Continue to optimize operations to reduce power demand and energy use.	DWS	$	2023	●		

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1A7.7	Continue to purchase and utilize leak detection equipment to reduce water leaks in water transmission systems. Reducing water loss will reduce DWS energy use.	DWS	$	2023	●		
	– *Continue partnership with Hawaiʻi Energy to help fund rebate leak detection equipment purchases*						
1A7.8	Continue to conduct and improve public outreach on water conservation, including drought-resistant landscapes, water conservation practices, and reducing waters leaks. Reducing water use will reduce DWS energy use.	DWS	$	2023	●		

1B. Transportation

Recommended actions at this intervention point fall under four strategies, with a total of twenty actions, as presented in the sections and tables below.

1B1. Continue implementation of the Multi-Modal Transportation Plan to decrease emissions from individual commutes and decrease emissions of the public transit fleet

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1B1.1	Make riding transit easier, reliable, and compatible with other multi-modal options	MTA	$$				
	– *Continue the multi-modal program*			2023			●
	– *Implement the multi-modal complete streets program for island-wide with a focus on urban areas.*			2025			●
1B1.2	Create a transit system to serve the employment and social needs of all people	MTA	$$	2023			●
	– *Continue to sustain and maintain the transit network and adjust as demographics and socioeconomic conditions change.*				●		
1B1.3	Implement technology to provide information to riders and others, including helping to achieve clean energy goals through alternate energy bus and infrastructure purchase, doing so in a fiscally responsible manner.	MTA	$$$				
	– *Three (3) hydrogen buses go into service on Kailua-Kona routes*			2023	●		
	– *Five (5) electric battery buses and charging equipment purchased*			2024	●		

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration <2 yrs	2 – 5 yrs	>5 yrs
	– Three (3) diesel hybrid buses purchased			2023	●		
	– 28 future purchases would be a combination of diesel-electric, hybrid, electric, and/or hydrogen if approved by HDOT.			2025			●
1B1.4	Create transit hubs and bus stops with amenities that provide rider comfort and safety and that help support community and village gathering	MTA	$$$				
	– Plan, design, and build the Kailua-Kona hub. Consider options to provide light service from Kailua-Kona side.			2023		●	
	– Design and develop a Puna hub and complete roadway improvements to allow for Intra-Puna service.			2023		●	
1B1.5	Phase implementation in a fiscally sustainable manner	MTA	$				
	– Test hydrogen and EV fueled buses on the island to demonstrate how well they work on the island's various climate and terrains.			2023			●
	– Add staffing to include an Assistant Mass Transit Administrator, Inventory Clerk, and a second shift of four mechanics and working supervisor.			2023		●	

1B2. Transition the County fleet to zero emissions

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration <2 yrs	2 – 5 yrs	>5 yrs
1B2.1	Create a shared-use mobility program among County depts. that use vehicles intermittently	R&D, DPW, DF	$	2024	●		
1B2.2	Develop an online platform to consolidate County vehicle fuel use, vehicle miles traveled, elevation profile of vehicle routes, and vehicle maintenance data	R&D, DPW	$	2025	●		
	– Integrate platform with energy management system identified in 1A1.6						
1B2.3	Conduct a study to identify high-priority vehicles for fleet transformation, including vehicles that need to be replaced and highest-emitting vehicles	R&D	$$$	2025			●
1B2.4	Publish an internal annual report and external annual summary on fleet use and fleet transition	R&D	$	2023			●
1B2.5	Create a fleet transformation plan for each dept.	All, R&D, DF	$$	2025			●

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
	– *Conduct an alternative fuel vehicle cost-benefit analysis for new vehicle purchases. The analysis should include IRA tax credits, third party financing, rebates, and methane-conversion.*						
	– *Conduct feasibility study on retrofitting heavy-duty vehicles with zero-emissions or renewable fuel technology. Include a cost-benefit analysis of retrofitting engines versus purchasing new vehicles*						
	– *Determine necessary, feasible steps and cost to build the capacity of the Automotive Division to work on zero emission vehicles, including: Training; Equipment Purchasing; and Public-Private partnerships with local automotive shops and dealerships to invest in training and equipment necessary for fleet transition.*						
1B2.6	Develop a Hilo and Kona hydrogen fueling station for County vehicles	DPW	$$$	2027		●	
1B2.7	Place charging infrastructure in all County buildings, public parks, and baseyards for County use	DPW, R&D	$$$	2028			●

1B3. Implement carbon-free vehicle purchasing policies in Hawaiʻi County

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1B3.1	Establish an alternative fuel checklist for all new County vehicle purchases	DF, R&D	$	2024	●		
	– *Utilize cost-benefit analysis (B2.5) to determine cost of alternative fuel vehicles*						
1B3.2	Mandate reporting of all new vehicle purchases including average mpg, emissions equivalent per gallon of fuel (or kWh), and estimated annual operation and maintenance costs	County Council, R&D, DF, DPW	$	2024	●		
1B3.3	Revise County purchasing process to prioritize local purchasing to reduce the emissions from importation of goods and services to the County.	DF	$	2024	●		

1B4. Increase accessibility of zero emissions vehicle infrastructure and alternative transportation options to the public

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1B4.1	Pass an ordinance to require County-built roads to include complete street measures where most effective to promote alternative transit options and pedestrian-friendly development	County Council	$	2025	●		
1B4.2	Increase and maintain electric vehicle and hydrogen vehicle charging stations on County sites at low to no cost for users	DPW	$	2028			●
1B4.3	Create a shared-use mobility system for County-owned electric vehicles	R&D, DPW	$	2026	●		
1B4.4	Partner with non-profits, schools, and State agencies to increase community-wide awareness and accessibility re: reducing transportation cost and emissions (i.e., the impact of keeping tires inflated on efficiency of cars) through education awareness program.	R&D	$	2023			●
1B4.5	Conduct public outreach around charging stations to align new construction of County infrastructure with business and community	DPW, R&D	$	2024			●

1C. Waste

Recommended actions at this intervention point fall under five strategies, with a total of twenty-two actions, as presented in the sections and tables below.

1C1. Reduce the carbon footprint of the landfill.

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1C1.1	Implement methane collection systems at landfill and wastewater treatment facilities so that the methane can be stored or converted for fuel	DEM, R&D	$$$	2023			●
	– *Acquire grant monies to conduct an assessment to determine methane produced at wastewater and waste facilities*						
1C1.2	Create a strategic plan for reducing the emissions of the landfill and wastewater treatment plant	DEM	$$	2024		●	
	– *Engage community stakeholders, businesses, and policymakers in plan creation through a taskforce*						

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1C1.3	Continue to explore opportunities with third parties to divert the waste from the landfill and/or repurpose the waste	DEM	$$$	2023			●
1C1.4	Explore opportunities with third parties to reduce greenhouse gas emissions from the wastewater treatment plants	DEM	$$$	2024			●

1C2. Advocate for policies that promote waste diversion through source reduction and recycling.

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1C2.1	Amend Chapter 20 of the HCC to establish waste management goals that are expressed and measured in terms of environmental and community impacts (e.g. greenhouse gas emissions, toxicity, energy use) and consider life cycle impacts, in addition to tonnage-based landfill diversion and waste recovery goals	County Council, DEM	$$	2024	●		
	– *Create recommendations based on the lifecycle impact report*						
1C2.2	Amend administrative rules and procedures to include a differential tipping fee and to mandate solid waste collection fees be reviewed and equitably updated on a regular basis.	DEM	$	2023	●		
1C2.3	Amend Chapter 20 of the HCC to include a schedule of select materials that shall be separately collected, recycled, and prohibited from entering the landfill.	County Council, DEM	$	2023			●
	– *Continue ongoing initiatives to implement extended producer responsibility*						
1C2.4	Continue to advocate for and streamline the process of state policy to increase accessibility of recycling	DEM	$	2023			●
	– *Advocate for mandated recycling and organic waste infrastructure be available in all public waste collection contracts*						
1C2.5	Develop legislation that requires owners and managers of multi-family dwellings and multi-tenant commercial building to provide recycling receptacles	County Council, DEM	$	2028		●	

1C3. Support local businesses and community members in reusing goods and materials.

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1C3.1	Hire staff to track waste collected at landfills, report findings, and connect local businesses to waste streams.	DEM, R&D	$				
	– *Procure a Landfill Diversion (LD) Database Software to collect primary data to track type, amount, and source, when possible, of materials diverted from the West Hawaiʻi Sanitary Landfill.*			2024	●		
	– *Procure a Surplus Database Software to establish a database for surplus materials and goods through redistribution, re-sale, or donation. Members can post listings or search for available surplus items or materials, automating the process of connecting those who have items they no longer need with those who do.*			2024	●		
1C3.2	Conduct assessment of current operational methodologies to improve efficiency	DEM	$$	2024		●	
1C3.3	Expand opportunities to recycle in public areas and during public events	DEM	$$				
	– *Continue to install additional recycling bins in parks and other public areas*			2023	●		
	– *Increase recycling opportunities at community events*			2025		●	
1C3.4	Expand opportunities for commercial recycling	DEM	$$	2024		●	
	– *Continue to work with HDOH Solid and Hazardous Waste Branch to modify recycling and transfer station operating permits to accommodate expanded residential recycling services.*						
1C3.5	Expand and improve public education and awareness programs	DEM	$				
	– *Develop a business waste audit and education program to build capacity for source reduction within the local business community*			2023		●	
	– *Develop a waste reduction education program that specifically targets educating visitors and the hotel and lodging industry on circular economy principles*			2023		●	
	– *Continue reuse education, outreach, and public awareness campaigns to encourage public participation and use of the reuse centers*			2023		●	
	– *Improve signage at recycling and transfer stations to provide the public with comprehensive information about recycling opportunities and procedures*			2023		●	
	– *Increase participation and vendor partnerships for used motor oil program*			2023	●		
1C3.6	Continue partnerships with organizations such as Goodwill Industries to develop reuse centers at existing outlets within the County	DEM	$	2023			●

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1C3.7	Establish a building deconstruction reuse and recycling program.	DEM, R&D	$$	2025			●
	– *Conduct a feasibility assessment of best practices and opportunities*						

1C4. Support mulching operations to allow for soil enhancement County-wide.

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1C4.1	Continue to explore decentralized options for mulching	DEM	$	2024	●		
	– *Partner with others to establish mulching demonstration gardens at recycling and transfer stations or other visible locations in the community*						
1C4.2	Continue to apply for grants and implement pilot composting systems for homeowners.	DEM	$	2023		●	

1C5. Decrease waste of County operations

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1C5.1	Mandate end-of-life requirements for County-owned renewable energy infrastructure.	County Council, R&D	$	2025	●		
	– *Conduct an end-of-life environmental impact assessment of County-owned renewable energy and battery storage infrastructure, including analysis of existing infrastructure, community outreach, and best practices for disposal.*						
1C5.2	Continue and expand the system for sharing infrequently used items among departments through Property Management.	DF	$	2023	●		
1C5.3	Continue to pilot procurement models that encourage reuse, including product-as-a-service, e-leasing, and product take-back.	DF	$	2024			●
1C5.4	Establish composting sites at County facilities and parks.	DPW, DPR	$	2027			●

1D. Land Use and Carbon Sequestration

Recommended actions at this intervention point fall under four strategies, with a total of eighteen actions, as presented in the sections and tables below.

1D1. Establish a system for collecting, monitoring, and evaluating the carbon sequestration potential of Hawaiʻi Island and the impact of land use

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1D1.1	Partner with State and federal agencies to identify a carbon sequestration baseline for Hawaiʻi Island	R&D, DP	$	2023	●		
1D1.2	Partner with State and federal agencies to develop a standardized platform to monitor carbon sequestration potential and land use over time	R&D, DP	$	2024	●		
	– *Publish a report that evaluates the impact of development and land use on Hawaiʻi Island carbon sequestration utilizing the platform.*				●		
1D1.3	Create policy recommendations based on carbon sequestration trends observed through monitoring system	DP	$	2028			●
1D1.4	Conduct a study to identify County-owned undeveloped or vacant lands that can be reforested	R&D	$	2025			●
1D1.5	Continue to pilot regional examples of carbon sequestering landscaping on public access and open spaces lands, County parks, and County assets	DF, DPR	$$	2023			●
	– *Conduct an inventory of existing studies done on public access and open space lands to demonstrate models for evaluating carbon sequestration*						

1D2. Promote reforestation and conservation of forest canopies, especially in mauka areas that benefit watershed capacity and quality

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1D2.1	Continue to plant only native or non-invasive species as part of public access and open spaces lands management practices	DF	$	2024	●		

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1D2.2	Establish an ordinance to require all County owned lands to plant only native or non-invasive species, specifically plants most able to thrive in the local environment	County Council, DPR, DPW	$	2024	●		
	– *Partner with conservation, landscaping industries, and local community members to develop a preliminary list of plants for specific sites*						
1D2.3	Amend Chapter 2, Article 42 of the Hawaiʻi County Code to prohibit the planting of invasive species in public access and open spaces lands	County Council, DF	$	2024	●		
1D2.4	In every grubbing and grading permit, include a list of local nurseries with which developers can partner for landscaping needs	DPW	$	2023			●
1D2.5	Amend Chapter 25 to require a percentage of open space to be preserved as open space as a condition of approval for any rezone or time extension	County Council, DP	$	2023			●

1D3. Encourage farming practices that increase soil quality and ability to capture carbon

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
1D3.1	Continue to provide funding to farmers through small grants, prioritizing projects that increase soil quality and improved manure management	R&D	$	2023			●
1D3.2	Explore the potential cost-benefits of creating a new category within the real property tax code with benefits for carbon neutral or carbon negative agricultural lands	DF	$	2027	●		
1D3.3	Partner with State agencies, local universities, and non-profits to provide technical assistance and educational materials on best farming practices that improve carbon sequestration potential and increase soil quality	R&D	$	2024			●
1D3.4	Increase tool-sharing to increase accessibility of local farming	R&D	$	2025			●
1D3.5	Collect baseline data on food importation and inform local producers and distributors on high demand products and incorporate this data into future County Greenhouse Gas Inventories	R&D	$	2024		●	

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration <2 yrs	Project Duration 2 – 5 yrs	Project Duration >5 yrs
1D3.6	Continue partnerships with State and federal agencies to expand programs like Da Bux to increase accessibility of local food	R&D	$	2023			●

1D4. Carbon Credit Programs

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration <2 yrs	Project Duration 2 – 5 yrs	Project Duration >5 yrs
1D4.1	Partner with the State to explore carbon markets for which the County is eligible	R&D	$	2023	●		
	– *Establish reporting standards to measure carbon sequestration of ag and conservation land.*						
1D4.2	Partner with State agencies to investigate the potential of accessing national carbon credit markets for County-owned and managed properties	R&D, DF	$	2028	●		

Climate Action Co-Benefits

Climate co-benefits describe the potential for actions to achieve multiple outcomes. In order to realize a co-benefit, each action must be planned, designed, and implemented with a conscious consideration of co-benefits.

	Co-Benefit	Action Number
Climate Risk Reduction	• Increased heat waves and average temperature will increase energy demand. Reducing dependence on fossil fuels for electricity will minimize the cost of increased demand on the County, residents, and businesses.	1A2, 1A3, 1A4, A5, 1A6, 1A7
	• Reducing emissions via restoring native ecosystems can increase wetland barriers against sea level rise and decrease urban heat zones through cooling.	1B4.1, 1D1.4, 1D1.5, 1D2
Socio-Cultural Equity	• Incentivizing new and implementing existing energy efficiency measures for LMI communities will decrease the percentage of income spent on electricity.	1A5.2, 1A5.3, 1A5.5, 1A6, 1A7
	• Increasing building energy efficiency increases access to temperature-regulated buildings for vulnerable members of the population, including kupuna, keiki, and people with chronic health conditions.	1A5.2, 1A5.3, 1A5.5, 1A6
	• Increasing transit-oriented development and public transit accessibility decreases cost of transportation and commute time, allowing people to spend more time with their families.	1B1, 1B4
	• Reducing waste decreases toxic runoff and water table pollution, increasing healthy watersheds that support families harvesting their own food.	1C2, IC3, IC4, IC5
	• Restoring and conserving native ecosystems preserves plants that are Native Hawaiian cultural staples.	1D2.1, 1D2.2, 1D2.3, 1D2.4
	• Increasing equitable resilience to climate hazards will benefit historically marginalized and frontline communities and communities that have been made vulnerable to climate change impacts.	All actions
Environmental Protection	• Vegetation management focused on removal of non-native and invasive trees and vegetation and restoration of native trees and vegetation will reduce risks from both wildfire and flooding and improve management of debris flows and sediment runoff during severe rainfall events.	1D2.1, 1D2.2, 1D2.3, 1D2.4, 1D2.5
	• Conservation of forest canopy and reforestation mauka decreases stream diversion and increases water tables.	1D2.1, 1D2.2, 1D2.3, 1D2.4
	• Incentivizing waste reduction decreases leakage of toxic chemicals from landfilled and non-landfilled waste.	1C1, 1C2, IC3, IC4, IC5
	• Incentivizing waste repurposing can build soil.	1C4, 1C5.4
	• Restoring and conserving native ecosystems reduces the vulnerability of native plants to invasive species.	1D2.1, 1D2.2, 1D2.3, 1D2.4
Economic Resilience	• Increasing re-use of waste creates local jobs that support local businesses.	1C3, 1C5.2
	• Reducing landfilled waste also reduces environmental externalities that are penalized by the EPA, require resources to address, and decrease the viability of land for agriculture.	IC
Plan Integration	• Incorporates policies and actions in Multi-Modal Transportation Plan and Integration Solid Waste Management Plan.	IB, IC
	• Consistent with Hawai‘i General Plan	1A, IB, ID

Greenhouse gas emissions

What can you do to reduce your emissions?

Use these tips to reduce your emissions and save on your energy and gas bills!

Energy

- Replace light bulbs with LEDs
- Invest in rooftop PV panels and home batteries
- Contact Hawaiʻi Energy for energy audits for your home and apply for their rebates ($$ back)
- Purchase electric lawn equipment (weedwhackers, leaf blowers, lawn mowers, etc)
- Update your home's insulation to reduce AC

Waste

- Compost your food
- Shop with reusable bags
- Avoid single use plastics
- Bring your own plates, utensils, water bottles, coffee cups
- Reuse and repurpose goods and materials where possible

Transportation

- Carpool with friends and coworkers
- Drive less by combining trips
- Use Hele-on public transit
- Bike or walk when you can
- Choose a fuel-efficient vehicle such as a hybrid or electric car
- Maintain your vehicle. Regular maintenance, such as changing the oil and keeping tires properly inflated, can improve fuel efficiency

Land Use

- Use organic fertilizers, reduce pesticides
- Plant trees
- Grow your own garden

CLIMATE CASCADE 2: AIR AND SEA SURFACE TEMPERATURE

Climate Cascade 2 focuses on the primary indicators of climate change: increasing air and sea surface temperature and lowering ocean water pH (acidification) (Figure 9). This section describes and evaluates this climate cascade and identifies intervention points for County actions and the potential co-benefits of such actions.

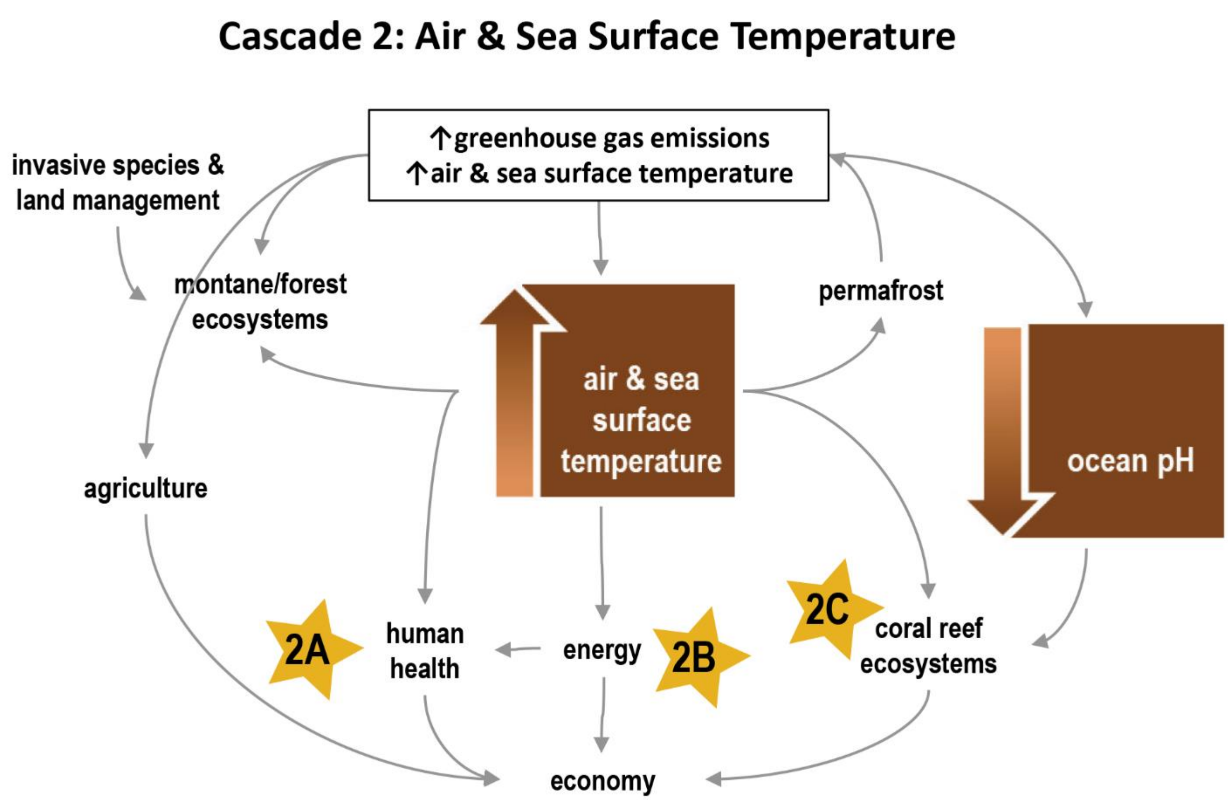

Figure 9. Climate Cascade 2. Air & sea surface temperature

Cascade Narrative

Rising greenhouse gas emissions increase air and sea surface temperature.

Increasing greenhouse gas emissions result in higher air and sea surface temperatures and greater absorption of carbon dioxide in the ocean, which decreases ocean pH (in other words, increases acidity). The number of hot days per year in Hawaiʻi has increased dramatically over the last decade.[58] Temperature is predicted to continue rising above historical averages (Figure 10).[59] Coastal communities on the island are especially susceptible to increased temperatures, with longer stretches of temperatures well above 80 ºF.

Higher temperatures alone can be dangerous for the health of humans and other living creatures. Higher temperatures also change the natural cycles of our planet. For example, higher temperatures can affect how the atmosphere retains water, leading to increased rain in some areas and drought in others. Global warming may accelerate even more as increasing air temperature mobilizes the release of methane from thawing Arctic permafrost.[60]

[58] Stevens, L.E., R. Frankson, K.E. Kunkel, P.-S. Chu, and W. Sweet (2022). Hawaiʻi State Climate Summary 2022. NOAA Technical Report NESDIS 150-HI. NOAA/NESDIS, Silver Spring, MD, 5 pp. https://statesummaries.ncics.org/chapter/hi/
[59] Hawaiʻi Department of Transportation. 2021. Hawaiʻi Highways, Climate Adaptation Action Plan, Exposure Assessments, https://hidot.Hawaiʻi.gov/wp-content/uploads/2021/07/HDOT-Climate-Resilience-Action-Plan-Exposure-Assessments-April-2021.pdf
[60] Froitzheim, N., Majka, J., & Zastrozhnov, D. (2021). Methane release from carbonate rock formations in the Siberian permafrost area during and after the 2020 heat wave. Proceedings of the National Academy of Sciences, 118(32), e2107632118. doi:10.1073/pnas.2107632118

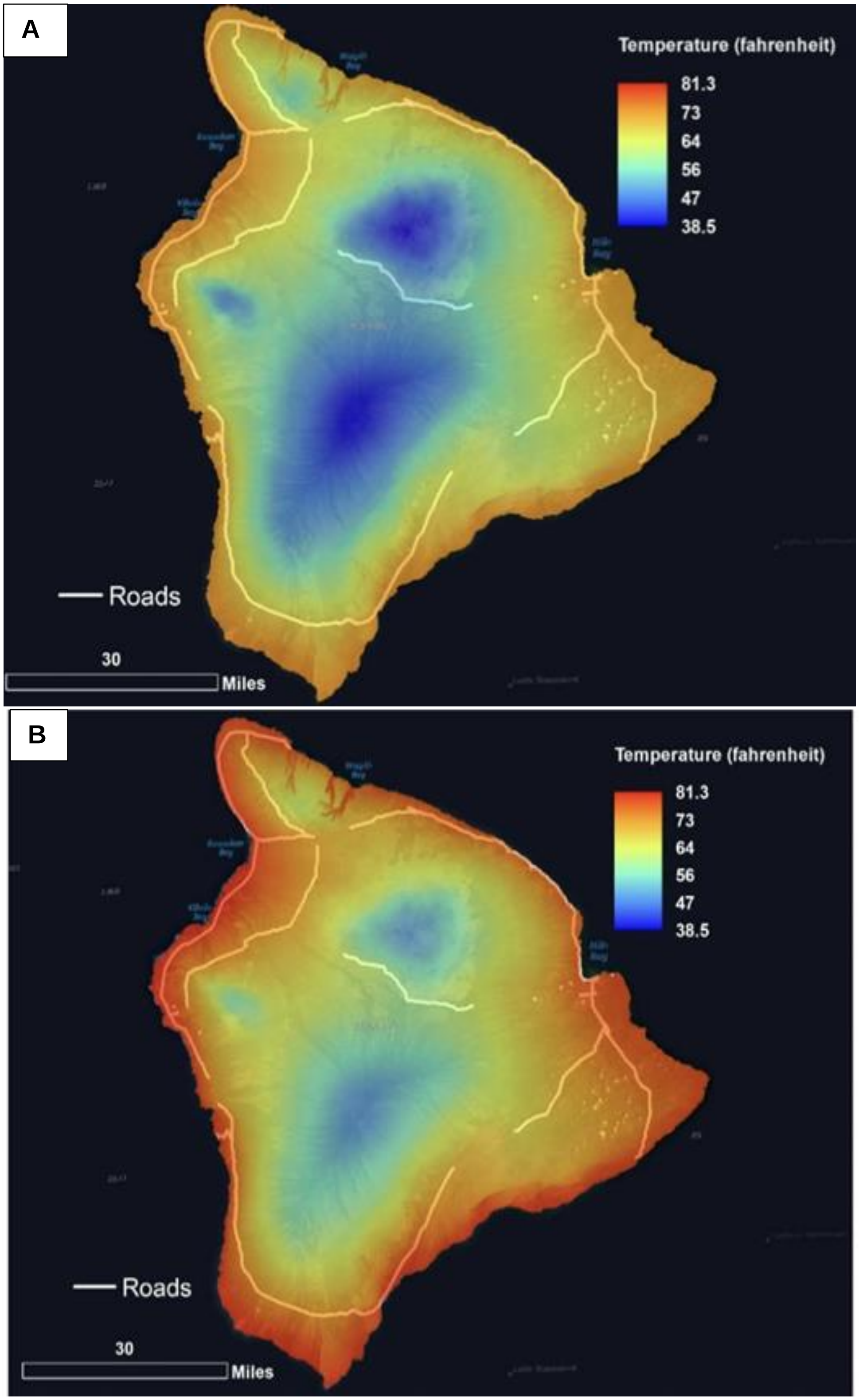

Figure 10. Annual mean temperature (A) historical and (B) end-of century under the IPCC high-emissions scenario (Scenario RCP 8.5)

Hotter air temperature poses risks to human health.

Hot temperatures can be unsafe, especially for vulnerable populations and people exposed to hot temperatures for extended periods of time. Kupuna and keiki, especially keiki playing sports outside, are even more susceptible to the effects of extreme heat. Prolonged exposure to extreme heat can cause heat exhaustion, heat stroke, and death, as well as exacerbating preexisting chronic conditions such as respiratory, cerebral, and cardiovascular diseases.[61] Urban areas lack the tree canopy and green spaces that absorb heat and provide shade. Instead, infrastructure, like buildings and roads, increases the surrounding temperature, creating an urban heat island effect.

Plants, birds, and other living beings will migrate and will likely be more stressed with increasing air temperature.

Temperature is an essential part of how living beings regulate our behavior. The gender of honu ʻea [hawksbill turtles] is affected by temperature, with warmer temperatures leading to more female honu born.[62] Mamo and other damselfish species regulate their metabolism through temperature. Higher temperatures have been shown to negatively affect their ability to metabolize and swim.[63] Increased air temperature will affect the behavioral patterns of living beings on Hawaiʻi island, often in ways we can't yet predict. For example, avian mosquitoes are migrating mauka with warmer air temperatures, harming native bird populations that live at higher elevations.[64]

Some plant species may benefit from higher concentrations of atmospheric carbon dioxide. Increased carbon may boost forest growth and crop yields by increasing rates of photosynthesis and decreasing the loss of water from transpiration.[65] However, other factors critical to plants' growth, such as nutrients, temperature, and water, may limit growth.[66] For example, the seed production of koa decreases in response to higher temperatures.[67] There are many ways living creatures can adapt to increased temperature. In alpine ecosystems across the Pacific, species have been migrating to higher elevations in response to climate change.[68] Increasing temperature exacerbates drought intensity due to higher

[61] National Institutes of Environmental Health. 2022. Climate and Human Health. https://www.niehs.nih.gov/research/programs/climatechange/health_impacts/heat/index.cfm#:~:text=Prolonged%20exposure%20to%20extreme%20heat,%2C%20cerebral%2C%20and%20cardiovascular%20diseases.

[62] National Oceanic and Atmospheric Administration. (2022). Hawaiian Hawksbill Sea Turtle Brochure. https://media.fisheries.noaa.gov/2022-02/hawaiian-hawksbill-sea-turtle-brochure-PIRO.pdf

[63] Johansen, J.L. and Jones, G.P. (2011), Increasing ocean temperature reduces the metabolic performance and swimming ability of coral reef damselfishes. Global Change Biology, 17: 2971-2979. https://doi.org/10.1111/j.1365-2486.2011.02436.x

[64] L. B. Fortini, L. R. Kaiser, D. A. LaPointe, Fostering real-time climate adaptation: Analyzing past, current, and forecast temperature to understand the dynamic risk to Hawaiian honeycreepers from avian malaria. Glob. Ecol. Conserv. 23, e01069 (2020).

[65] NASA. 2022. NASA Study: Rising Carbon Dioxide Levels Will Help and Hurt Crops https://www.nasa.gov/feature/goddard/2016/nasa-study-rising-carbon-dioxide-levels-will-help-and-hurt-crops

[66] Cho, Renee. 2022. How will climate change affect plants? https://news.climate.columbia.edu/2022/01/27/how-climate-change-will-affect-plants/

[67] Pau, S, Cordell, S, Ostertag, R, Inman, F, Sack, L. Climatic sensitivity of species' vegetative and reproductive phenology in a Hawaiian montane wet forest. *Biotropica*. 2020; 52: 825– 835. https://doi.org/10.1111/btp.12801

[68] Frazier, A. G., & Brewington, L. (2020). Current Changes in Alpine Ecosystems of Pacific Islands. In M. I. Goldstein & D. A. DellaSala (Eds.), Encyclopedia of the World's Biomes (pp. 607-619). Oxford: Elsevier.

evaporation which can increase tree mortality and therefore contributing to forest decline.[69] Species in Hawaiʻi are most vulnerable when they are also threatened by habitat loss and invasive species.[70]

Increased temperature places greater demand on energy systems.

Increasing air temperature places greater demand on energy consumption. Increased use of air conditioners will be necessary for organizations that serve vulnerable populations, such as hospitals and schools. Additionally, technology like data servers require immense amounts of cooling, which will increase energy demand as temperatures rise. Disasters from climate change can also increase energy demand, as power sources go out and need to be replaced with fossil fuel.[71] Heightened energy demand further increases greenhouse gas emissions, especially without renewable and reliable energy sources.

A warmer ocean and more acidic ocean stresses coral reef ecosystems.

Decreasing ocean pH (ocean acidification) can damage coral reefs both directly and indirectly from increasing rainfall and runoff. Increasing sea surface temperature, also associated with increasing storm intensity[72] can cause similar damage. This ultimately affects fish populations, the larger food web in marine ecosystems, and the people who depend on them. Hawaiʻi is impacted not only by global ocean acidification, but also coastal acidification resulting from localized land-based pollution, such as runoff and cesspools.[73]

Coral bleaching may occur annually with increasing ocean temperature. Rising levels of carbon dioxide dissolved in the ocean and the resulting increase in acidity changes the balance of minerals in the water.[74] Ocean acidification makes it more difficult for corals, some types of plankton, and other creatures to produce calcium carbonate used to produce hard skeletons or shells, making it more difficult for these animals to thrive and jeopardizing the health of the reef.

Cascade Exposure Analysis

Climate exposure analysis was based on a literature review. A geospatial analysis of climate exposure and risk (as conducted for Climate Cascades 3, 4, and 5) was not conducted. Climate exposure and risk analyses for air temperature should be conducted as described in the Limitations section.

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[69] Brodribb, T.J., Powers, J., Cochard, H. and Choat, B. (2020). Hanging by a thread? Forests and drought. Science, 368(6488), pp.261-266.

[70] Lucas Fortini, Jonathan Price, James Jacobi, Adam Vorsino, Jeff Burgett, Kevin Brinck, Fred Amidon, Steve Miller, Sam `Ohukani`ohi`a Gon III, Gregory Koob, and Eben Paxton (2013) A Landscape-based assessment of climate change vulnerability for all native hawaiian plants. Technical Report HCSU-044. https://hilo.hawaii.edu/hcsu/documents/TR44_Fortini_plant_vulnerability_assessment.pdf

[71] Perera, A.T.D., Nik, V.M., Chen, D. *et al.* (2020) Quantifying the impacts of climate change and extreme climate events on energy systems. *Nat Energy* 5, 150–159. https://doi.org/10.1038/s41560-020-0558-0

[72] Walsh, K.J., McBride, J.L., Klotzbach, P.J., Balachandran, S., Camargo, S.J., Holland, G., Knutson, T.R., Kossin, J.P., Lee, T.C., Sobel, A. and Sugi, M. (2016). Tropical cyclones and climate change. Wiley Interdisciplinary Reviews: Climate Change, 7(1), pp.65-89.

[73] State of Hawaiʻi (2021). State of Hawaiʻi Ocean Acidification Action Plan 2021 – 2031 https://dlnr.hawaii.gov/dar/files/2021/09/State_of_Hawaii_OA_Action_Plan.pdf

[74] EPA (2022). Climate Change Indicators: Ocean Acidity. https://www.epa.gov/climate-indicators/climate-change-indicators-ocean-acidity

Intervention Points and Actions

Actions are associated with three intervention points (2A – 2C) within the climate change indicators cascade (Figure 9). Entities responsible for implementing these actions are mostly County departments but also include the private sector and individuals. Lead County departments for this cascade are as follows:

- Planning Department (DP)
- Department of Public Works (DPW)
- Department of Finance (DF)
- Department of Parks and Recreation (DPR)
- Department of Environmental Management (DEM)
- Research & Development (R&D)

2A. Human Health

Recommended actions at this intervention point fall under three strategies, with a total of seven actions, as presented in the sections and tables below.

2A1. Reduce risk to community members participating in events at Parks facilities

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
2A1.1	Track the temperature of parks facilities weekly to determine trends in temperature.	DPR	$	2024			●
	– *Determine parks that are experiencing significant increases in temperature*			2025	●		
	– *Conduct community meetings to determine which policies, such as hours of sport events or providing water to keiki during after-school events, need to change.*			2026		●	
2A1.2	Include a requirement for forest canopy or a facility that provides shade in future parks developed.	DPR	$		●		

2A2. Increase tree canopy in urban areas to reduce urban heat island effect

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
2A2.1	Pass an ordinance to require new County-built roads to include complete street measures where most effective to encourage planting of trees along streets to provide shade for pedestrians. [See also 1B1.1]	County Council, DPW	$	2024	●		

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration <2 yrs	2 – 5 yrs	>5 yrs
2A2.2	Identify and rank roads that would be most feasible and beneficial to retrofit to include complete street measures	DPW	$$	2024	●		
	– Conduct a vulnerability assessment for existing roads. This assessment should include vulnerability of population to heat and should identify most-highly traversed areas.						
	– Identify trees that are most appropriate to plant to minimize infrastructure damage from root systems or falling trees.						
2A2.3	Pass an ordinance to require all development in urban zones to include urban tree cover. This requirement should be scaled based on the increasing temperature of the area	County Council, DP	$	2024	●		
2A2.4	Create a County-sponsored tree-planting program	R&D	$	2026		●	

2A3. Increase awareness of effects and prevention of heat exposure

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration <2 yrs	2 – 5 yrs	>5 yrs
2A3.1	Partner with public and private entities to increase awareness of heat risks and care for people exposed to extreme heat	R&D	$	2024		●	

2B. Energy Resilience

Recommended actions at this intervention point include one action under one strategy, as presented in the section and table below.

2B1. Ensure County facilities are resilient to increased temperatures

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration <2 yrs	2 – 5 yrs	>5 yrs
2B1.1	Include an energy resilience assessment and roadmap in the Energy Management Plan for County facilities. [See 1A1.5, 1A1.6, 1A1.7]	R&D, DPW	$	2025	●		
	– Include an assessment of energy load from technology and vulnerability of populations that utilize facilities				●		

2C. Coral Reefs

Recommended actions at this intervention point include six actions under two categories, as presented in the section and table below.

2C1. Encourage preservation of coral reefs at County beach parks

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
2C1.1	Include infographics about reef-safe activities at every County beach park	DPR	$	2024	●		
2C1.2	Assist with enforcement of restriction of non-reef safe sunscreen	DPR	$	2025	●		
2C1.3	Continue to partner with the Kohala Center to provide educational resources to visitors and residents at Kahaluʻu Bay	DPR	$	2023			●

2C2. Encourage conversion of cesspools

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
2C2.1	Continue to partner with State and other entities to fund cesspool conversions and research best conversion practices	DEM	$$$	2023			●
2C2.2	Promote findings of State Cesspool Conversion Working Group and integrate findings into wastewater management, planning, and outreach	DEM	$$	2024			●
2C2.3	Explore additional opportunities to fund cesspool conversions for individuals	DEM, R&D	$$	2024			●

Climate Action Co-Benefits

Climate co-benefits describe the potential for actions to achieve multiple outcomes. In order to realize a co-benefit, each action must be planned, designed, and implemented with a conscious consideration of co-benefits.

Co-Benefit		Action Number
Greenhouse Gas Reduction	• Preserving and restoring coral reef systems preserves corals as a source of carbon sequestration.	2C1.1, 2C1.2, 2C1.3
	• Increasing tree canopy to reduce ambient temperature increases carbon sinks.	2A1, 2A2
Climate Risk Reduction	• Increasing tree canopy and green infrastructure in areas experiencing flooding and sea level rise will help absorb the excess water. • Preserving and restoring reefs provides natural protection from high waves and inundation.	2A1, 2A2, 2C2
Socio-Cultural Equity	• Restoring and preserving coral reefs preserves the cultural resources associated with reefs.	2C1, 2C2
	• Greening urban areas and developing climate-resilient energy systems increases the availability of cool areas for vulnerable populations, such as kupuna and keiki, to live and recreate.	2A1, 2A2, 2A3, 2B1
	• Increasing equitable resilience to climate hazards will benefit historically marginalized and frontline communities and communities that have been made vulnerable to climate change impacts.	All actions
Environmental Protection	• Increasing urban forestry can create corridors for species to migrate, so they can survive reductions in their natural habitat caused by development.	2A2.1, 2A2.2, 2A2.3, 2A2.4
Economic Resilience	• Preserving and protecting coral reefs preserves the industries that rely on reefs, such as fishing.	2C1, 2C2
Plan Integration	• Consistent with Hawaiʻi State Cesspool Conversion Working Group Research Summary Report	2C2.1, 2C2.2, 2C2.3

air & sea surface temperature

What can you do to prepare?

1. Plant trees in places that don't have shade
2. Respect signs asking you not to touch fish or reefs
3. Bring extra water to outdoor events with keiki and kupuna
4. Use reef-safe sunscreen to minimize damage to coral reefs
5. Before swimming, take off makeup, hair products, and lotions that may damage reefs
6. Place benches in shaded areas so keiki and kupuna can rest when it's hot
7. Replace your cesspool with a septic tank or other system to reduce sewage leaking into reefs

CLIMATE CASCADE 3: DROUGHT AND EXTREME RAINFALL EVENTS

Climate Cascade 3 focuses on how climate change—specifically changes in temperature and climate variability—can impact drought and extreme rainfall events, with compounding risks from wildfire, landslides, riverine flooding, and high winds (Figure 11). This section describes and evaluates this climate cascade and identifies intervention points for County actions and the potential co-benefits of such actions.

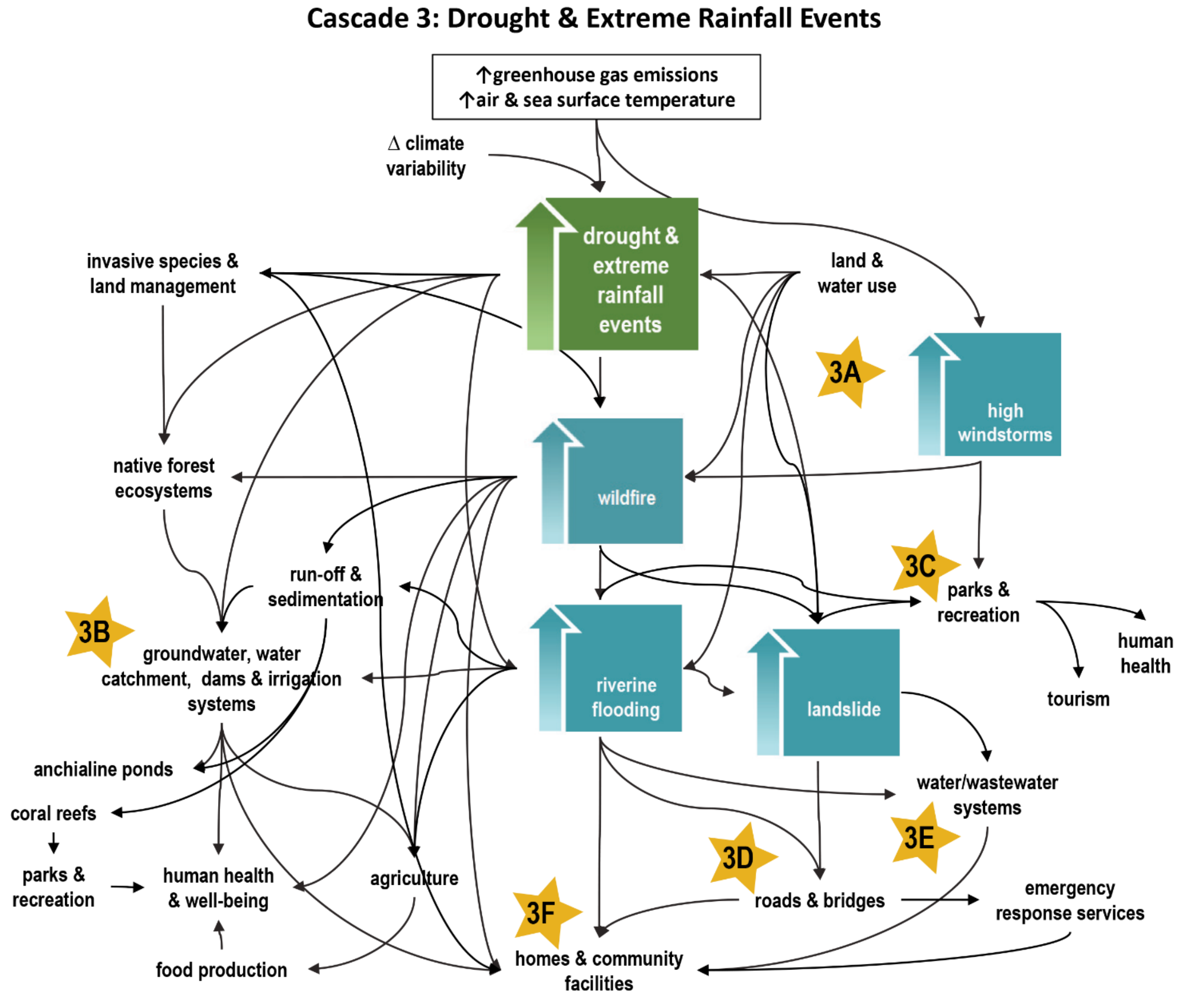

Figure 11. Climate Cascade 3: Drought and extreme rainfall

Cascade Narrative

Rising global air and sea surface temperatures are changing rainfall patterns which may impact the frequency and intensity of future drought and extreme rainfall events

Climate change and climate variability lead to highly variable drought and extreme rainfall conditions over long-term trends. Rainfall trends from 1920 to 2012 show a decrease in annual rainfall for all Hawaiian Islands, with the sharpest decline in the western part of Hawaiʻi Island.[75] Droughts originate from a deficiency in rainfall, which can last months or years. The worst drought of the past century on Hawaiʻi Island occurred from 2007 to 2014. Droughts have become detectably more severe and longer lasting. Most droughts are associated with El Niño events.

Extreme rainfall events on Hawaiʻi Island have become more frequent.[76] Extreme rainfall refers to the intensity of a rainfall event that delivers a high quantity of rainfall over a period of time. Rainfall patterns in Hawaiʻi are influenced by natural climate variability from the El Niño-Southern Oscillation (ENSO), the Pacific Decadal Oscillation, and the Pacific North American teleconnection pattern.[77] Extreme rainfall events increase in La Niña years and decrease in El Niño years.[78]

Drought has cascading effects on agriculture, native ecosystems, and the socioeconomy

Prolonged drought has cascading effects on native ecosystems, the economy, agriculture, and public health. Drought can be classified into five categories depending on effects and duration: meteorological, agricultural, hydrological, socioeconomic, and ecological (Figure 12).[79] The first three types of drought typically occur in sequence, while socioeconomic and ecological drought can occur at any point in a drought's progression[80] and depends on the capacity of state and county resources to respond and the degree to which other ecosystem threats are mitigated. Drought reduces stream flow, which decreases the water available to support stream and wetland habitats,

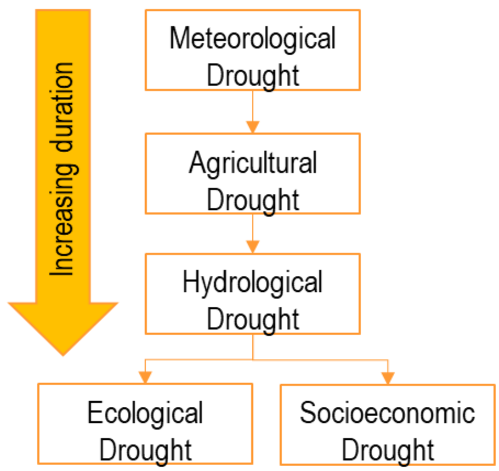

Figure 12. Types of Drought

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[75] Frazier, A. G., & Giambelluca, T. W. (2017). Spatial trend analysis of Hawaiʻian rainfall from 1920 to 2012. International journal of climatology, 37(5), 2522-2531. doi:10.1002/joc.4862

[76] Chen, Y. R., & Chu, P. S. (2014). Trends in precipitation extremes and return levels in the Hawaiʻian Islands under a changing climate. International Journal of Climatology, 34(15), 3913-3925. doi:10.1002/joc.3950

[77] Frazier, A. G., Elison Timm, O., Giambelluca, T. W., & Diaz, H. F. (2017). The influence of ENSO, PDO [Pacific Decadal Oscillation] and PNA [Pacific North American teleconnection pattern] on secular rainfall variations in Hawaiʻi. Climate dynamics, 51(5-6), 2127-2140. doi:10.1007/s00382-017-4003-4

[78] Chen, Y. R., & Chu, P. S. (2014). doi:10.1002/joc.3950

[79] Crausbay, S.; Ramirez, A.R.; Carter, S.L.; Cross, M.S.; Hall, K.R.; Bathke, D.J.; Betancourt, J.L.; Colt, S.; Cravens, A.E.; Dalton, M.S.; et al.(2017). Defining Ecological Drought for the Twenty-First Century. Bull. Am. Meteorol. Soc. 98, 2543–2550.

[80] Frazier, A.G.; Giardina, C.P.; Giambelluca, T.W.; Brewington, L.; Chen, Y.-L.; Chu, P.-S.; Berio Fortini, L.; Hall, D.; Helweg, D.A.; Keener, V.W.; et al. (2022). A Century of Drought in Hawaiʻi: Geospatial Analysis and Synthesis across Hydrological, Ecological, and Socioeconomic Scales. Sustainability, 14, 12023. https://doi.org/10.3390/su141912023

agricultural irrigation, cultural practices, and aquifer recharge and freshwater supplies.[81] Rain-fed fields and pasture lands are the most vulnerable to drought effects in Hawaiʻi; although if a drought persists, irrigated areas also can become vulnerable.[82] The two worst droughts for the State of Hawaiʻi in the past century were 1998–2002 and 2007–2014. Over $80 million in drought relief was provided to the agriculture sector as a result of these droughts. [83]

Native forests are degraded by warming and drought through increased tree mortality and accelerated grass invasion, which together can reduce the cover of high quality forest and increase vulnerability to fire impacts.[84] Freshwater ecosystems are particularly vulnerable to drought. Stream fauna are negatively affected by reductions in stream flow through the limited availability of freshwater habitat, loss of hydrological connectivity, and impaired water quality.[85] Reduced surface water and groundwater inputs into nearshore environments may also have negative effects on organisms in brackish and marine environments.

Groundwater discharge to streams has significantly decreased over the past 100 years, indicating a decrease in groundwater storage.[86] Longer and more frequent droughts increase the demand for potable and non-potable water for municipal and agricultural uses. Water supply from County, private, and individual systems will be impacted by drought conditions and increased water use to support residents, agriculture, ranching, and tourism.

Improving water infrastructure and conservation by increasing water storage capacity, reducing leakages from water systems, providing backup water systems, and conducting education and outreach activities are some of the key pre-drought management actions needed in a changing climate.[87]

Severe rainfall events, compounded by flooding and landslides, increase risks to critical infrastructure and communities and disrupt emergency services

Heavy continuous rainfall over a period of several hours can create disaster conditions in high-sloping areas of the island, which are prone to landslides, and in low-lying areas with poor drainage. Runoff and flooding are some of the most disastrous impacts of severe rainfall events. As stream flows and

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[81] Hawaiʻi County Multi-Hazard Mitigation Plan 2020. https://www.Hawaiʻicounty.gov/departments/civil-defense/multi-hazard-mitigation-plan-2020
[82] Frazier, A.G.; Giardina, C.P.; Giambelluca, T.W.; Brewington, L.; Chen, Y.-L.; Chu, P.-S.; Berio Fortini, L.; Hall, D.; Helweg, D.A.; Keener, V.W.; et al., (2022). A Century of Drought in Hawaiʻi: Geospatial Analysis and Synthesis across Hydrological, Ecological, and Socioeconomic Scales. Sustainability 2022, 14, 12023. https://doi.org/10.3390/su141912023
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[85] Clilverd, H.M., Tsang, Y.P., Infante, D.M., Lynch, A.J. and Strauch, A.M., 2019. Long-term streamflow trends in Hawaiʻi and implications for native stream fauna. Hydrological Processes, 33(5), pp.699-719.
[86] Hawaiʻi Water Resources Commission. 2019. Hawaiʻi Water Resources Protection Plan. https://files.Hawaiʻi.gov/dlnr/cwrm/planning/wrpp2019update/WRPP_201907.pdf
[87]Abby G. Frazier, Jonathan L. Deenik, Neal D. Fujii, Greg R. Funderburk, Thomas W. Giambelluca, Christian P. Giardina, David A. Helweg, Victoria W. Keener, Alan Mair, John J. Marra, Sierra McDaniel, Lenore N. Ohye, Delwyn S. Oki, Elliott W. Parsons, Ayron M. Strauch, Clay Trauernicht (2019), Managing Effects of Drought in Hawaiʻi and U.S.-Affiliated Pacific Islands. In: Vose, James M.; Peterson, David L.; Luce, Charles H.; Patel-Weynand, Toral, eds. Effects of drought on forests and rangelands in the United States: translating science into management responses. Gen. Tech. Rep. WO-98. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office. 95-121. Chapter 5.

velocities change, erosion patterns also change, altering channel shapes and depths, possibly increasing sedimentation behind dams, and affecting habitat and water quality. Changes in watershed vegetation and soil moisture conditions also change runoff and recharge patterns.

Deforestation augments the impact of extreme rainfall events. When forests are removed from a watershed, stream flows can easily double. Increased sediment prevents streambeds from carrying the increased discharge, causing floodplains and floodplain elevations to increase.

Many County roads, bridges, and structures are exposed severe rainfall events and compounding hazards, especially flooding and landslides. Impacts to roads, powerlines, and other critical facilities result in disruption of emergency services.

Compounding effects of severe rainfall and landslides on cliff erosion and public safety

Wildfires compounded with heavy rainfall events, hot dry weather, and windstorms increase risk to native ecosystems and human health

Rainfall-vegetation interactions are key predictors of fire risk.[88] Heavy rainfall events prior to a drought season magnify the growth of vegetation that serves as fuel for wildfires.[89] Subsequent declining rainfall and stream flow increase the likelihood of wildfire by drying out the vegetation that serves as fuel. As a result, forests are more susceptible to wildfires. Invasive species further compound the impacts of

[88] Trauernicht, C. (2019). Vegetation—rainfall interactions reveal how climate variability and climate change alter spatial patterns of wildland fire probability on Big Island, Hawaiʻi. The Science of the Total Environment, 650(Pt 1), 459-469. doi:10.1016/j.scitotenv.2018.08.347
[89] Pacific Islands Climate Science Center. (2017). Ecological Drought in the Hawaiʻian Islands: Unique tropical systems are vulnerable to drought. (Report from the Pacific Islands Climate Science Center Workshop, March 6-8, 2017). Honolulu, HI.

wildfire. Fire that spreads through fire-adapted invasive grasses and shrubs kills native plants that are highly vulnerable to fire.[90]

Hot dry spells create the highest fire risk. Increased temperatures may intensify wildfire danger by warming and drying out vegetation. Future drying with climate change will shift peak fire risk to higher elevations, endangering native forests mauka.[91]

High windstorms spread fire, increasing the risk of wildfire. The probability of high windstorms increases in a warmer climate, so climate change may increase the frequency of high windstorms and therefore the frequency and intensity of fires. Faster, wind-driven fires are harder to contain, and thus are more likely to expand into residential neighborhoods. High winds reduce the effectiveness of fuels reduction strategies, such as mown and grazed fuel breaks, and emphasize the need for additional strategies, especially reforestation of grasslands.

Direct impacts of wildfires may include loss of structures, crops, and grazing land. Indirect impacts include health and safety issues, loss of nutrients from the soil, soil runoff to coral reefs, and economic impacts on agriculture and tourism. When heavy rains occur following a wildfire, flooding and landslides release sediment into rivers, permanently changing floodplains and damaging sensitive habitat and riparian areas. Fire followed by a severe rainfall event could release millions of cubic yards of sediment into streams and nearshore waters.

Potential losses from wildfire include human life, structures and other improvements, and natural resources. Given the immediate response times to reported fires, the likelihood of injuries and casualties is minimal. Smoke and air pollution from wildfires can be a health hazard, especially for sensitive populations including children, the elderly and those with respiratory and cardiovascular diseases. Wildfire may also threaten the health and safety of those fighting fires. First responders are exposed to the dangers from the initial incident and after-effects from smoke inhalation and heat stroke. In addition, wildfire can lead to ancillary impacts such as landslides in steep ravine areas and flooding due to silt in local watersheds and nearshore receiving areas.

[90] Helweg, Dave; Giardina, Christian (2017). Ecological drought in the Hawaiian Islands: unique tropical systems are vulnerable to drought. University of Maryland Center for Environmental Science (UMCES) Integration & Application Network Newsletter 581. 4p.
[91] Trauernicht, C. (2019). Vegetation—rainfall interactions reveal how climate variability and climate change alter spatial patterns of wildland fire probability on Big Island, Hawaiʻi. The Science of the Total Environment, 650(Pt 1), 459-469. doi:10.1016/j.scitotenv.2018.08.347

Wildfire near Waimea on July 31, 2021, prompts evacuations and threatens ranches and native forests.
Source: 25th Infantry Division/Handout

Cascade Exposure Analysis

The exposure analysis for this climate cascade identified County assets exposed and socially vulnerable communities at risk to multiple hazards. The County can use the information from these analyses to identify areas and assets to prioritize climate action. For Climate Cascade 3, exposure and risk were assessed from the geographic overlap of five hazards:

1. Drought
2. Wildfire
3. Riverine flooding
4. Landslide (moderate or high)
5. High windstorms

The following are key take-aways from the exposure analysis for this climate cascade:

- Example areas with high climate cascade exposure (exposure to four or five hazards) are in North Kohala, North Kona, and South Hilo (Figure 13).
- All types of County assets are exposed to the high cascade exposure level (exposure to four or five hazards; Table 4).
- The low and medium exposure levels (exposure to one to three hazards; Table 4) can still pose a risk to County assets and communities.
- North Kohala and South Kona had the highest number of County assets exposed to the high cascade exposure level (exposure to four or five hazards; Table 5).
- Census block groups in South Hilo, Puna, and North Kona have the highest climate cascade risk (exposure to five or six hazards) (See Appendix B).

For more information on the individual hazards see Appendix A. The climate risk analysis methodology and maps are provided in Appendix B. To fully explore the exposure and risk analysis, please visit the County's **Climate Cascade Exposure Tool**.

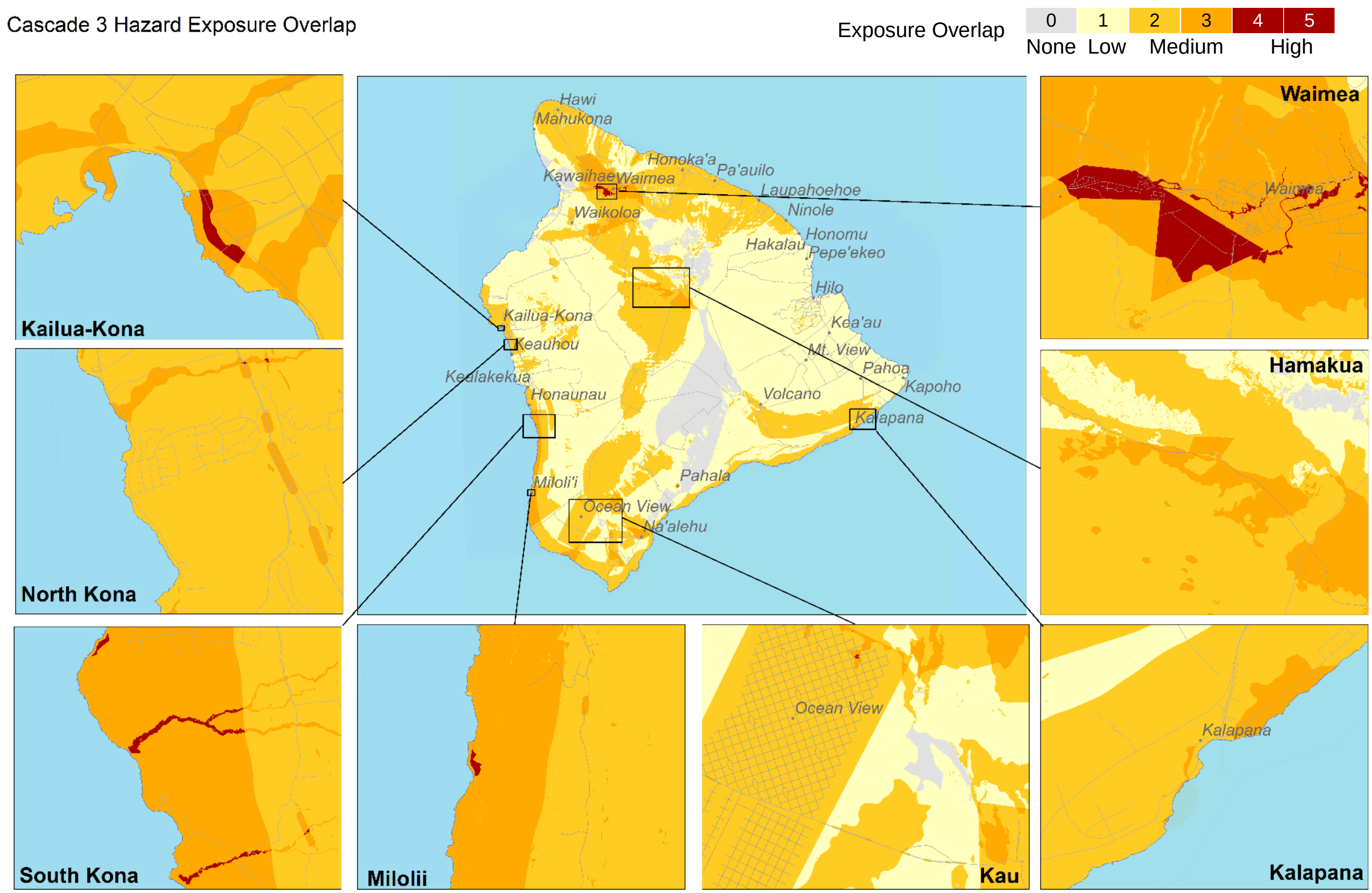

Figure 13. Climate Cascade 3: Areas exposed by number of overlapping hazard layers

Table 4. Climate Cascade 3: Number and type of County assets exposed

CASCADE 3 DROUGHT AND EXTREME RAINFALL EVENTS		Climate Hazards	Number of Assets: Structures	Road Segments	Bridges	Water Tanks (County and Private)	Water Line Segments	Onsite Sewage Disposal Systems (County and Private	Wastewater Line Segments	Parks
Individual Hazard Exposure		Drought	137	4,224	27	234	9,816	14,497	1,719	62
		Wildfire	130	3,357	24	118	6,157	9,253	1,691	51
		Riverine Flooding	33	597	28	6	1,047	1,030	326	48
		Landslide (moderate or high)	461	8,737	182	265	14,472	39,243	2,322	174
		High Winds	129	3,136	107	147	4,448	9,780	160	58
Cascade Hazard Exposure	None	No Exposure	4	33	12	2	69	21	7	1
	Low	1 Hazard Exposure	363	7,188	90	261	13,669	35,810	1,965	87
	Medium	2 Hazard Exposures	177	5,150	124	214	8,917	15,602	1,859	85
	Medium	3 Hazard Exposures	44	679	7	23	1,192	1,665	169	29
	High	**4 Hazard Exposures**	**9**	**114**	**1**	**3**	**179**	**366**	**7**	**11**
	High	**5 Hazard Exposures**	**1**	**14**	**1**	**0**	**29**	**66**	**0**	**1**

Table 5. Climate Cascade 3: Number of County assets by district with high cascade exposure (4 or 5 hazard exposures)

Cascade 3 Drought AND Extreme Rainfall Districts	Assets							
	Structures	Roads	Bridges	Water Tanks	Water Lines	Onsite Sewage Disposal Systems	Wastewater Lines	Parks
South Hilo	0	0	0	0	0	0	0	0
Puna	0	1	0	0	0	0	0	1
Hāmākua	0	2	0	0	0	0	0	1
North Kohala	0	0	0	0	0	0	0	0
South Kohala	**7**	**108**	**2**	**3**	**198**	**431**	**0**	**6**
North Kona	**3**	**7**	**0**	**0**	**10**	**0**	**7**	**2**
South Kona	0	4	0	0	0	1	0	1
Kaʻū	0	6	0	0	0	0	0	1

Intervention Points and Actions

Actions are associated with six intervention points (3A – 3F) within the drought and severe rainfall cascade (Figure 11). Actions were developed based on the County asset exposure analysis, capital improvement program projects (proposed and completed), and the 2020 County of Hawaiʻi Multi-Hazard Mitigation Plan update. Entities responsible for implementing these actions are mostly County departments. Lead County departments for this cascade are as follows:

- Planning Department (DP)
- Department of Public Works (DPW)
- Fire Department (FD)
- Department of Environmental Management (DEM)
- Department of Water Supply (DWS)

3A. New Development

Recommended actions at this intervention point fall under two strategies, with a total of seven actions, as presented in the sections and tables below.

3A1. Improve climate hazard risk knowledge

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
3A1.1	Assess compounding risk of severe rainfall events and landslides on bluff failure for susceptible shorelines in Hāmākua	CD	$$	2026			●
3A1.2	Improve rainfall data collection and flood risk identification and notification by installing rain and stream gauges in Hāmākua	CD	$$$	2026			●
	– *Identify locations/quantity of rain and stream gauges*			2024	○		
3A1.3	Update drought trends	CD	$$	2026		●	
3A1.4	Use spatial and real-time assessments of fire risk and integrate these into emergency response plans and forecasts	CD	$	2026			●
3A1.5	Perform needs assessment and riverine flood studies for Puna, North Kona, and South Kohala	DPW	$$	2024		●	

3A2. Update County codes, regulatory standards, and policies to reduce risks from drought, flooding, and fire based on best available climate projections and observed trends

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
3A2.1	Update zoning (Chapter 25) and subdivision (Chapter 23) codes to incorporate new hazard mitigation requirements for drought and fire risk reduction	DP	$	2024		●	
3A2.2	Update floodplain management requirements (Chapter 27) to incorporate new floodplain management requirements for extreme rainfall events	DPW	$$	2024		●	

3B. Water Resources

Recommended actions at this intervention point fall under four strategies, with a total of 10 actions, as presented in the sections and tables below.

3B1. Increase water storage capacity and groundwater recharge

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
3B1.1	Increase water tank capacity county-wide	DWS	$$$				●
	– *Identify priorities for water tank capacity improvements in areas at risk to drought*			2023	○		
3B1.2	Increase groundwater recharge through watershed protection	DWS	$$				●
	– *Develop a watershed protection plan for Kona, Kaʻū, and Kohala*			2024		○	
3B1.3	Encourage private landowners to increase storage capacity in areas at risk to drought	DP	$	2025			●

3B2. Reduce water system leakages

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
3B2.1	Conduct annual system-wide water audit to identify sources of water loss	DWS	$				●
	– *Develop criteria to consider drought and other climate impacts in setting retrofit priorities as part of the annual system-wide water audit*			2024	●		

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration <2 yrs	2 – 5 yrs	>5 yrs
3B2.2	Retrofit dams/reservoirs to address embankment stability and waterproofing	DWS	$$$				●
	– Complete design for retrofit for Waikoloa Reservoir No. 1			2023	○		

3B3. Identify alternative water supplies for times of drought

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration <2 yrs	2 – 5 yrs	>5 yrs
3B3.1	Develop a water reuse program	DEM	$$			●	
	– Identify opportunities for water reuse for all County systems			2024	○		
3B3.2	Identify and create groundwater backup sources	DWS	$$$				●
	– Update water use and development plan incorporating climate change island-wide			2024			○
	– Update water master plan incorporating climate change island-wide			2023			○

3B4. Develop water conservation program

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration <2 yrs	2 – 5 yrs	>5 yrs
3B4.1	Integrate climate change into public outreach for water conservation including drought-resistant landscapes, water conservation practices, and reducing waters system losses	DWS	$$	2024			●
3B4.2	Review/update criteria for water conservation triggers for the Waimea water system	DWS	$	2024			
3B4.3	Update rate structure to influence active water conservation techniques every 5 years	DWS	$$			●	
	– Review/update rate structure based on changing use and projected future impacts of climate change on water supply			2023			○

3C. Parks and Recreational Areas

Recommended actions at this intervention point include two actions under one strategy, as presented in the section and table below.

3C1. Upgrade/relocate parks and park facilities exposed to flooding, drought, and other hazards

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
3C1.1	Assess risks to park facilities as part of the design of renovation or construction projects	DPR	$$				●
	– *Develop assessment tool to assess risks to structural conditions, landscaping, irrigation system and drainage*			2025	○		
	– *Conduct assessment using tool at Kamakoa Nui*			2026		○	
3C1.2	Investigate green and nature-based flood and drainage adaptation options where appropriate	DPR	$$	2026		●	

3D. Roads and Bridges

Recommended actions at this intervention point include three actions under one strategy, as presented in the section and table below.

3D1. Upgrade/relocate roads and bridges vulnerable to flooding from extreme rain events

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
3D1.1	Retrofit/relocate roads and bridges in flood prone areas	DPW	$$$				●
	– *Review flood complaint logs to identify high flood risk areas*			2024	○		
	– *Assess flood risk to identified priorities including roads to access to Hilo hospital; roads above and below highway in Hāmākua; and Alaneo St, Haleaha Pl, Keanuiomano St, Waiaka St.*			2024	○		
	– *Conduct multi-hazard assessment that includes climate risk to support retrofit needs*						
3D1.2	Install drainage improvements, flood channels, and retention basins to address flood risk to communities	DPW	$$$				●
	– *Conduct hydrology studies to address risks to development in South Kohala, North Kona, and South Kona*			2024		○	
	– *Map floodplains for South Kohala, North Kona, and South Kona*			2024		○	

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration <2 yrs	2 – 5 yrs	>5 yrs
	– *Plan for future climate impacts as a standard part of building new county facilities and infrastructure*			2024			●
3D1.3	Harden Wailuku Bridge #1 in South Hilo	DPW	$$$	2025			●

3E. Water and Wastewater Systems

Recommended actions at this intervention point include two actions under one strategy, as presented in the section and table below.

3E1. Upgrade/relocate wastewater systems exposed to extreme rainfall events

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration <2 yrs	2 – 5 yrs	>5 yrs
3E1.1	Expand wastewater lines in urban areas to connect those converting from OSDS within wastewater service areas	DEM	$$$				●
	– *Assist DOH link County residents to federal and State funding to upgrade on-site disposal systems in wastewater service areas*			2023		○	
	– *Conduct wastewater facility planning and resilience assessment by wastewater service area*			2023		○	
3E1.2	Coordinate with the State on wastewater upgrades associated with State roads and bridges	DEM	$$				●
	– *Assess vulnerability of wastewater system associated with Wailuku Bridge*			2023		○	

3F. Existing Development

Recommended actions at this intervention point fall under two strategies, with a total of six actions, as presented in the sections and tables below.

3F1. Establish a fire risk reduction program

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration <2 yrs	2 – 5 yrs	>5 yrs
3F1.1	Establish fire breaks around communities and along roadways in high fire risk areas	FD	$$	2024		●	

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
3F1.2	Continue to develop partnerships between communities and landowners to support fire risk reduction practices, improve access for firefighters, and identify where water infrastructure can support livelihoods (grazing, agriculture	FD	$$	2023			●
3F1.3	Conduct public education on evacuation routes and safe zones	CD	$	2024			●
3F1.4	Improve hazard tree management in fire and flood prone areas with special focus on removing non-native and invasive species and replanting appropriate native species	DPW	$$			●	
	– *Amend landscape rules to promote drought-resistant landscape*			2024		○	
3F1.4	Participate in the Hawaiʻi Firewise Community Program to prepare Community Fire Plans	CD	$	2024			●

3F2. Improve floodplain management

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
3F2.1	Maintain good standing and compliance under the NFIP	DPW	$$	2023			●
3F2.2	Enhance the County's classification under the CRS program	DPW	$$			●	
	– *Coordinate with State to improve BCEGS*			2023	○		

Climate Action Co-Benefits

Climate co-benefits describe the potential for actions to achieve multiple outcomes. In order to realize a co-benefit, each action must be planned, designed, and implemented with a conscious consideration of co-benefits.

	Co-Benefit	Action Number
Greenhouse Gas Reduction	• Limiting the spread of fires reduces the associated greenhouse gas emissions.	3A1.1, 3F1.1
	• Capturing methane from wastewater systems can generate renewable energy or fuel.	3E1.1, 3E1.2
	• Encouraging drought-resistant landscaping increases the area of vegetation, resulting in more carbon sequestration.	3F1.3, 3F1.4
	• Reducing the risks of flooding, landslides, and fire reduces the greenhouse gas emissions associated with reconstruction of infrastructure and need for alternative routes which increase emissions during road and bridge outages	3D2.1, 3D2.2, 3D2.3
Social-Cultural Equity	• Continued participation in the FireWise program supports community-driven action to promote safety and wellbeing.	3F1.5
	• Increasing equitable resilience to climate hazards will benefit historically marginalized and frontline communities and communities that have been made vulnerable to climate change impacts.	All actions
Environmental Protection	• Vegetation management focused on removal of non-native and invasive trees and vegetation and restoration of native trees and vegetation will reduce risks from both wildfire and flooding and improve management of debris flows and sediment runoff during severe rainfall events.	3F1.1 – 3F1.4
	• Fire risk reduction around communities potentially limits fire spreading into upland areas, reducing fire-driven forest loss.	
Economic Resilience	• Limiting new development in fire and drought prone areas would reduce economic loss to landowners and businesses.	3A1.1
	• Maintaining good standing and compliance under the NFIP and enhancing the County's classification under the CRS program will reduce the cost of flood insurance for property owners.	3F21, 3F2.2
Plan Integration	• Incorporates policies and actions in General Plan and Hazard Mitigation Plan	3A1.1,3A1.2, 3A2.1, 3A2.2, 3D1.3, 3F1.1
	• Consistent with Hawaiʻi Fire Management Organization Firewise	3F1.5

drought & extreme rainfall events

What can you do to prepare?

Droughts

- Plant drought-resistant crops and decorative plants
- Use water saving kits

Wildfires

- Clear out dry, overgrown underbrush and diseased trees that could be fuel for wildfire
- Mow regularly
- Use fire-resistant building materials
- Use recommendations from the Hawaiʻi Wildfire Management Organization to safeguard home
- Identify alternative water supplies for firefighting
- Install/replace roofing material with non-combustible materials

Land Slides

- Stabilize slopes
- Minimize vegetation removal

Wind Storms

- Trim trees like albizia and eucalyptus away from structures

Riverine Flooding

- Clear storm drains and culverts
- Raise structures above base flood elevation
- Elevate items within house above base flood elevation
- Flood-proof essential structures
- Buy flood insurance

CLIMATE CASCADE 4: SEA LEVEL RISE

Climate Cascade 4 focuses on how climate change—specifically changes in temperature and climate variability—contributes to the slowly emerging impacts of sea level rise, with compounding hazard risk from coastal and riverine flooding and landslides (Figure 14). This section describes and evaluates this climate cascade and identifies intervention points for County actions and the potential co-benefits of such actions.

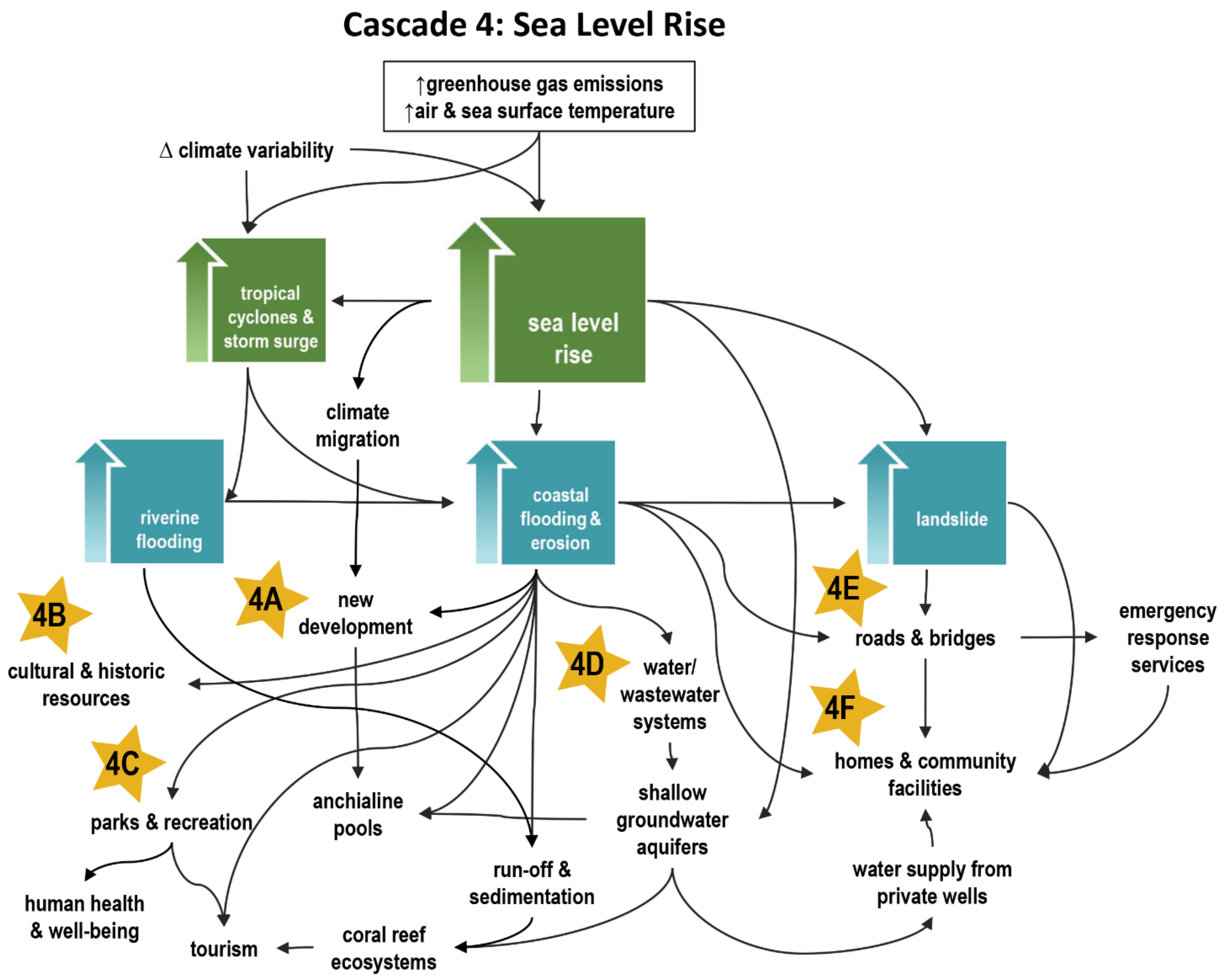

Figure 14. Climate Cascade 4: Sea level rise

Cascade Narrative

Sea level rise is accelerating and is projected to continue to rise, even if future GHG emissions are reduced to net zero and global warming halted.

Sea level is rising globally and the rate of sea level rise is accelerating due entirely to unabated human activities.[92] Sea level will continue to rise even if global warming is halted, as greenhouse gas emissions have a lag effect on temperature.[93] Higher global temperatures, driving melting global ice caps and glaciers and thermal ocean expansion, are resulting in rising sea level. Relative sea level rise is higher around Hawaiʻi Island due to subsidence of the growing island. The observed rate of sea level rise for Hawaiʻi Island is 1.6 inches per decade, higher than Maui, Oʻahu, and Kauaʻi.[94] The projected rate of sea level rise at Hilo, Hawaiʻi, is 0.95 feet by 2040, 2.1 feet by 2060, 4.0 feet by 2080, and 6.2 feet by 2100 for an intermediate high scenario.[95] The State Climate Commission and Honolulu Climate Commission recommends the intermediate scenario for most planning.

Climate change and climate variability both play a role in shorter-term sea level variability. Sea level rise variability is a result of variations in astronomical tides, wave setup, and migration of warm buoyant waters through the islands brought in by winds and currents. Sea level extremes are caused by shifts of the tropical Pacific thermocline associated with El Niño-Southern Oscillation (ENSO).[96] Hawaiʻi experienced record-high sea levels during 2017 following a strong El Niño event in 2015.[97] These record high water levels were produced by a combination of phenomena that included long-term global sea level rise, peak annual astronomical tides ("king tides"), wave setup, and migration of warm buoyant waters brought in by winds and currents.

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[92] Dangendorf, S., Hay, C., Calafat, F.M. et al. Persistent acceleration in global sea-level rise since the 1960s. Nat. Clim. Chang. 9, 705–710 (2019). https://doi.org/10.1038/s41558-019-0531-8

[93] IPCC (2023) Synthesis Report of the IPCC Sixth Assessment (AR6), Summary for Policy Makers (2023) https://report.ipcc.ch/ar6syr/pdf/IPCC_AR6_SYR_SPM.pdf

[94] Marra, J.J and M.C.. Kruk (2017). State of Environmental Conditions in Hawaiʻi and the U.S. Affiliated Pacific Islands under a Changing Climate, NOAA NESDIS National Centers for Environmental Information (NCEI). https://coralreefwatch.noaa.gov/satellite/publications/state_of_the_environment_2017_hawaii-usapi_noaa-nesdis-ncei_oct2017.pdf

[95] Sweet, W. V., B.D. Hamlington, R.E. Kopp, C.P. Weaver, P.L. Barnard, D. Bekaert, W. Brooks, M. Craghan, G. Dusek, T. Frederikse, G. Garner, A.S. Genz, J.P. Krasting, E. Larour, D. Marcy, J.J. Marra, J. Obeysekera, M. Osler, M. Pendleton, D. Roman, L. Schmied, W. Veatch, K.D. White, and C. Zuzak,. (2022). *Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines*. Retrieved from Silver Spring, MD: https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nos-techrpt01-global-regional-SLR-scenarios-US.pdf

[96] Widlansky, M. J., Timmermann, A., & Cai, W. (2015). Future extreme sea level seesaws in the tropical Pacific. *Science Advances, 1*(8), e1500560. doi:doi:10.1126/sciadv.1500560

[97] Long, X., Widlansky, M. J., Schloesser, F., Thompson, P. R., Annamalai, H., Merrifield, M. A., & Yoon, H. (2020). Higher Sea Levels at Hawaiʻi Caused by Strong El Niño and Weak Trade Winds. Journal of climate, 33(8), 3037-3059. doi:10.1175/jcli-d-19-0221.1

Coastal flooding and erosion from high tides, waves, and storm surge are increasing, driven by rising sea level and other climate change effects.

Sea level rise increases the extent of coastal flooding and erosion from high tides[98], waves, floods, and storm surge. The number of minor flood days for Hawaiʻi Island increased from 3 days per year on average in the 1960s to 11 days per year in the decade starting in 2005.[99]

ENSO is one of the principal contributors to long-term wave climate variability in Hawaiʻi.[100] ENSO events can increase or reduce the amount of wave power at the coast, affecting the probability of coastal flooding or erosion. Wave power around the Hawaiian Islands is highly correlated with ENSO events, increasing during El Niño and decreasing during La Niña events.

Riverine flooding and landslides compound the impacts of coastal flooding and erosion along Hawaiʻi Island's coastline.

Increased riverine flooding during severe rainfall events results in coastal flooding and erosion where the river meets the sea. Severe rainfall and riverine flooding events increase risks from landslides and cliff failure. Many of Hawaiʻi Island's disaster declarations have been associated with severe storms, high surf, flooding, and mudslides.[101]

Critical infrastructure, homes, and beach parks along the coastline are exposed to coastal hazards exacerbated by sea level rise.

Many County roads, bridges, parks, and structures are exposed to coastal hazards exacerbated by sea level rise. Critical infrastructure impacted by sea level rise includes hazard materials and waste storage facilities, wastewater treatment facilities, and transportation, communication, energy, and safety and security systems. Structures along the coastline in South Hilo, North Kona, and South Kohala have the greatest sea level rise exposure.

Sea level rise jeopardizes shallow groundwater aquifers used for drinking water wells and degrades water lines and wastewater systems, which leak into groundwater aquifers and coastal ecosystems.

Many wastewater line segments, water line segments, and on-site disposal systems are exposed to sea level rise. Saltwater intrusion from sea level rise into shallow coastal aquifers impacts potable water supply from shallow coastal groundwater wells and underground infrastructure such as water and wastewater infrastructure. Underground infrastructure may become corroded and contaminate freshwater and nearshore waters.[102] Sea level rise and associated inland and coastal flooding increase

[98] Vitousek, Sean et al. "Doubling of Coastal Flooding Frequency Within Decades Due to Sea-Level Rise." Scientific reports 7.1 (2017): 1399–9. Web.
[99] Marra, J.J and M.C.. Kruk (2017) https://coralreefwatch.noaa.gov/satellite/publications/state_of_the_environment_2017_hawaii-usapi_noaa-nesdis-ncei_oct2017.pdf
[100] Odériz, I., Silva, R., Mortlock, T. R., & Mori, N. (2020). El Niño-Southern Oscillation Impacts on Global Wave Climate and Potential Coastal Hazards. Journal of geophysical research. Oceans, 125(12), n/a. doi:10.1029/2020JC016464
[101] Hawaiʻi County. 2020. Multi-Hazard Mitigation Plan
[102] Befus, K. M. et al.(2020). "Increasing Threat of Coastal Groundwater Hazards from Sea-Level Rise in California." Nature climate change 10.10 (2020): 946–952. Web.

corrosion of metallic pipelines, resulting in more main breaks and higher repair and replacement costs.[103] As sea level rises, sewer lines and cesspools in coastal areas will release wastewater into the groundwater and nearshore waters.[104]

Cultural resources and coastal ecosystems will be impacted by coastal flooding and storm surge.

Cultural and historic resources located near the shoreline are at risk to coastal flooding and storm surge exacerbated by sea level rise. National historic landmarks are cultural and historic places that hold national significance.[105] They are sites of great cultural significance sacred to the Hawaiian people. Some sites that may be impacted include Kamakahonu and Pu'u Ali'i. Kamakahonu, the residence of Kamehameha I, is located at the north end of Kailua Bay in Kailua-Kona on the Island of Hawaiʻi. Pu'u Ali'i (the South Point Complex) is thought to be the site of one of the earliest settlements in the Hawaiian Islands and is believed to be the landing place of Hawaii's first inhabitants.

Saltwater intrusion from sea level rise into shallow coastal aquifers impacts coastal ecosystems.[106] Coastal ecosystems vulnerable to coastal hazards include beaches and cliffs, estuaries, fishponds, and anchialine pools.[107] Anchialine pools are unique brackish water environments that form in lava fields near the ocean. These pools are fed by subsurface groundwater (freshwater) and tides (seawater) with no visible connection to the ocean.[108] Anchialine pools are fed by groundwater elevated above mean sea level.[109] As sea levels rise, groundwater will be pushed upward, exacerbating flooding in some coastal areas.[110] In some cases, new pools will emerge in low-lying areas and existing pools will join together. In other areas, a daily connection to the ocean means pools and the species that depend on them will disappear. Large storm waves or extreme flooding events may connect pools, allowing invasive fish to disperse. Cesspools and other coastal wastewater systems may contaminate groundwater fed ecosystems such as anchialine pools with rising seas. Existing and future development and land use near the shoreline will jeopardize anchialine pools as sea level rises. Hawaiʻi is the only state with these special pools. Anchialine pools provide critical habitat for rare invertebrate species, including shrimp, snails, and damselflies. Many of these species are endemic to the Hawaiian Islands, meaning they exist nowhere else in the world.

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[103] Habel, Shellie et al. (2020). "Sea-Level Rise Induced Multi-Mechanism Flooding and Contribution to Urban Infrastructure Failure." Scientific reports 10.1 (2020): 3796–3796. Web.
[104] McKenzie, T., Habel, S., & Dulai, H. (2021). Sea-level rise drives wastewater leakage to coastal waters and storm drains. Limnology and Oceanography Letters, 6(3), 154-163. doi:https://doi.org/10.1002/lol2.10186
[105] National Park Service.National Historic Sites. https://www.nps.gov/locations/Hawaiʻi/landmarks.htm, accessed January 2023
[106] Befus, K. M. et al. "Increasing Threat of Coastal Groundwater Hazards from Sea-Level Rise in California." Nature climate change 10.10 (2020): 946–952. Web.
[107] Gregg, R.M., editor (2018).Hawaiian Islands Climate Vulnerability and Adaptation Synthesis. EcoAdapt, https://www.cakex.org/sites/default/files/documents/EcoAdapt_Hawaiʻian%20Islands%20Climate%20Vulnerability%20and%20Adaptation%20Synthesis%20Report_January2018.pdf
[108] National Park Service. https://www.nps.gov/im/pacn/anchialine_pool.htm#:~:text=Anchialine%20pools%20are%20unique%20brackish,visible%20connection%20to%20the%20ocean.
[109] Sea Level Rise Effects on Groundwater-fed Anchialine Pools https://tnc.maps.arcgis.com/apps/MapJournal/index.html?appid=4cc09bec75e94d909070610c9d4b7016
[110] National Park Service, Pacific Islands Network, Anchialine Pools: Vulnerability to Climate Change in West Hawaiʻi https://media.coastalresilience.org/HI/Anchialine_Pools_FAQ.pdf

Cascade Exposure Analysis

The exposure analysis for this climate cascade identifies County assets exposed to multiple hazards. The County can use the information from these analyses to identify areas and assets to prioritize for climate action. For Climate Cascade 4, exposure and risk were assessed from the geographic overlap of five hazards:

1. Riverine flooding
2. Event-based coastal flooding
3. Event-based coastal flooding with 3.2 feet of sea level rise (SLR)
4. Chronic coastal flooding with 3.2 feet SLR (SLRXA, passive inundation)
5. Landslide susceptibility (moderate or high)

The following are key take-aways from the exposure and risk analyses for this climate cascade:

- Example areas with high climate cascade exposure (exposure to four or five hazards) are located in North Kona, Kaʻū, Puna, and South Hilo (Figure 15).
- All types of County assets are exposed to the high cascade exposure level (exposure to four or five hazards; Table 6).
- The low and medium exposure levels (exposure to one to three hazards; Table 6) can still pose a risk to County assets and communities.
- North Kona and Puna had the greatest number of County assets exposed to the high cascade exposure level (exposure to four or five hazards; Table 7).
- Census block groups in South Hilo, Puna, and North Kona have the highest climate cascade risk (exposure to four or five hazards) (See Appendix B).

For more information on the individual hazards see Appendix A. The climate risk analysis methodology and maps are provided in Appendix B. To fully explore the exposure and risk analysis, please visit the **County's Climate Cascade Exposure Tool**.

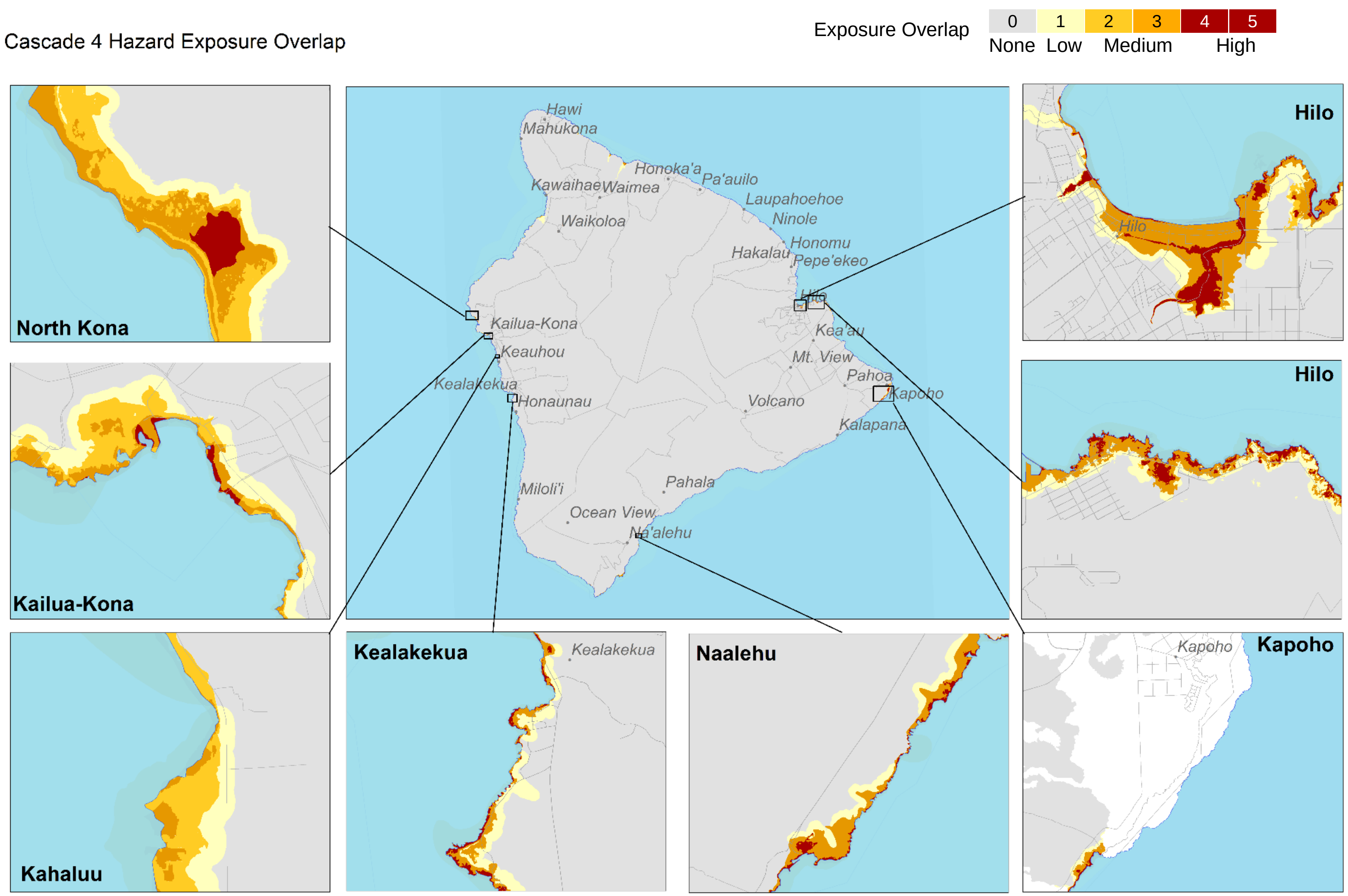


Figure 15. Climate Cascade 4: Areas exposed by number of overlapping hazard layers

Table 6. Climate Cascade 4: Number and type of County assets exposed

CASCADE 4 SEA LEVEL RISE		Climate Hazards	Assets								
			Structures	Road Segments	Bridges	Onsite Sewage Disposal Systems (County and Private)	Water Tanks	Water Line Segments	Onsite Sewage Disposal Systems (County and Private)	Wastewater Line Segments	Parks
Individual Hazard Exposure Totals		Riverine Flooding	10	54	3	129	0	70	129	58	17
		Event-Based Coastal Flooding	67	212	3	270	0	326	270	354	55
		Event-Based Coastal Flooding With 3.2 Feet SLR	98	421	14	653	2	802	653	691	63
		Passive Coastal Flooding With 3.2 Feet SLR	7	71	7	92	0	65	92	42	48
		Landslide (moderate or high)	57	224	9	288	0	308	288	328	52
Cascade Exposure Totals	None	No Exposure	500	12,755	221	52,873	501	23,253	52,873	3,315	150
	Low	1 Hazard Exposure	20	174	5	247	2	412	247	305	3
	Medium	2 Hazard Exposures	22	23	0	117	0	62	117	46	0
		3 Hazard Exposures	49	154	5	221	0	278	221	292	20
	High	**4 Hazard Exposures**	**7**	**60**	**4**	**72**	**0**	**49**	**72**	**45**	**28**
		5 Hazard Exposures	**0**	**12**	**0**	**0**	**0**	**1**	**0**	**4**	**12**

Table 7. Climate Cascade 4: Number of County assets by district with high cascade exposure (4 or 5 hazard exposures)

Cascade 4 Sea Level Rise County Districts	Assets Exposed to 4 and 5 Hazard Exposures							
	Structures	Roads	Bridges	Water Tanks	Water Lines	Onsite Sewage Disposal Systems	Wastewater Lines	Parks
South Hilo	**7**	**27**	**4**	**0**	**32**	**1**	**47**	**17**
Puna	**0**	**29**	**0**	**0**	**3**	**68**	**0**	**4**
Hāmākua	0	0	0	0	0	0	0	0
North Kohala	0	1	0	0	0	1	0	3
South Kohala	0	0	0	0	0	1	0	1
North Kona	**0**	**6**	**0**	**0**	**15**	**0**	**2**	**7**
South Kona	0	7	0	0	0	1	0	4
Kaʻū	0	2	0	0	0	0	0	4

Intervention Points and Actions

Climate adaptation actions are associated with five intervention points (4A – 4F) within the sea level rise cascade (Figure 14). Actions were developed based on the County asset exposure analysis, capital improvement program projects (proposed and completed), and the 2020 County of Hawaiʻi Multi-Hazard Mitigation Plan update. Entities responsible for implementing these actions are mostly County departments. Lead County departments for this cascade are as follows:

- Planning Department (DP)
- Department of Public Works (DPW)
- Department of Parks and Recreation (DPR)
- Department of Environmental Management (DEM)

4A. New Development

Recommended actions at this intervention point fall under three strategies, with a total of 13 actions, as presented in the sections and tables below.

4A1. Improve climate hazard risk knowledge

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
4A1.1	Monitor and map landslide events along the shoreline	DP	$$	2023		●	
4A1.2	Conduct shoreline change studies	DP	$$	2023			●
4A1.3	Map shoreline regions	DP	$$	2023		●	
4A1.4	Update urban growth models in the General Plan for potential influx of climate migrants from Pacific Island countries	DP	$	2026	●		

4A2. Update County codes, regulatory standards, and policies requiring all coastal development to incorporate measures to reduce risk from coastal hazards and sea level rise

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
4A2.1	Revise shoreline setbacks to protect public safety and comply with new State requirements (Rule 11)	DP	$$	2023		●	
4A2.2	Revise subdivision rules to require sea level rise mitigation in new subdivisions in flood prone areas (Chapter 23)	DP	$$	2023		●	
4A2.3	Integrate sea level rise risk reduction policies and actions in General Plan update	DP	$	2023			●
4A2.4	Update floodplain management requirements (Chapter 27) to incorporate new hazard mitigation requirements for sea level rise	DPW	$$	2023		●	
4A2.5	Use overlay hazard zones to develop conditions for land use and design within high-risk zones and within or adjacent to urban growth areas outside of high-risk areas	DP	$				●
	– Adopt the SLR Area as an overlay for planning and rules (Chapter 25)			2023	○		●
	– Integrate hazard overlays in General Plan update			2024		○	
	– Review/update hazards overlay, as needed, based on the 5-year in County Hazard Mitigation Plan update			2025		○	

4A3. Set aside shoreline areas as open space to benefit natural resources and public access and reduce risk to structures from sea level rise

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration <2 yrs	Project Duration 2 – 5 yrs	Project Duration >5 yrs
4A3.1	Use 2% real estate fund to acquire coastal parcels in areas exposed to coastal hazards exacerbated by sea level rise	DP	$	2030			●
4A3.2	Identify receiving areas for transfer of development rights from areas exposed to coastal hazards and sea level rise	DP	$$	2024			●
4A3.3	Identify need for expansion and provide additional shoreline access points	DP	$$				●
	– *Map all County existing shoreline access points and make accessible to the public on-line*			2025		○	

4B. Cultural and Historic Resources

Recommended actions at this intervention point fall under two strategies, with a total of two actions, as presented in the sections and tables below.

4B1. Assess risks to cultural and historic resources in sea level rise prone areas

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration <2 yrs	Project Duration 2 – 5 yrs	Project Duration >5 yrs
4B1.1	Conduct a sea level rise vulnerability assessment of cultural and historic resources in coastal hazard prone areas beginning with County lands	DP	$$	2027		●	
	– *Create Cultural Commission rules allowing for permitted interaction groups to focus on this topic*			2024	○		

4B2. Develop adaptation strategies for cultural and historic resources

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration <2 yrs	Project Duration 2 – 5 yrs	Project Duration >5 yrs
4B2.1	Develop place-based cultural adaptation protocols with Aha Moku council, cultural practitioners, and lineage descendants to proactively address impacts to cultural and historic resources beginning with County lands	DP	$$	2030			●

4C. Parks and Recreational Areas

Recommended actions at this intervention point include one action under one strategy, as presented in the section and table below.

4C1. Upgrade/relocate parks and park facilities exposed to sea level rise and other coastal hazards

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
4C1.1	Assess sea level rise risks to County parks with high exposure and risk to sea level rise	DPR	$$				●
	– *Develop assessment tool that includes identification of potential adaptation strategies*			2025	○		
	– *Use assessment tool for Kahaluʻu Beach Park (North Kona)*			2026		○	

4D. Water and Wastewater Systems

Recommended actions at this intervention point fall under two strategies, with a total of four actions, as presented in the sections and tables below.

4D1. Upgrade/relocate water infrastructure exposed to sea level rise

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
4D1.1	Retrofit/relocate water infrastructure county-wide	DWS	$$$				●
	– *Assess vulnerability of water mains subject to inundation by sea level rise and review every 5 years*			2024	○		
	– *Coordinate with DPW and DEM on road retrofit/realignment for Hilo Bay waterfront, Kailua-Kona and other locations vulnerable to sea level rise*			2024		○	

4D2. Upgrade/relocate wastewater systems exposed to sea level rise

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
4D2.1	Expand wastewater lines in Hilo and Kona wastewater service areas to connect those converting from OSDS	DEM	$$$				●

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration <2 yrs	Project Duration 2 – 5 yrs	Project Duration >5 yrs
	– Assist DOH link County residents to federal and State funding to upgrade on-site disposal systems in wastewater service areas			2023			○
	– Conduct wastewater facility planning and resilience assessment by wastewater service area			2023		○	
4D2.2	Assess vulnerability of wastewater gravity mains in South Hilo	DEM	$$			●	
	– Puʻuʻeo Bridge			2024	○		
	– Hilo Bayfront			2028	○		
	– Banyan Drive			2028	○		
4D2.3	Assess vulnerability of wastewater forcemains/pump stations in South Hilo	DEM	$$				
	– Pua (underway, design completed)			2023	○		
	– Paukaʻa			2030	○		
	– Onekahakaha			2030	○		
	– Kōlea			2030	○		
	– Wailoa			2030	○		
	– Hale Halewai			2030	○		

4E. Roads and Bridges

Recommended actions at this intervention point include two actions under one strategy, as presented in the section and table below.

4E1. Upgrade/relocate roads and bridges vulnerable to sea level rise and other coastal hazards

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration <2 yrs	Project Duration 2 – 5 yrs	Project Duration >5 yrs
4E1.1	Develop adaptation priorities and options for coastal roads and bridges at risk to sea level rise	DPW	$$			●	
	– Hilo Bay waterfront				○		
	– Puʻuʻeo Street bridge over Wailuku River, South Hilo				○		
	– Aliʻi Drive, North Kona				○		
4E1.2	Reassess sea level rise risks to Kalanianaʻole infrastructure improvements, South Hilo	DPW	$	2024	●		

4F. Existing Development

Recommended actions at this intervention point include two actions under one strategy, as presented in the section and table below.

4F1. Reduce repetitive flood loss to structures and properties

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
4F1.1	Expand and maintain home buyout program established for volcanic hazard recovery as a long-term program to incorporate properties affected by sea level rise	DP	$$$	2030			●
4F1.2	Review and revise non-conforming use clauses in all County codes for rebuilding or repairing damaged structures to reduce repetitive flood loss	DPW	$$	2023		●	

Climate Action Co-Benefits

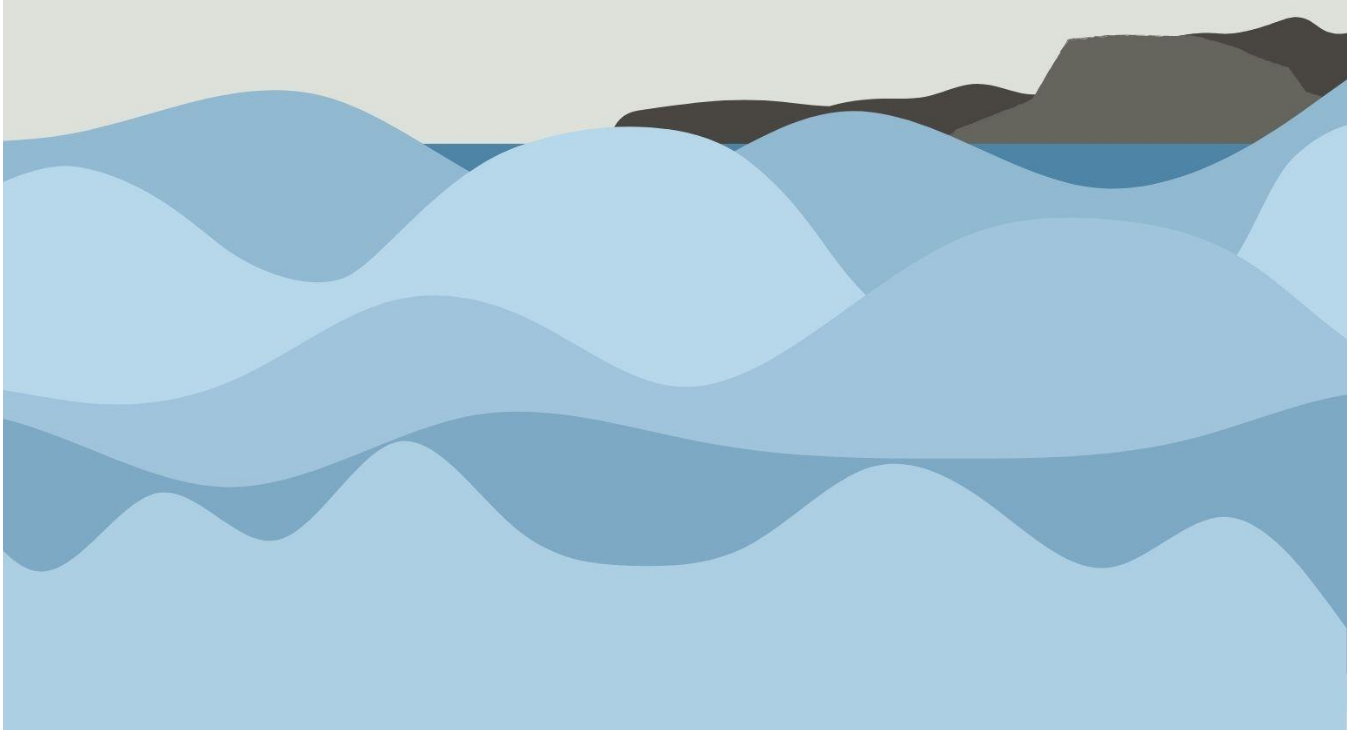
Climate co-benefits describe the potential for actions to achieve multiple outcomes. In order to realize a co-benefit, each action must be planned, designed, and implemented with a conscious consideration of co-benefits.

Co-Benefit		Action Number
Greenhouse Gas Reduction	• Integrating energy savings and waste management provides an opportunity mitigate greenhouse gas emissions in new development	4D2.1
	• Retrofitting or relocating bridges and roads provide an opportunity to reduce greenhouse gas emissions by reducing miles travelled	4E1.1, 4E1.2
	• Upgrading County wastewater systems would reduce greenhouse gas (methane) leakage	4D
Social-Cultural Equity	• Maintaining and increasing shoreline access for all and not just those who can afford beachfront property must be a consideration for sea level rise management and shoreline setback policy.	4A3.4
	• Maintaining parks and recreational areas provides valuable community services.	4C1.1
	• Increasing equitable resilience to climate hazards will benefit historically marginalized and frontline communities and communities that have been made vulnerable to climate change impacts.	All actions
Environmental Protection	• Improvements to County and private wastewater management systems would reduce the release of pollutants to nearshore waters as sea level rises.	4D2.1
	• New shoreline setback rules would expand open space along the shoreline to support coastal ecosystems such as anchialine pools.	4A2.1
Economic Resilience	• Floodplain management rule revisions that reduce risk of coastal flooding and include consideration of increasing flood hazards with SLR will provide credits to the County's Community Rating System reducing the cost of flood insurance and repetitive losses to properties and business.	4A2.4
Plan Integration	• Actions integrates policies and actions in General Plan and Hazard Mitigation Plan	4A2.1, 4A2.2, 4A2.3, 4A2.5

sea level rise

What can you do to prepare?

1. Retrofit home to elevate it above potential sea level rise
2. Advocate for public shoreline access points to County Council
3. Use online mapping tools to understand which areas will be impacted by sea level rise and be aware of your own exposure and risk to it
4. Relocate to higher ground



CLIMATE CASCADE 5: TROPICAL CYCLONES AND STORM SURGE

Climate Cascade 5 focuses on how climate change—specifically sea level rise and changes in temperature and climate variability—can impact tropical cyclones and storm surge, with compounding risks from high windstorms, riverine flooding, landslides and coastal flooding and erosion (Figure 16). This section describes and evaluates this climate cascade and identifies intervention points for County actions and the potential co-benefits of such actions.

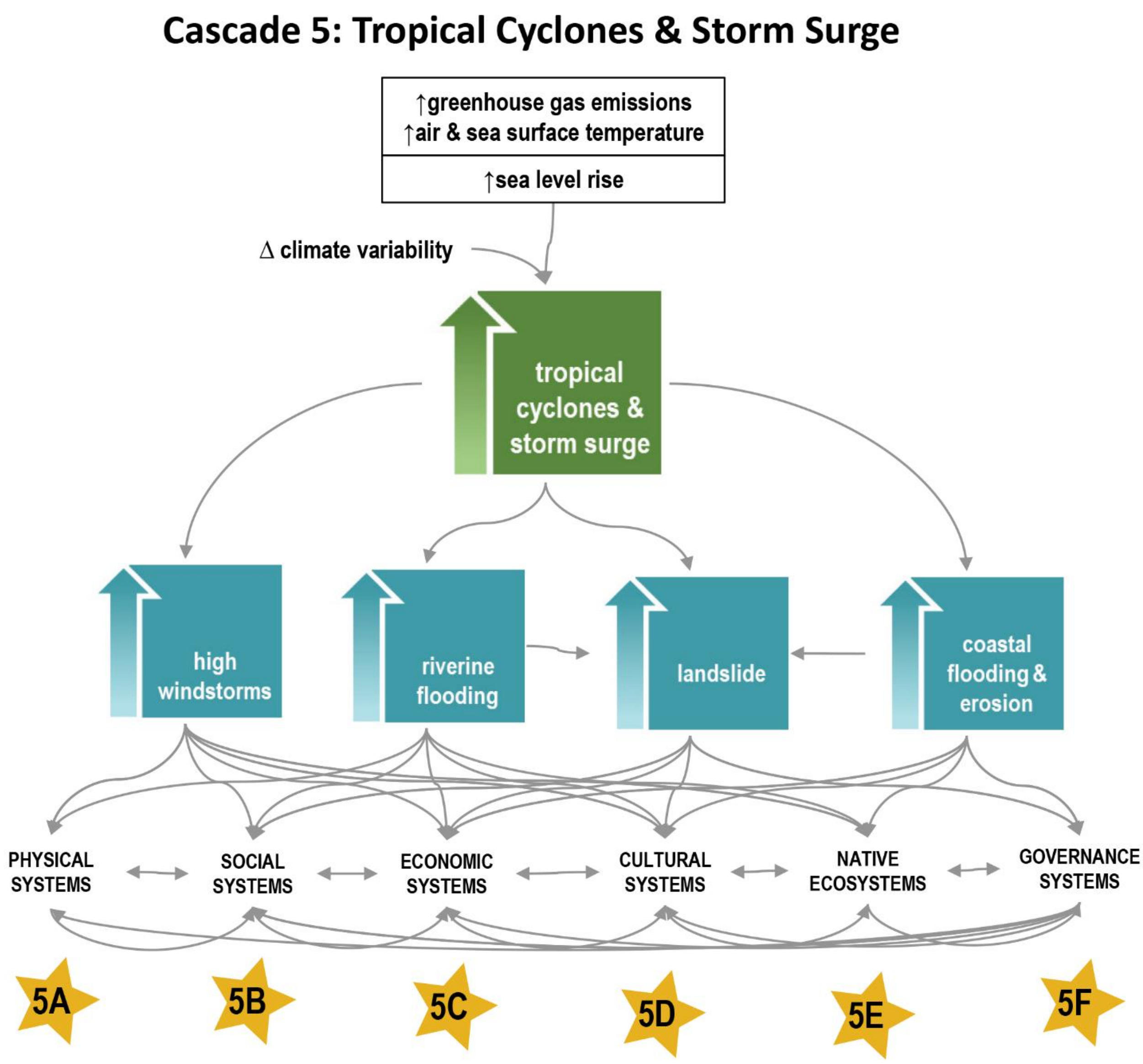


Figure 16. Climate Cascade 5: Tropical cyclones and storm surge

Cascade Narrative

Tropical cyclones are becoming more powerful and possibly more frequent due to climate change.

Higher temperatures are causing more extreme weather events. Sea level rise increases storm surge-related flooding along the coast. Tropical cyclones are weather events generated in tropical latitudes characterized by very heavy rainfall and strong and damaging winds. They can generate storm surge and extremely high waves that can result in devasting coastal flooding regardless of whether or not they directly hit the island. Higher temperatures are causing more extreme weather events. Sea level rise increases storm surge-related flooding along the coast. Once a tropical cyclone reaches maximum sustained winds of 74 miles per hour or higher, it is then classified as a hurricane, typhoon, or tropical cyclone, depending upon where the storm originates in the world.[111] In the North Atlantic, central North Pacific, and eastern North Pacific, the term hurricane is used.

Hawaiʻi lies in the Central Pacific, which, on average, experiences four to five tropical cyclones every year. Almost all tropical cyclones in the Pacific basin form between June 1 and November 30. While the number of tropical cyclones in the central Pacific is highly variable from year to year, more tropical cyclone activity is generally correlated with El Niño events. More El Niño events are expected in response to greenhouse warming.[112]

In 2015, the Central Pacific saw a historic number of tropical cyclones, with 15 named storms, 8 hurricanes, and 5 major hurricanes, making 2015 the most active season at that time since reliable record-keeping began in 1970.[113] The 2018 hurricane season in the eastern North Pacific broke the 2015 record in terms of frequency, intensity, and duration of hurricanes.[114] The 2015 record occurred during a strong El Niño event where increased ocean temperature fueled the hurricane season. The 2018 record was set under a weaker and later El Niño; however, surface ocean temperature was warmer than normal where the hurricanes formed, which helped their development and made them last longer.

As the easternmost island in the state, the island of Hawaiʻi has a slightly higher probability of tropical cyclone landfall. Disaster declarations were issued for six tropical cyclones and severe flood events over the last 20 years, compared to four events over the previous 40 years.[115]

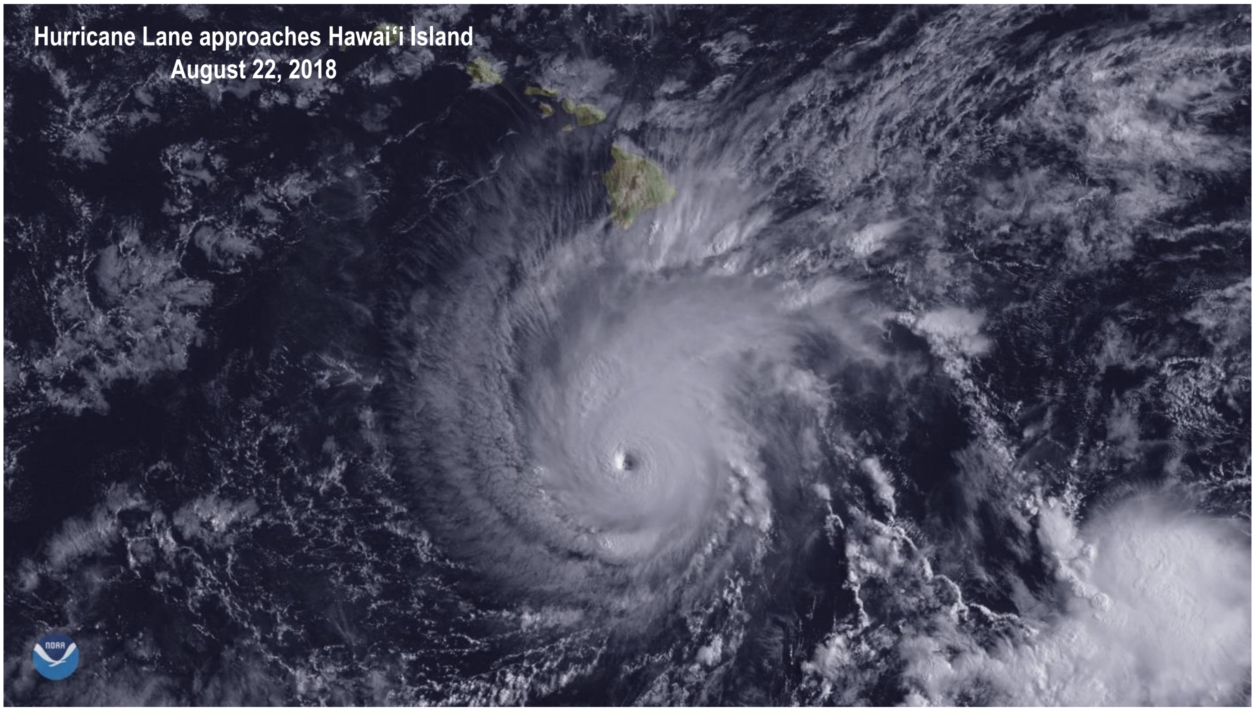
[111] NOAA. What is the difference between a hurricane and a typhoon? https://oceanservice.noaa.gov/facts/cyclone.html#:~:text=Once%20a%20tropical%20cyclone%20reaches,the%20term%20hurricane%20is%20used. Accessed January 2023
[112] Cai, W., Borlace, S., Lengaigne, M., van Rensch, P., Collins, M., Vecchi, G., . . . Jin, F. F. (2014). Increasing frequency of extreme El Nino events due to greenhouse warming. Nature Climate Change, 4(2), 111-116. doi:10.1038/nclimate2100
[113] NOAA National Centers for Environmental Information, Monthly Tropical Cyclones Report for Annual 2015, published online January 2016, retrieved on Apr 1, 2023 from https://www.ncei.noaa.gov/access/monitoring/monthly-report/tropical-cyclones/201513.
[114] Wood, K. M., Klotzbach, P. J., Collins, J. M., & Schreck, C. J. (2019). The Record-Setting 2018 Eastern North Pacific Hurricane Season. Geophysical research letters, 46(16), 10072-10081. doi:10.1029/2019GL083657
[115] County of Hawaiʻi (2020). Multi-Hazard Mitigation Plan. https://www.Hawaiʻicounty.gov/departments/civil-defense/multi-hazard-mitigation-plan-2020

More powerful tropical cyclones compound risks from other hazards.

> *“The compounding nature of the hazards produced during the Hurricane Lane event highlights the need to improve anticipation of complex feedback mechanisms among climate- and weather-related phenomena.”*[116]

Hurricane Lane in 2018 put a spotlight on the risk of compounding hazards associated with tropical cyclones.[117] Hurricane Lane did not make landfall on Hawai‘i Island yet it was the wettest tropical cyclone ever recorded in Hawai‘i. The island of Hawai‘i received an average of 17 inches of rainfall with a maximum of 57 inches over a 4-day period. Extreme and prolonged record-breaking rainfall, in part due to the interaction of tropical cyclones with mountains, caused flooding and landslides that closed roads across the island of Hawai‘i.

Powerful tropical cyclones result in higher winds, greater area impacted by flooding, stronger storm surge, and increased risk of landslides. High winds can contribute to strong surf, which in turn results in coastal erosion. A tropical cyclone does not have to directly hit the Island of Hawai‘i to create storm surge that causes extensive coastal flooding. High winds result in downed trees and power lines that block roads, impede emergency response operations, and together with flooding, create debris that block waterways.



[116] Nugent, A. D., Longman, R. J., Trauernicht, C., Lucas, M. P., Diaz, H. F., & Giambelluca, T. W. (2020). Fire and Rain: The Legacy of Hurricane Lane in Hawai‘i. Bulletin of the American Meteorological Society, 101(6), E954-E967. doi:10.1175/bams-d-19-0104.1
[117] Nugent, A. D. et al., (2020) https://journals.ametsoc.org/view/journals/bams/101/6/BAMS-D-19-0104.1.xml

Risks to critical infrastructure from tropical cyclones and storm surge jeopardize public safety

Many County roads, bridges, parks, and structures are exposed to multiple hazards analyzed in Climate Cascade 5. Power outages caused by high winds and downed debris would close roads and schools and ingress and egress for communities. Temporary structures and other structures unable to resist sustained wind speeds may collapse, posing an immediate threat to those within or around the structure. Long-term effects may include the removal of collapsed buildings and removal of debris from waterways.

It's not if, but when.

A direct hit of a Category 3 or greater hurricane would result in widespread damage to private and public property, including critical facilities and assets.[118] Long-term power outages are expected, which may result in loss of utilities such as potable water and wastewater systems. Loss of transportation facilities such as the harbor and airport would exacerbate the magnitude of the event by taxing already limited resources and further isolating the islands from response and recovery resources. Many facilities and structures would require months or years to return to pre-event functionality. Tourism, supporting industries, and the local tax base would experience long-term impacts. The County's emergency services will be especially stretched if a tropical cyclone occurs together with other hazards on the island.[119]

[118] County of Hawaiʻi (2020) Multi-Hazard Mitigation Plan.
[119] Nugent, A. D., Longman, R. J., Trauernicht, C., Lucas, M. P., Diaz, H. F., & Giambelluca, T. W. (2020). Fire and Rain: The Legacy of Hurricane Lane in Hawaiʻi. Bulletin of the American Meteorological Society, 101(6), E954-E967. doi:10.1175/bams-d-19-0104.1

Cascade Exposure Analysis

The exposure analysis for this climate cascade identifies County assets exposed to multiple hazards. The County can use the information from these analyses to identify areas and assets to prioritize for climate action. For Climate Cascade 5, exposure was assessed from the geographic overlap of six hazards:

1. Hurricane – wind
2. Hurricane - storm surge
3. Riverine flooding
4. Event-based coastal flooding
5. Event-based coastal flooding with 3.2 feet of SLR
6. Landslide susceptibility – med/high

The following are key take-aways from the exposure analysis for this climate cascade:

- Example areas with high climate cascade exposure (exposure to five or six hazards) are located in districts of North Kohala and North Kona (5 and 6 exposures, Figure 17).
- County roads, water and wastewater lines, and parks are most likely to be exposed to the high climate cascade exposure (exposure to five or six hazards; Table 8)
- The low and medium exposure levels (exposure to one to four hazards; Table 8) can still pose a risk to County assets and communities.
- North Kona and South Hilo had the greatest number of County assets exposed to the high climate cascade exposure (exposure to five or six hazards; Table 9).
- Census block groups in South Hilo, Puna, and North Kona have the highest climate cascade risk (exposure to four or five hazards) (See Appendix B).

For more information on the individual hazards see Appendix A. The climate risk analysis methodology and maps are provided in Appendix B. To fully explore the exposure and risk analysis, please visit the County's **Climate Cascade Exposure Tool**.

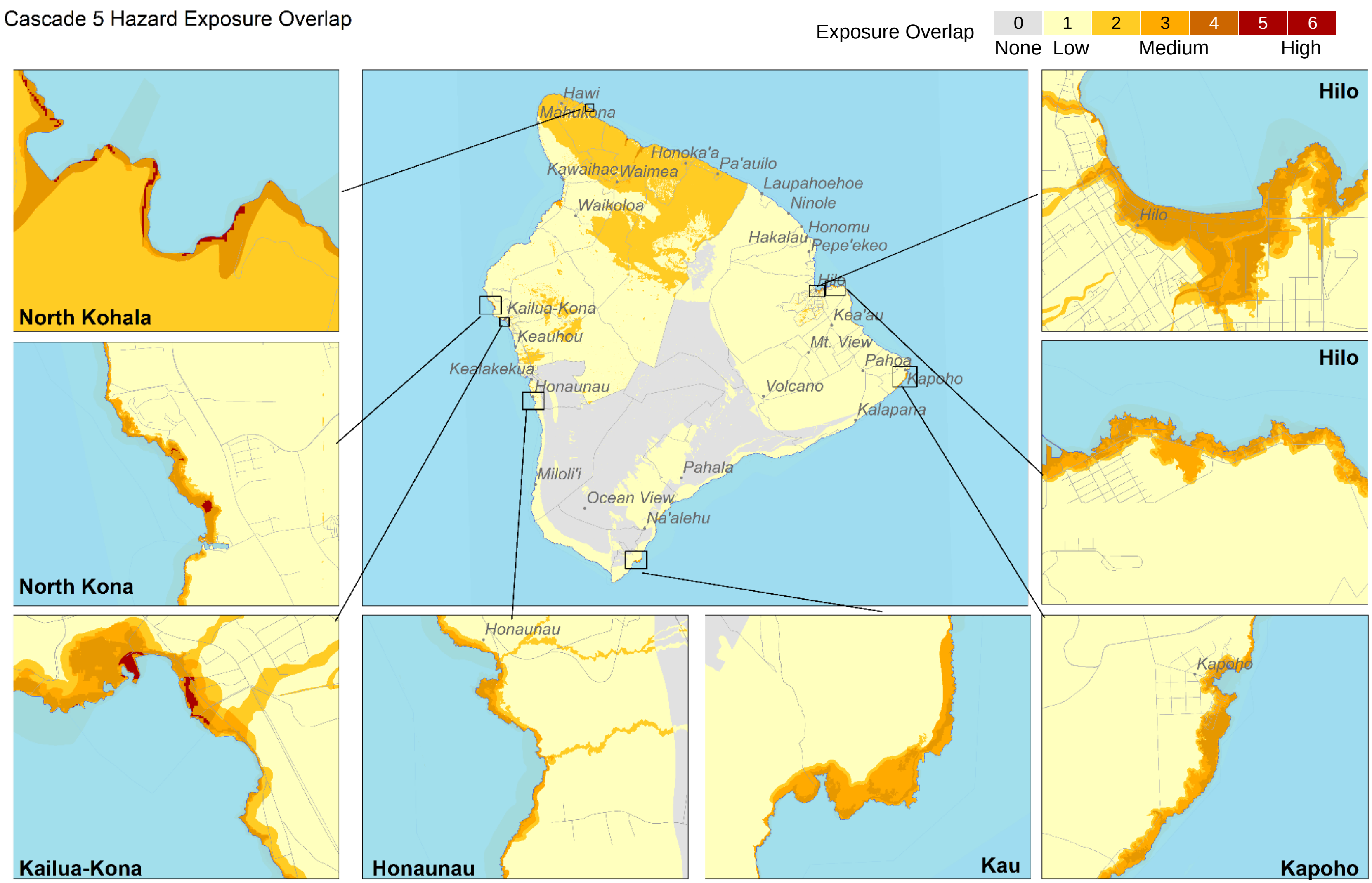


Figure 17. Climate Cascade 5: Areas exposed by number of overlapping hazard layers

Table 8. Climate Cascade 5: Number and types of County assets exposed

CASCADE 5 TROPICAL CYCLONES AND STORM SURGE Climate Hazards			COUNTY ASSETS							
			Structures	Road Segments	Bridges	Water Tanks	Water Line Segments	Onsite Sewage Disposal Systems	Wastewater Line Segments	Parks
Single Hazard Exposure Totals		hurricane - wind	189	4,593	114	311	12,253	16,583	1,860	63
		hurricane - storm surge	58	226	6	0	387	287	344	56
		riverine flooding	33	597	28	6	1,047	1,030	326	48
		event-based coastal flooding	67	212	3	0	326	270	354	55
		event-based coastal flooding with 3.2 feet of SLR	98	421	14	2	802	653	691	63
		landslide susceptibility – med/high	461	8,737	182	265	14,472	39,243	2,322	174
Cascade Hazard Exposure Totals	None	No Exposure	24	1,522	11	33	612	4,531	0	19
	Low	1 Hazard Exposure	400	9,234	117	361	18,674	40,852	3,064	85
	Medium	2 Hazard Exposures	78	2,003	94	104	4,063	7,465	392	41
		3 Hazard Exposures	34	203	10	5	385	444	211	17
		4 Hazard Exposures	62	146	3	0	274	238	286	21
	High	**5 Hazard Exposures**	**0**	**67**	**0**	**0**	**46**	**0**	**52**	**29**
		6 Hazard Exposures	**0**	**3**	**0**	**0**	**1**	**0**	**2**	**2**

Table 9. Climate Cascade 5: Number of County assets by district with high cascade exposure (5 or 6 hazard exposures)

CASCADE 5 TROPICAL CYCLONES AND STORM SURGE County Districts	Assets Exposed to HIGH CASCADE EXPOSURE (5 and 6 Exposures) in Cascade 5							
	Roads	Bridges	Onsite Sewage Disposal Systems	Water Tanks	Water Lines	Wastewater Lines	Parks	Structures
South Hilo	**36**	**0**	**0**	**0**	**23**	**41**	**13**	**0**
Puna	12	0	0	0	0	1	2	0
North Kohala	1	0	0	0	0	0	3	0
South Kohala	0	0	0	0	0	0	1	0
North Kona	**12**	**0**	**0**	**0**	**23**	**13**	**7**	**0**
South Kona	6	0	0	0	0	0	2	0
Kaʻū	3	0	0	0	0	0	3	0

Intervention Points and Actions

Actions are associated with six intervention points (5A – 5F) within the tropical cyclone and storm surge cascade (Figure 16). Actions were developed based on the County asset exposure analysis, capital improvement program projects (proposed and completed), and the 2020 County of Hawaiʻi Multi-Hazard Mitigation Plan update. Entities responsible for implementing these actions are mostly County departments. Lead County departments for this cascade are as follows:

- Planning Department (DP)
- Department of Public Works (DPW)
- Department of Water Supply (DWS)
- Department of Finance, Department of Parks and Recreation (DPR)
- Department of Environmental Management (DEM)
- Office of Housing and Community Development (OHCD)
- Police Department (POL)
- Civil Defense (CD)

5A. Critical Infrastructure

Recommended actions at this intervention point include seven actions under one strategy, as presented in the section and table below.

5A1. Upgrade/harden public safety facilities to remain operational during severe storm events

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
5A1.1	Harden the County's radio communications system through replacement of the following systems: microwave system, direct current (DC) power system, photovoltaic energy systems, and tower refurbishment	CD	$$$	2023			●
5A1.2	Upgrade County public safety complex to eliminate flooding and failure of the entire electrical system and upgrade to be able to withstand high winds from at least a Category 1 hurricane	POL	$$$	2023			●
5A1.3	Install backup power systems for County wastewater systems	DEM	$$				●
	– *Conduct analysis to identify priorities based on criticality*			2024		○	
5A1.4	Increase resilience of existing water producing facilities to incorporate backup power at various sites (Parker #1, Parker #2, Lālāmilo B, Lālāmilo C, Honokaʻa, Makapala, Waiaha, Kahaluʻu, Queen Liliʻuokalani Trust (QLT), Piʻihonua #1, Piʻihonua #3A and ʻŌlaʻa #3)	DWS	$$$	2023			●
5A1.5	Assess resilience of roads to tropical cyclones (Aliʻi Drive, Kona downtown roads, North Kona)	DPW	$$	2026		●	
5A1.6	Assess resilience of wastewater systems to tropical cyclones (Gravity mains in Alii Dr. and Palani Road right-of ways, North Kona)	DEM	$$	2026		●	
5A1.7	Develop/routinely review multiple/alternate tsunami evacuation routes	CD	$				●
	– *Identify priority roads based on Police response plan*			2024	○		

5B. Social Resilience

Recommended actions at this intervention point include four actions under one strategy, as presented in the section and table below.

5B1. Enhance community resilience to withstand and recover from a disaster event

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
5B1.1	Determine feasibility of an earthquake/tropical cyclone retrofit incentive program to encourage	DPW	$$	2024		●	

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
	private property owners to retrofit their properties against the impacts of earthquakes and tropical cyclones						
5B1.2	Incentivize homeowners to retrofit homes to meet current building code standards for wind and flood hazards	DPW, OHCD	$$	2024		●	
5B1.3	Encourage private property owners to purchase flood Insurance and maintain drainage facilities	CD	$	2024		●	
5B1.4	Support resilience hubs in communities with high cascade hazard risk	CD	$$	2024		●	

5C. Economic Resilience

Recommended actions at this intervention point include two actions under one strategy, as presented in the section and table below.

5C1. Support incentives to enhance economic resilience to withstand a disaster event

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
5C1.1	Incentivize private sector to purchase flood insurance and maintain drainage facilities that service private properties.	CD	$$			●	
5C1.2	Conduct training for private sector to develop continuity of operations plans to address operations before, during and after coastal storm events.	CD	$$			●	

5D. Cultural and Historic Resources

Recommended actions at this intervention point include one action under one strategy, as presented in the section and table below.

5D1. Develop cultural resource restoration protocols by ahupua'a

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
5D1.1	Convene a cultural resources recovery group to develop restoration priorities and approach and pre-planning for post-storm assessment	DP	$$			●	
	– *Create Cultural Commission rules allowing for permitted interaction groups to focus on this topic*			2025	○		

5E. Hazard Tree Management

Recommended actions at this intervention point include three actions under one strategy, as presented in the section and table below.

5E1. Develop a hazard tree management program to prioritize removal of trees that pose risks to critical infrastructure from multiple hazards

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
5E1.1	Develop a procedure, evaluation rating system, and GIS database for hazard tree management	DPW	$$	2024		●	
5E1.2	Remove trees that pose safety hazards during high windstorms, tropical cyclones, and extreme rainfall and flooding events	DPW	$$	2026		●	
5E1.3	Revegetate public areas with appropriate native species	DPW	$$	2028		●	

5F. Operational Capacity

Recommended actions at this intervention point include six actions under one strategy, as presented in the section and table below.

5F1. Increase human resource and technological capacity for disaster response

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
5F1.1	Develop an active recruitment, retention and training program for the Volunteer Firefighting Division and CERT team	FD	$$	2024		●	

Action Number	Action	County Lead	Cost ($, $$, $$$)	Start Year	Project Duration		
					<2 yrs	2 – 5 yrs	>5 yrs
5F1.2	Develop/update integrated preparedness plan for training and qualifications for the Incident Command System	CD	$$				●
	– *Create/update qualifications task books for each position*						○
	– *Conduct training to fill ICS positions*						○
5F1.3	Develop and maintain an information management system in ArcGIS for disaster preparedness and response	CD	$$$				
	– *Acquire hardware for data management and processing*			2023	○		
	– *Increase human resource capacity in GIS*			2024		○	
	– *Acquire unmanned aerial system (UAS) and train and license personnel to operate for data collection*			2026		○	
	– *Develop capacity for pre-impact data capture and analysis to create decision-making tools and briefs*			2025		○	
	– *Develop capacity for collection and analysis of critical information requirements and elements of information to create the common operation picture and situation report*			2025		○	
	– *Develop post-impact protocols for collecting and storing data necessary for damage assessments including potential for use of drone technology and IT solutions*			2025		○	
5F1.4	Develop public information and warning policies, methods, and procedures for identified hazards	CD	$$			●	
	Conduct a needs assessment that identifies gaps in coverage in the County's audible warning (sirens) system based on population as well as existing systems that need to be replaced and/or updated			2024	○		
5F1.5	Improve and expand high wind shelter capacity	CD	$$$				●
	– *Conduct best available refuge area (BARA) assessments within existing facilities*			2024		○	
	– *Develop evacuation and sheltering protocol, policies, and procedures*			2023	○		
5F1.6	Develop distribution plan for policies and procedure for logistics, management and resource support during disasters	CD	$$			●	
	– *Develop agreement with State, federal and private partners to implement the plan*			2023	○		

Climate Action Co-Benefits

Climate co-benefits describe the potential for actions to achieve multiple outcomes. In order to realize a co-benefit, each action must be planned, designed, and implemented with a conscious consideration of co-benefits.

Co-Benefit		Action Number
Greenhouse Gas Reduction	• Integrating renewable energy and smart energy systems into County infrastructure will reduce greenhouse gas emissions.	5A1.1 – 5A1.7 5F2.1 – 5F2.6
Social-Cultural Equity	• Upgrading and hardening public infrastructure and safety systems with an all-hazards approach and improving evacuation routes will increase County capacity to remain operational during disaster events.	5A1.1 – 5A1.7
	• Building information capacity for pre-, during, and post-disaster events will save lives and property.	5F1.3 – 5F1.4
	• Supporting resilience hubs enables community-driven actions for greater self-reliance in response to and recovery from disaster events.	5B1.4
	• Creating a cultural resources recovery group with pre-disaster protocols for restoration and preservation of cultural sites will support rapid post-disaster response.	5D1.1
	• Removing tree hazards will improve public safety during severe storm events.	5E1.1 – 5E1.2
	• Increasing equitable resilience to climate hazards will benefit historically marginalized and frontline communities and communities that have been made vulnerable to climate change impacts.	All actions
Environmental Protection	• Removal of tree hazards and revegetation with native species will improve ecosystem health, reduce sediment runoff to coastal ecosystems, and decrease debris from disaster events.	5E1.3
Economic Resilience	• A well-prepared private sector that integrates disaster preparedness planning such as continuity of operations plans, will recover quickly to a disaster event and reduce downtime and economic losses.	5C1.1 – 5C1.2
Plan Integration	• Incorporates policies and actions in General Plan and Hazard Mitigation Plan	5A1.1 – 5A1.4, 5F1.3, 5F1.4

tropical cyclones & storm surge

What can you do to prepare?

1. Protect, preserve, and restore beaches and dunes
2. Elevate homes
3. Retrofit your home to meet current building code standards for wind driven forces
4. Make a list of what you can do to protect your property protection once you receive notice of pending coastal storms
5. Institute warning system and develop evacuation plan

PLAN IMPLEMENTATION

The actions in the Cascades help the County achieve goals 2 and 3 (see below). Plan Implementation outlines how the County will accomplish goal 1, which is essential for goals 2 and 3.

1. Increase County capacity to implement climate action.
2. Reduce the County’s contribution to global greenhouse gas emissions
3. Increase the resilience of County infrastructure, assets, and services to climate change impacts.

Hawai‘i Island is already feeling the effects of climate change. While climate change touches all parts of our lives, it is not the only challenge the island faces. In order to successfully implement the actions in this plan, the County must integrate climate action into existing County processes, community partnerships, funding streams, and efforts. To do this, the County must build up the capacity of departments and community partners to include climate mitigation, risk, and adaptation into their internal and external operations and processes. **This implementation section outlines the capacity and financing improvements required to execute the ICAP and the County’s process for monitoring and evaluation**.

Implementation priority areas reflect the systems-level needs the County will address through climate action implementation. The priority area timelines reflect existing and anticipated capacity (Figure 18).

IMPLEMENTATION PRIORITIES

SHORT-TERM 2023 - 2025

- Establish a centralized coordinating authority to oversee action implementation
- Establish regular stakeholder engagement

MID-TERM 2025 - 2030

- Integrate climate change risk into County planning and decision-making
- Establish a County climate database
- Maintain robust stakeholder engagement

LONG-TERM 2030 - 2040

- Update the General Plan using lessons learned from climate action implementation
- Support place-based management of Hawai‘i Island lands and waters as part of climate action efforts

Figure 18. Plan Implementation Priorities

County Processes

The changes to processes are critical for integrating climate action into the County structures that determine policy and infrastructure. The County can accomplish changes to these processes with minimal contracting and financial investment. Process changes must align with and support existing efforts, which will provide benefits beyond climate action.

Short-Term Implementation Priorities: (2023-2025)

Establish a centralized coordinating authority to oversee and manage County-wide climate actions and mainstream interdepartmental collaboration

The Integrated Climate Action Plan is a joint effort between the Departments of Planning and Research and Development. It is integral to plan success that a central coordinating authority be established to consistently engage with and provide support to other departments and community partners in their climate action implementation. The central coordinating authority must be able to:

1. Collaborate with other departments through existing County processes
2. Provide technical assistance and support to:
    a. Streamline climate-related data gathering and dissemination
    b. Conduct cost-benefit analyses for climate action implementation
    c. Secure federal and State funding

County departments and their operations often fall into silos, limiting the amount of interdepartmental collaboration that happens to address an interdisciplinary threat like climate change. The County must continue interdepartmental collaboration on climate action. This will help the County proactively minimize exposure to climate hazards and avoid long term costs.

Establish regular stakeholder engagement to increase transparency of climate action

Climate Data Dashboard and Portal: Climate change information and data must be accessible to the public. The County will establish a centralized dashboard to show current progress on individual strategies and actions. This dashboard will help serve as a monitoring and implementation tool for each department to report on plan implementation targets and opportunities for collaboration. Community stakeholders could also use the data on this site for their own climate action planning.

Place-Based Knowledge: The County must engage communities for place-based feedback and qualitative data to guide implementation priorities and decision making. Place-based data refers to local knowledge of place. This lived experience holds more information than captured in the Climate Change Exposure Tool or any dataset the County may use. Place-based knowledge must guide decision-making on climate action projects that may require changes in development or behavior within communities. This would include incorporating regional history from lineal descendants, indigenous practices, local values, and place-based protocols in the County's decision-making processes. Historically, the County has not incorporated these decision-making processes in its actions. Establishing partnerships and ongoing relationships with communities in implementing climate action is essential to prioritizing place-based knowledge.

Promote Funding Opportunities: Accurate data is essential to access federal funds for mitigation and adaptation. A centralized repository collecting climate data will streamline the County's efforts to access these funds.

Engagement Strategy: The County must actively engage with communities to increase transparency, contribute resources, and share stories. To build on existing engagement, the County will:

- Attend community days and County-sponsored events to share resources and talk story
- Partner with schools and after-school programs to play the Hawaiʻi Island Climate Action Game and develop other climate change-related materials for keiki
- Produce marketing materials around climate change that can be shared in physical spaces (like grocery stores, parks, and churches) and virtual spaces (like social media)
- Support existing sectors in their climate action efforts
- Develop a communications strategy to inspire hope in climate communications

Mid-Term Implementation Priorities: (2025-2030)

Integrate climate change hazards and risk assessment into County planning and decision-making processes

During the creation of the ICAP, County departments recognized that integrating climate action principles and tools into existing processes would be more effective to 1) ensure success of actions in the near-term by minimizing additional staffing and funding burdens on departments and 2) ensure that climate change becomes an integral piece of how the County approaches its work long-term. Initial processes that have been identified as opportunities for integration include:

1. **Capital Improvement Project Review**
    a. Utilize the Climate Cascade Exposure Tool to identify hazards associated with capital infrastructure and prioritize projects accordingly
    b. Coordinate projects between departments to improve project efficiency
    c. Incorporate greenhouse gas emissions reduction as a piece of capital improvement program prioritization and implementation
    d. Align capital improvement plans with multi-hazard mitigation plan
2. **Purchasing and Procurement**
    a. Prioritize local product purchasing to reduce emissions associated with air and marine transportation and support the local economy
    b. Gather detailed specifications and resources about zero emission technology options
3. **Asset Management**
    a. Procure County-wide software to digitally manage County assets to simplify the process of analyzing greenhouse gas reduction opportunities and climate change hazard exposure while streamlining efficiency of County asset management.
    b. Compile existing asset management data to update the Climate Cascade Exposure Tool.

4. **Budgeting for Climate Action in Operating Budget:**
   a. Include suggestions for including climate action in Operating Budget during annual review.
   b. Assess how climate change will impact County financing and long-term budgetary requirements to better inform priority areas for operation budget. Key actions to assess financial risk include:
      i. Improving infrastructure project review processes
      ii. Developing longer-term financial plans
      iii. Describe specific co-benefits and estimate monetary value of future savings
      iv. Describe how budgeted items support census block groups at highest risk and historically marginalized communities, frontline communities, and communities that have been made vulnerable to climate change impacts.

5. **Grant Management & Applications**
   a. Establish interdepartmental coordinating unit to co-apply for grants and manage grant monies associated with the Inflation Reduction Act, Infrastructure Investment and Jobs Act, and other sources of federal and state funding.

6. **County Auditor**
   a. Request that the County auditor consider climate change risks and implementation progress for designated climate actions on a 5-year basis to inform plan updates.

Coordinate with departments to establish a centralized internal County climate database

Mitigation: In order to measure greenhouse gas emissions, the County currently extrapolates much of its data from State and third-party datasets. By establishing a County-managed framework for data collection on our assets, we can more accurately measure the emissions of individual departments and the private sector. Accurate measurements will allow the County to establish data-based metrics for emissions mitigation and accurately measure our success in implementation. This will also direct the conversion of the County's buildings and fleet to zero emissions.

Adaptation: In this plan, the best available data to identify climate hazards is used. This data was used to create a living **Climate Change Exposure Tool** that can be used for real-time decision-making. However, this data will need updates and improvements in the future. Hazard events, such as a landslide or wildfire, may also change the priority of some of the actions. Coordination between departments and public partners will be essential in keeping this tool up to date.

Maintain robust long-term, regular stakeholder engagement

State and Federal: The limitations of the County's physical and legal jurisdiction will make cross-agency collaboration more imperative across the County, State, and federal levels. As demonstrated in the Climate Action Framework, the County can impact pieces of the climate change cascade, but certain items are outside the County's jurisdiction. The County must grow partnerships with State and federal agencies to tackle the impact of invasive species, cesspools, and rising sea levels. Working with our State and federal partners for larger-scale actions is one aspect of our stakeholder engagement.

Residents, Private Sector, Non-Profits and Other Stakeholders: Climate change will affect everyone, but the impacts are not felt equally among all communities, and not all communities have the same risks and vulnerabilities. Social and cultural equity and locally driven knowledge will serve as a primary determinant in how we implement climate action in a place-appropriate manner and how communities are empowered to take action that works for them. Climate action engagement and implementation will focus on actions that prioritize our historically disadvantaged communities and actions that support community services for those at the greatest risk to climate change. Key factors to be considered in prioritizing social and cultural equity are health, affordability, accessibility, community capacity, locally driven place-based preservation, accountability, and an equitable transition to green jobs.

Long-Term Implementation Priorities: (2030-2040)

Update the General Plan using lessons learned from climate action implementation

The best practices identified as part of the monitoring and evaluation of the ICAP will guide the climate change section of the General Plan. The County will also consider the impact of climate change as part of all sections of the General Plan. The County will use lessons learned from ICAP implementation to determine priority climate action policy areas.

Support place-based management of Hawaiʻi Island lands and waters as part of climate action efforts

By 2030, the County and community aim to have more examples of place-based management and more localized data. The County will support departments and communities in collecting place-based information and developing place-based protocols. Future climate action decisions regarding management of infrastructure, parks, and other County assets should include place-based management with the support of localized climate data. The County should also encourage place-based management beyond County assets through zoning and funding such as community grants.

Climate Action Financing

Identify funding opportunities

The County will increase its capacity to pursue money to finance climate actions. The federal government has recently passed legislation, including the Inflation Reduction Act and the Infrastructure Investment and Jobs Act, that increases the funding available to implement climate action. In order to access these funds, the County must have dedicated staff to write and manage grants specific to climate action. These staff members will need to work closely with the departments that will implement the actions.

Increase the capacity of the Finance Department to manage ICAP implementation

Increasing the capacity of the Finance Department to manage climate action monies is essential. The ICAP identifies the capital improvement program process, operations management, and procurement as opportunities to implement internal climate action. In order to do this, the Finance Department will need additional support to establish protocols that align with existing processes and priorities. The Finance Department will also need additional support to incorporate climate action into the operating budget annually.

Monitoring and Evaluation

Establish regular monitoring, evaluating, and annual reporting on the status of actions and targets

This plan will be monitored on an ongoing basis through the previously mentioned online dashboard and will include a brief project description, project status, and project location when appropriate. Actions and targets will be updated on an annual basis and reported on to make changes where necessary and incorporate best available data. Actions under each intervention point will be tracked as: *No Action, Proposed, In Progress,* or *Completed*.

Annual reports of the ICAP will include:

- A summary of action adjustments that were made
- Assessment of best practices for implementation
- Targets reached
- Evaluation of co-benefits of ICAP actions and documenting lessons

Climate cascade narratives and exposure analysis will be reviewed and updated every 5 years in conjunction with the County's Multi-Hazard Mitigation Plan update. This review will identify any changes in projections for climate change indicators and hazards based on the best available information. Cascading effects that have not been previously considered will be identified based on hazard projections and documented impacts. Climate cascade narratives, risk analysis, and intervention points will be updated based on this review. The annual evaluations will also be used to inform best practices for actions and implementation in the 5-year plan updates.

Conduct 5-Year Plan Evaluation and Update

Annual reports and evaluations will be used to determine major document changes as the ICAP is updated on a 5-year basis. This will allow for more accurate datasets, improved community engagement efforts, and updated hazard and risk analyses. Once we refine implementation strategies based on lessons learned and best practices, we can coordinate our priorities in line with updates to the Hazard Mitigation Plan.

Timeframes and funding for many actions in the ICAP are integrated into other plans and projects, such as capital improvement projects, hazard mitigation projects, maintenance, purchasing policies, and policies developed in the General Plan. The ICAP identifies the actions that will contribute the most to minimizing the impacts of each climate cascade. Other actions, including infrastructure and policies, may become higher priority over time as the impacts of climate change evolve and community priorities change.

CALL TO ACTION

As we face the reality of climate change, it is time for us to take action to protect our beloved island and planet. Hawaiʻi County is committed to the ambitious goals and concrete actions in this plan. We need to take accountability as a County government for our own contribution to climate change and the resilience of our infrastructure and services. We must ensure that our services will be resilient for current and future generations in the years to come.

We have the opportunity to create a thriving, vibrant Hawaiʻi Island. We can choose how we spend our money and our time to care for people and the place where we live. The actions in this plan represent the ways all our departments are committed to create a future that is not only sustainable but also thriving in the face of the worst effects of climate change.

But climate action is not just about what government can do. And it's not just about policies, processes, or infrastructure. Climate action is about what each of us can do to reduce our carbon footprint, preserve our natural resources, and ensure the resilience of our community. Climate action is about doing what we already do in our homes, our schools, our businesses, our churches, and our agriculture in a way that intentionally mitigates and adapts to climate change.

Climate action is also about environmental justice. We cannot allow the burden of climate change to fall disproportionately on marginalized communities. We cannot pursue reduction of greenhouse gas emissions or climate adaptation in a way that increases the cost of living here or disproportionately impacts low- and middle-income communities. Our solutions must be equitable and just. We must ensure that, when we are pursuing each policy or infrastructure change, everyone has a voice in shaping our future.

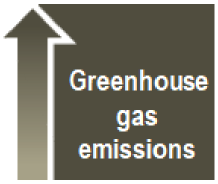
We must recognize the impact of climate change in our community and hold ourselves accountable to act. The impacts include the potential displacement of our island brothers and sisters as climate refugees. We are lucky that our island has high shores and a lot of land. Not all places will be easy or possible to inhabit as the effects of climate change intensify and cascade across all parts of our lives. We must lift up Hawaiʻi for ourselves and also for those who may seek refuge as we all feel the effects of climate change. Let us take action now to ensure a brighter future for our island and planet.

"E lauhoe mai nā waʻa; i ke kā, i ka hoe; i ka hoe, i ke kā; pae aku i ka ʻāina."

- Everybody paddle the canoes together; bail and paddle, paddle and bail, and the shore is reached.

APPENDIX A: A CLOSER LOOK AT THE DATA

Greenhouse Gas Emissions



Greenhouse gas emissions from human activities are warming the atmosphere, ocean and land at an unprecedented rate.[120] Increased fossil fuel combustion, cement production, deforestation, and other human activities[121] have raised the average concentration of carbon dioxide over the last 200 years,[122] higher than any time in at least 800,000 years (Figure A-1).[123,]

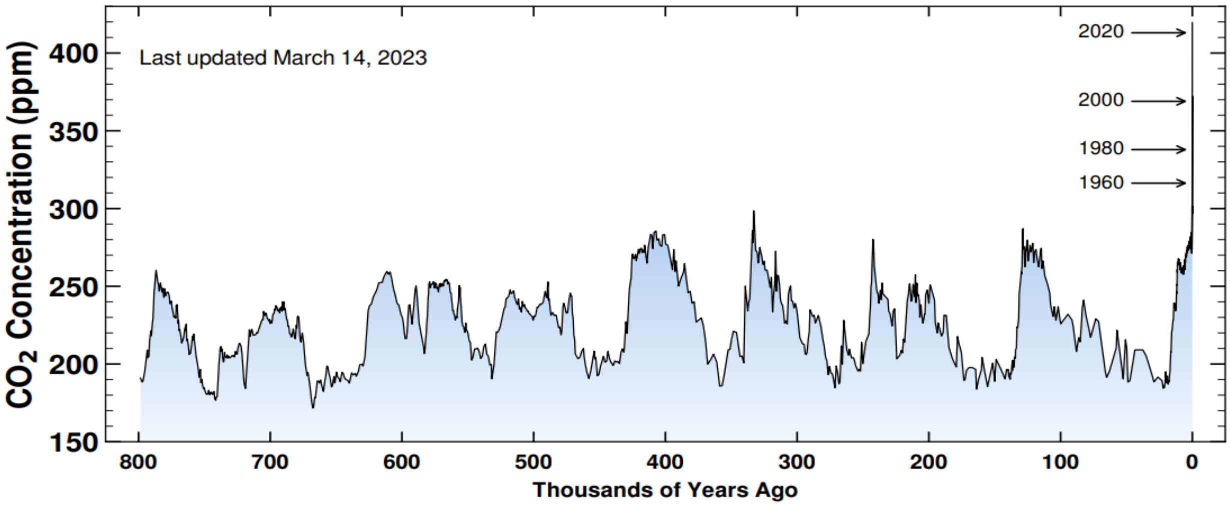


Figure A-1. Global carbon dioxide concentration over the last 800,000 years (ice core data before 1958. Mauna Loa data after 1958)

Greenhouse gases, such as carbon dioxide and methane, trap heat in Earth's atmosphere.[124] Methane emissions represent a smaller portion of global greenhouse gases than carbon dioxide, but methane is more than 25 times as potent at trapping heat in the atmosphere (Figure A-2).[125] Hawaii's energy sector produces about 86 percent of all greenhouse gas emissions in the state (Figure A-3).[126] In Hawaiʻi

[120] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3−32, doi:10.1017/9781009157896.001.

[121] Friedlingstein, P., et al. (2020) Global Carbon Budget 2020, Earth Syst. Sci. Data, 12, 3269–3340, https://doi.org/10.5194/essd-12-3269-2020

[122] Lüthi, D., M. Le Floch, B. Bereiter, T. Blunier, J.-M. Barnola, U. Siegenthaler, D. Raynaud, J. Jouzel, H. Fischer, K. Kawamura, and T.F. Stocker. 2008. High-resolution carbon dioxide concentration record 650,000-800,000 years before present. Nature, Vol. 453, pp. 379-382, 15 May 2008. https://keelingcurve.ucsd.edu/

[123] C. D. Keeling, S. C. Piper, R. B. Bacastow, M. Wahlen, T. P. Whorf, M. Heimann, and H. A. Meijer, Exchanges of atmospheric CO_2 and 13CO2 with the terrestrial biosphere and oceans from 1978 to 2000. I. Global aspects, SIO Reference Series, No. 01-06, Scripps Institution of Oceanography, San Diego, 88 pages, 2001. http://escholarship.org/uc/item/09v319r9

[124] US Environmental Protection Agency (EPA), EPA. 2022. https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

[125] EPA. 2022. https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

[126] Hawaiʻi Greenhouse Gas Program. 2022. https://health.Hawaiʻi.gov/cab/Hawaiʻi-greenhouse-gas-program/

County, transportation and commercial energy production are the largest contributors of greenhouse gas emissions (Figure A-4).

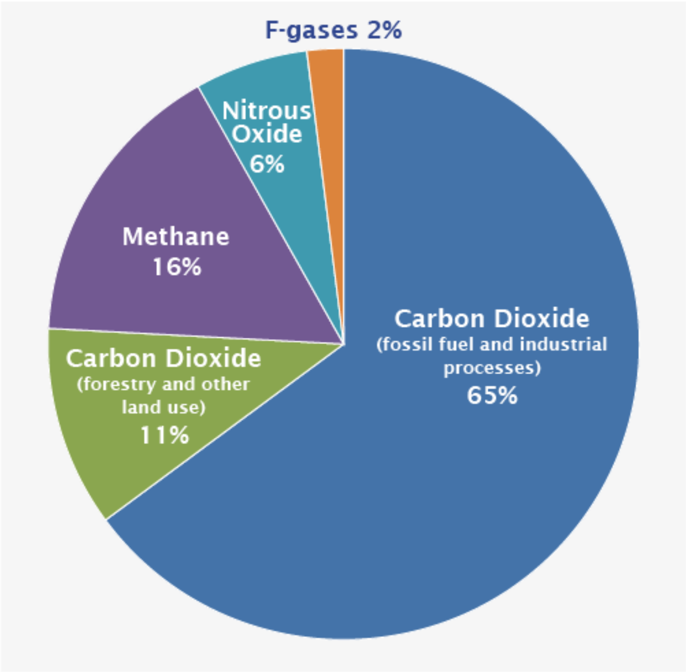
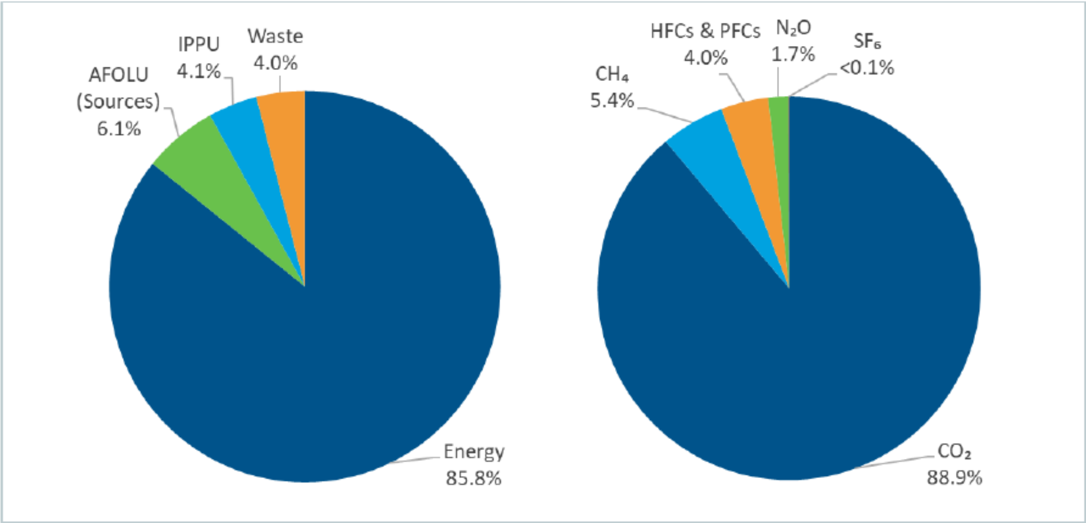


Figure A-2. Global greenhouse gas emission by gas



Note: Percentages represent the percent of total emissions excluding sinks.

Figure A-3. Hawaiʻi State 2017 greenhouse gas emissions by sector and gas

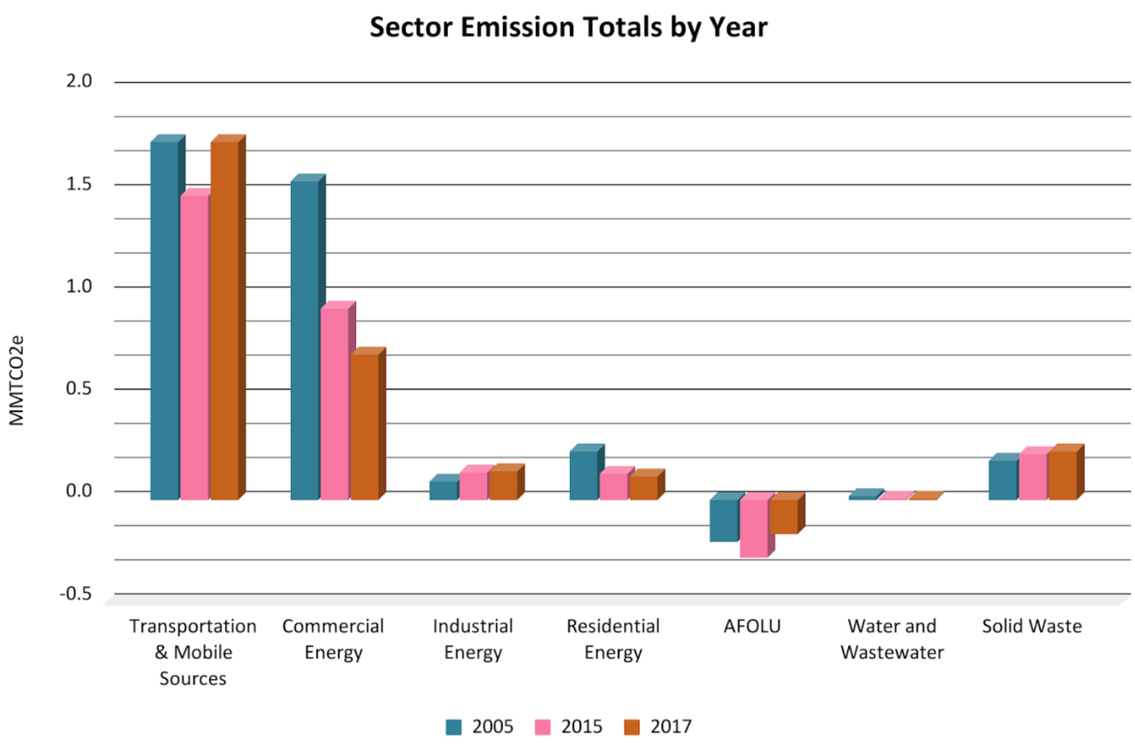
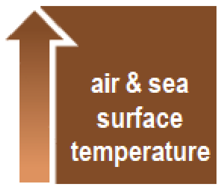


Figure A-4. Hawaiʻi County sector overview of MTCO2e emissions for years 2005, 2015, and 2017

Air and Sea Surface Temperature



The planet continues to warm (Figure A-5).[127] The year 2022 ranked as the sixth-warmest year on record since 1880.[128] Excess heat trapped in the Earth system due to human-caused global warming has been absorbed by the oceans (Figure A-6),[129] with the top 2,300 feet of ocean showing warming of more than 0.4 ºF since 1969. Increasing ocean heat content is contributing to sea level rise, ocean heat waves, coral bleaching, and melting of ocean-terminating glaciers and ice sheets around Greenland and Antarctica.

Climate models are unequivocal that the tropical Pacific Ocean will continue to warm this century.130 The surface of both the Earth and the tropical Pacific specifically have already warmed by more than 0.5°C. Air temperatures have risen by about 1.1ºC since 1950 in Hawaiʻi (Figure A-7).131 A sharp increase in warming, indicated by the observed number of hot days, has occurred over the last decade. Temperatures are projected to increase by the end-of-century, especially along the coastline (Figure A-8).[132]

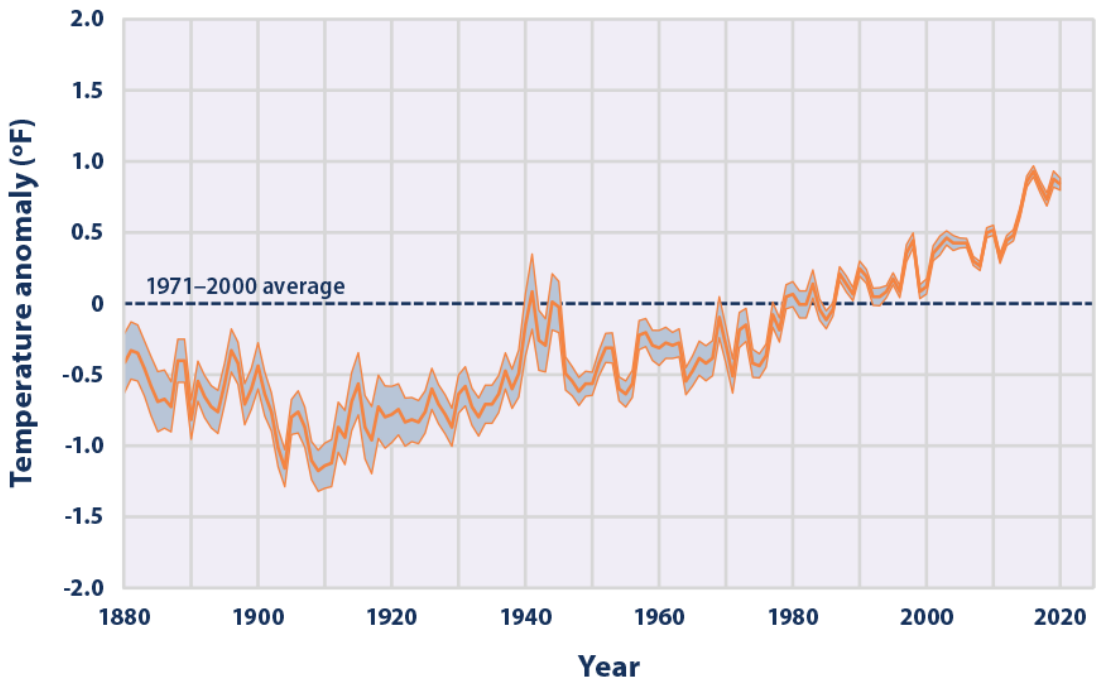


Figure A-5. Global temperature compared to average (1971 – 2000)

[127] US EPA. 2022. Climate Change Indicators. https://www.epa.gov/climate-indicators/climate-change-indicators-sea-surface-temperature
[128] National Oceanic and Atmospheric Administration National Centers for Environmental Information. https://www.noaa.gov/news/2022-was-worlds-6th-warmest-year-on-record
[129] Dahlman, L. and Lindsey, R. 2022. Climate Change: Ocean Heat Content. https://www.climate.gov/news-features/understanding-climate/climate-change-ocean-heat-content#:~:text=More%20than%2090%20percent%20of,NOAA%20Climate.gov%20graph
[130] Dhage, L., & Widlansky, M. J. (2022). Assessment of 21st century changing sea surface temperature, rainfall, and sea surface height patterns in the tropical Pacific Islands using CMIP6 greenhouse warming projections. *Earth's Future*, *10*, e2021EF002524. https://doi.org/10.1029/2021EF002524
[131] Stevens, L.E., R. Frankson, K.E. Kunkel, P.-S. Chu, and W. Sweet, 2022: Hawaiʻi State Climate Summary 2022. NOAA Technical Report NESDIS 150-HI. NOAA/NESDIS, Silver Spring, MD, 5 pp. https://statesummaries.ncics.org/chapter/hi/
[132] Hawaiʻi Department of Transportation. 2021. Hawaiʻi Highways, Climate Adaptation Action Plan, Exposure Assessments, https://hidot.Hawaiʻi.gov/wp-content/uploads/2021/07/HDOT-Climate-Resilience-Action-Plan-Exposure-Assessments-April-2021.pdf

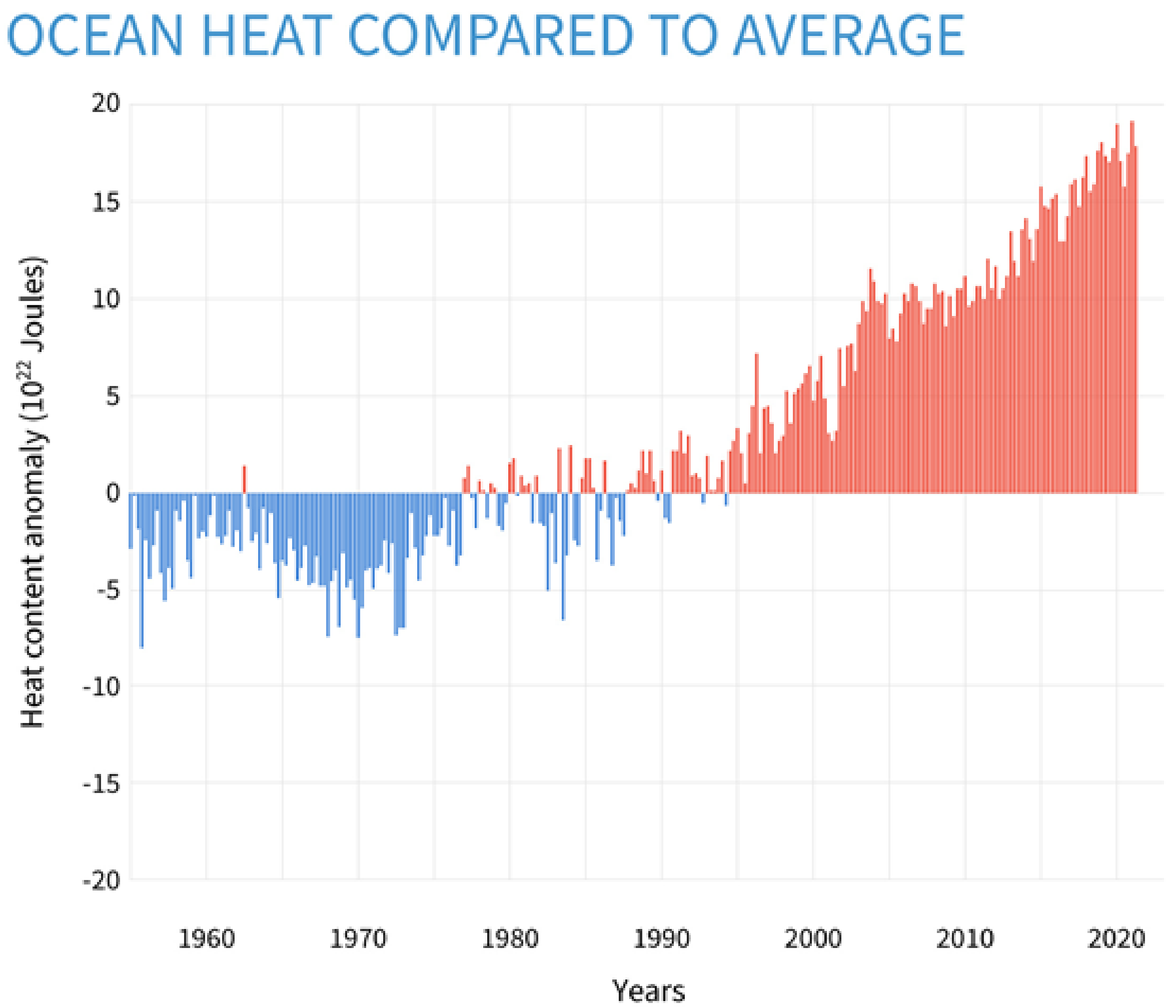
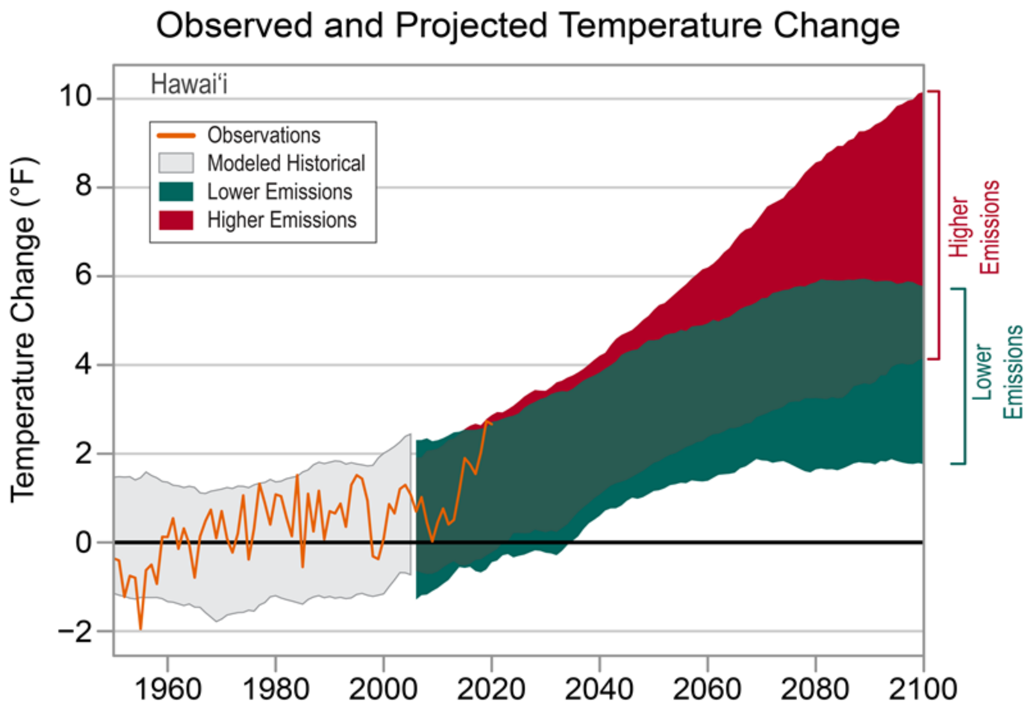


Figure A-6, Increase in global ocean heat content compared to average (1971 – 2021)



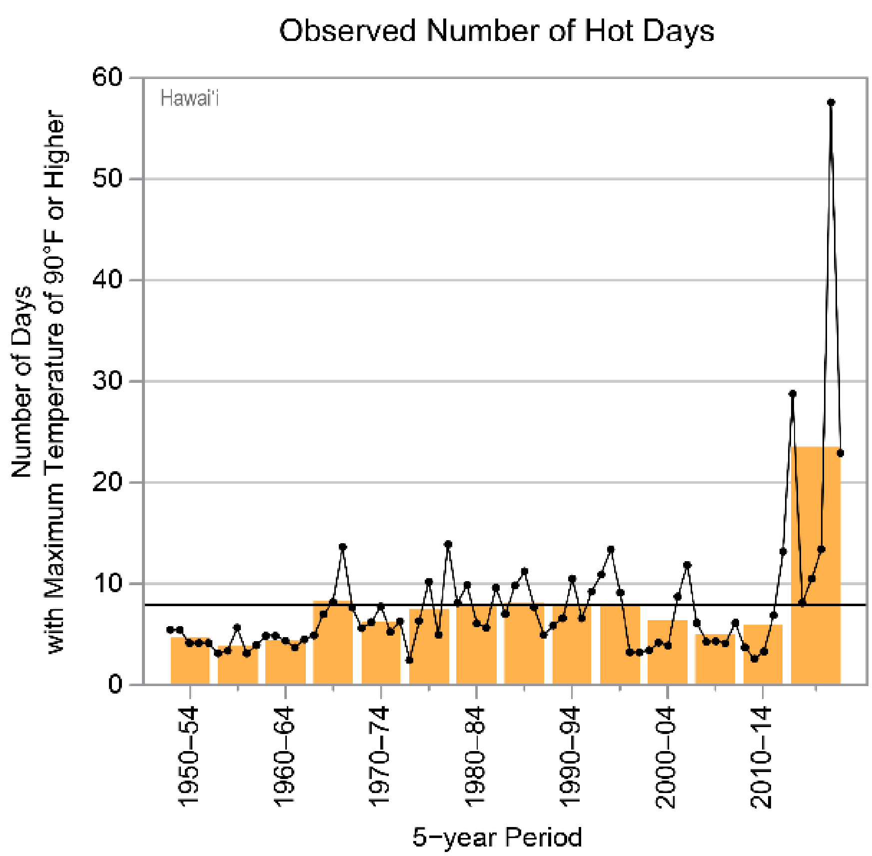


Figure A-7. Observed and projected temperature change and observed number of hot days for Hawaiʻi Island

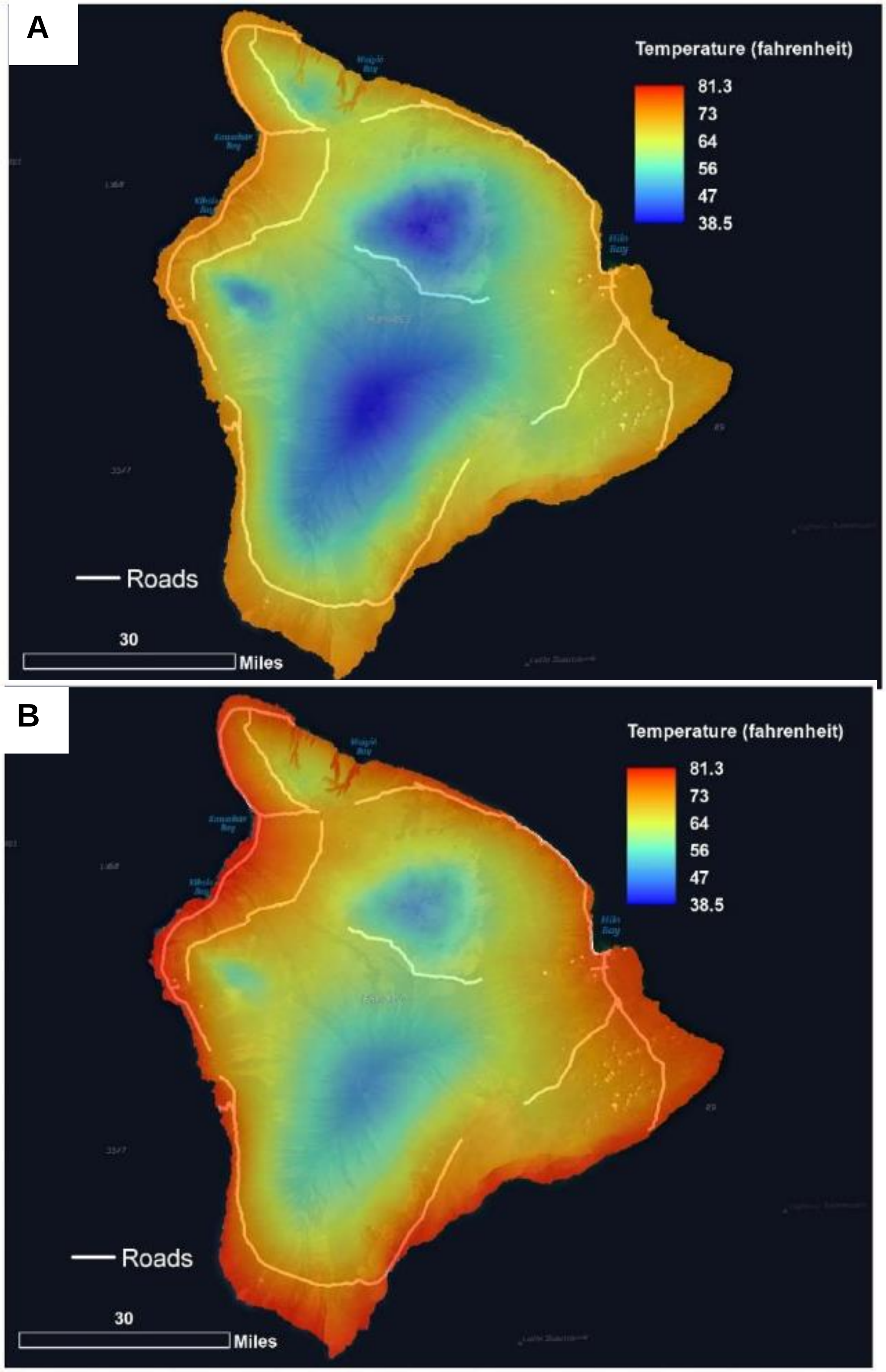


Figure A-8. Historical annual mean temperature values (A) and future annual mean temperature values at the end of the century for Hawaiʻi Island (B)

Coral bleaching has increased in frequency and severity since 1996 across the Hawaiian Archipelago.[133] The last major bleaching event occurred in 2014–2015; however, increased ocean temperatures in 2019 set off another mass bleaching event in Hawaiʻi. Key contributors to coral bleaching in Hawaiʻi are environmental factors, such as heat stress, depth, and surface light, and human impacts, including sewage effluent and urban runoff. Annual coral bleaching events, resulting from periods of increased sea surface temperature, are expected to occur on some reefs around Hawaiʻi Island by 2030. Under projected warming of approximately 0.3°C per decade, coral reefs will experience annual bleaching beginning in about 2040 throughout the Hawaiian Islands (Figure A-9).[134]

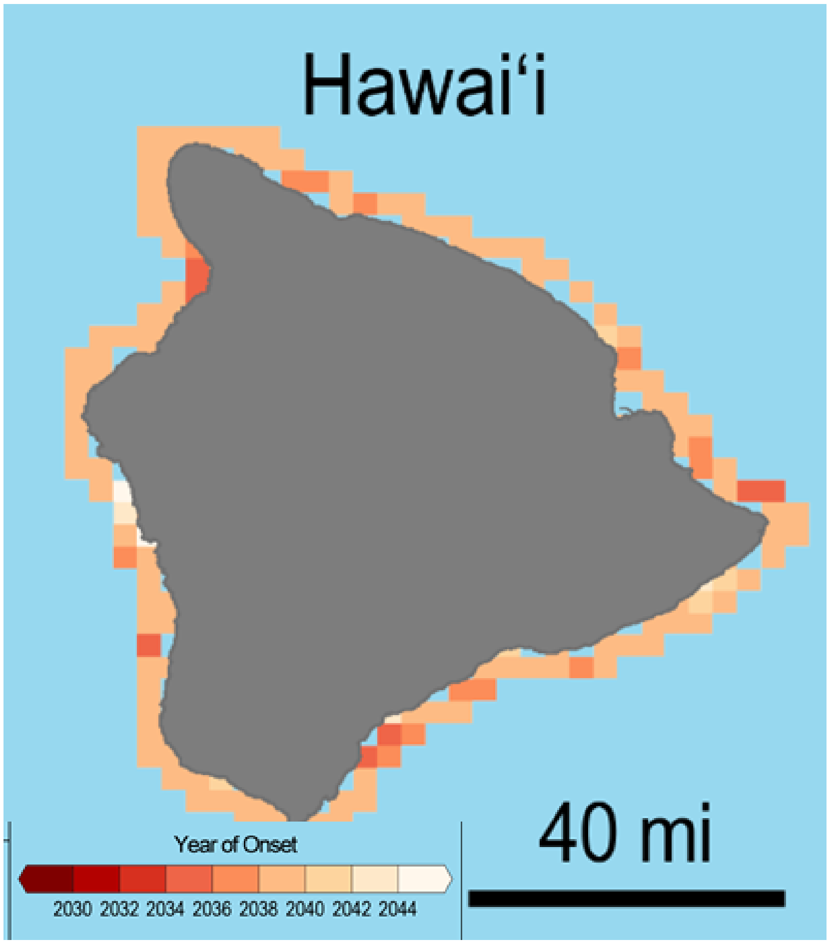
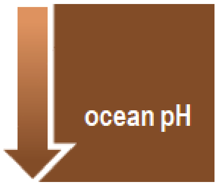


Figure A-9. Projected onset of annual severe coral reef bleaching around Hawaiʻi Island under a high greenhouse gas emissions scenario (RCP 8.5)

[133] NOAA Fisheries, Pacific Fisheries Science Center, 2022. A Cautionary Tale: The 2019 Coral Bleaching Event in Hawaiʻi, https://www.fisheries.noaa.gov/feature-story/cautionary-tale-2019-coral-bleaching-event-Hawaiʻi
[134] Keener, V., D. Helweg, S. Asam, S. Balwani, M. Burkett, C. Fletcher, T. Giambelluca, Z. Grecni, M. Nobrega-Olivera, J. Polovina, and G. Tribble, 2018: Hawaiʻi and U.S.-Affiliated Pacific Islands. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 1242–1308. doi: 10.7930/NCA4.2018.CH27 On the Web: https://nca2018.globalchange.gov/chapter/Hawaiʻi-pacific

Ocean Acidification



Ocean acidification is the progressive increase of acidity in the ocean. The ocean is becoming more acidic (Figure A-10).[135] The increase in carbon dioxide in the atmosphere from anthropogenic sources has led to an increase of carbon dioxide absorbed in the ocean. Dissolving carbon dioxide in the ocean results in a chemical reaction releasing hydrogen ions (H+). An increase in hydrogen ions is analogous to a decrease in the pH scale and an increase in acidity.[136] Since the beginning of the Industrial Revolution, the acidity of surface ocean waters has increased by about 30 percent. The amount of carbon dioxide absorbed by the upper layer of the oceans is increasing by about 2 billion tons per year.[137]

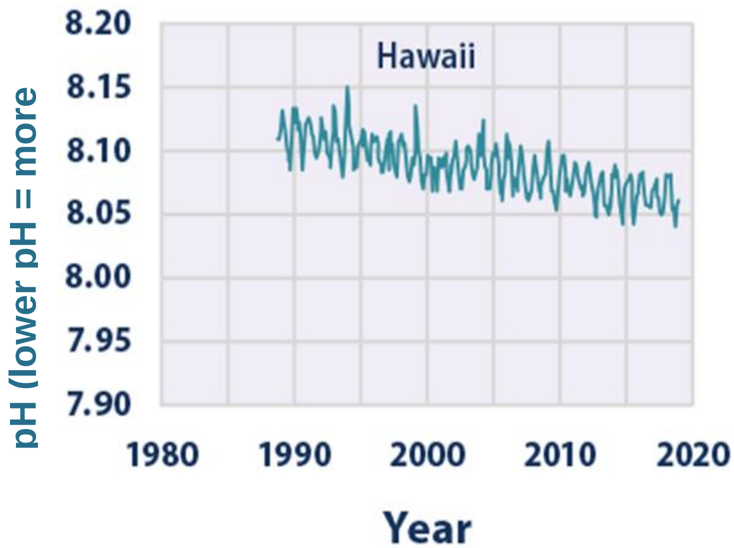


Figure A-10. Decrease in ocean pH (more acidic) in Hawaiʻi

The global crisis for coral reefs caused by increasing sea surface temperatures, pollution, over-fishing, habitat destruction and invasive species is exacerbated by ocean acidification.[138] A global study reported that the majority of coral reefs will be unable to maintain positive net carbonate production by 2100 under high greenhouse gas emissions scenarios RCP (representative concentration pathways) 4.5 and RCP 8.5.[139] Hawaiʻi is impacted by global ocean acidification and more localized coastal acidification resulting from localized land-based pollution that can exacerbate the coastal water chemistry changes.[140]

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135 EPA. 2022. Climate Change Indicators: Ocean Acidity. https://www.epa.gov/climate-indicators/climate-change-indicators-ocean-acidity; University of Hawaiʻi. 2021. Hawaiʻi Ocean Time-series (HOT). Accessed February 2021. https://hahana.soest.Hawaiʻi.edu/hot
136 PacIOOS. 2022. Ocean Acidification. https://www.pacioos.Hawaiʻi.edu/projects/acid/#about
137 Hawaiʻi County Multi-Hazard Mitigation Plan
138 Allemand, D., & Osborn, D. (2019). Ocean acidification impacts on coral reefs: From sciences to solutions. Regional Studies in Marine Science, 28, 100558. doi:https://doi.org/10.1016/j.rsma.2019.100558
139 Cornwall, C. E., Comeau, S., Kornder, N. A., Perry, C. T., van Hooidonk, R., DeCarlo, T. M., . . . Lowe, R. J. (2021). Global declines in coral reef calcium carbonate production under ocean acidification and warming. Proceedings of the National Academy of Sciences, 118(21), e2015265118. doi:doi:10.1073/pnas.2015265118
140 Department of Land and Natural Resources, Division of Aquatic Resources. 2020. State of Hawaiʻi Ocean Acidification Action Plan 2021 – 2031

Sea Level Rise

sea level rise

Sea level is rising globally and the rate of sea level rise is accelerating due largely unabated human activities.[141] Global mean sea level has risen faster since 1900 than over any preceding century in at least the last 3,000 years.[142] Over the last three decades, observed global sea level is rising at a rate of about 3.6 mm per year and accelerating (Figure A-11).[143] Global mean sea level is driven primarily by thermal expansion of ocean waters and the melting of glaciers and land-based ice sheets due to global warming.[144]

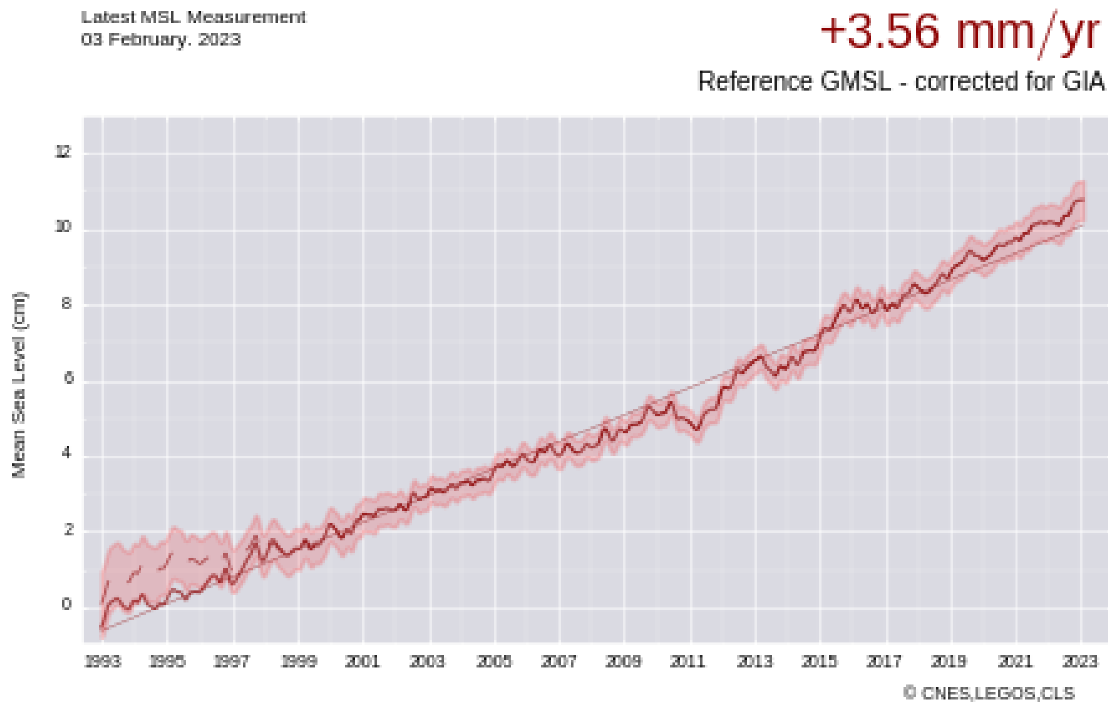

Figure A-11. Observed global sea level rise measured by satellite altimetry from January 1993 to December 2021

The Sea Level Rise and Coastal Flood Hazard Scenarios and Tools Interagency Task Force provides global mean and local relative sea level rise scenarios through 2150.[145] Five scenarios are defined based on target values for global mean sea level rise in 2100: Low (0.3 m), Intermediate Low (0.5 m),

[141] Dangendorf, S., Hay, C., Calafat, F.M. et al. Persistent acceleration in global sea-level rise since the 1960s. Nat. Clim. Chang. 9, 705–710 (2019). https://doi.org/10.1038/s41558-019-0531-8

[142] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3−32, doi:10.1017/9781009157896.001.

[143] Guérou, A., Meyssignac, B., Prandi, P., Ablain, M., Ribes, A., & Bignalet-Cazalet, F. (2022). Current observed global mean sea level rise and acceleration estimated from satellite altimetry and the associated uncertainty. EGUsphere, 2022, 1-43. doi:10.5194/egusphere-2022-330

[144] Frederikse, T., Landerer, F., Caron, L., Adhikari, S., Parkes, D., Humphrey, V. W., . . . Wu, Y.-H. (2020). The causes of sea-level rise since 1900. Nature, 584(7821), 393-397. doi:10.1038/s41586-020-2591-3

[145] Sea Level Rise and Coastal Flood Hazard Scenarios and Tools Interagency Task Force; https://sealevel.nasa.gov/task-force-scenario-tool

Intermediate (1 m), Intermediate High (1.5 m), and High (2 m). These values are regionalized to provide projections for individual tide gauges. The City and County of Honolulu Climate Commission recommended the use of the Intermediate scenario as the minimum scenario for all planning and design and the Intermediate High scenario for all planning and design of public infrastructure projects and projects with low tolerance to risk.[146]

Regionalized sea level rise planning scenarios for the Hilo tide gauge are shown in (Figure A-12).[147] The Intermediate High sea level rise projection for Hawaiʻi Island, based on the Hilo Tide gauge, is almost 4 feet by 2080 and over 6 feet by 2100 (Table A-1).

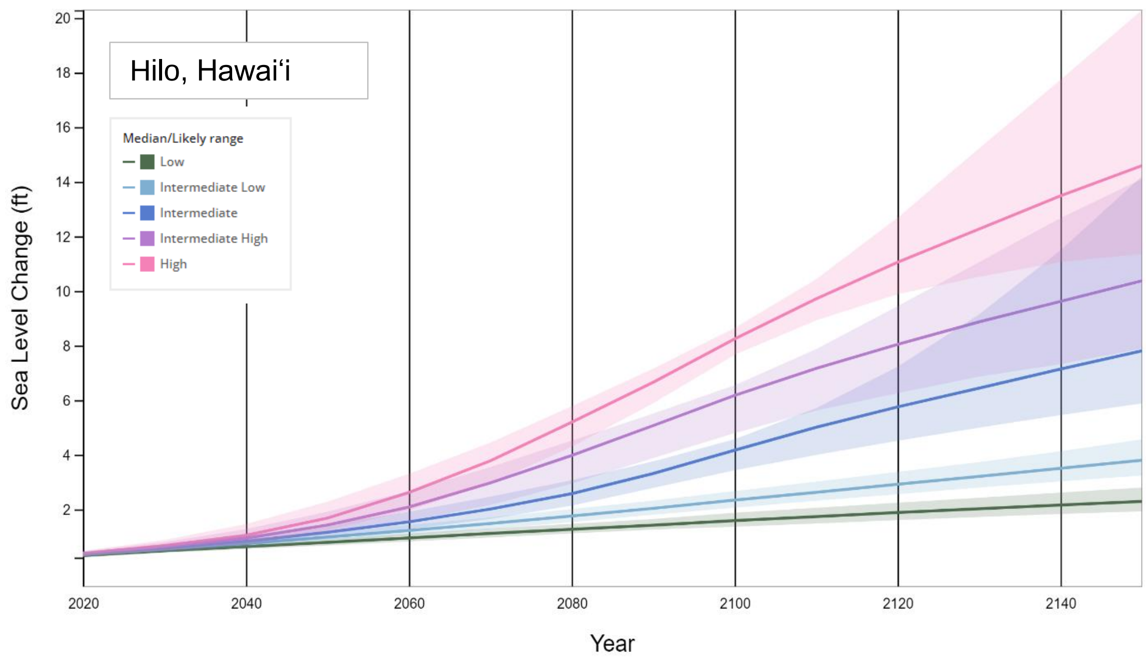

Figure A-12. Sea level change time series for the 5 sea level scenarios: low, intermediate-low, intermediate, intermediate-high and high, Hilo tide gauge

Table A-1. Planning scenarios based on relative sea level rise scenarios for the Hilo Tide Gauge

Year	Relative Sea Level Rise Scenarios (feet)	
	Intermediate	Intermediate High
2040	0.8	0.9
2060	1.5	2.1
2080	2.6	4.0
2100	4.2	6.2

146 City and County of Honolulu Climate Change Commission, Sea Level Rise II – Guidance Document, updated July 29, 2022.
147 Sweet, W. V., B.D. Hamlington, R.E. Kopp, C.P. Weaver, P.L. Barnard, D. Bekaert, W. Brooks, M. Craghan, G. Dusek, T. Frederikse, G. Garner, A.S. Genz, J.P. Krasting, E. Larour, D. Marcy, J.J. Marra, J. Obeysekera, M. Osler, M. Pendleton, D. Roman, L. Schmied, W. Veatch, K.D. White, and C. Zuzak,. (2022). Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines. Retrieved from Silver Spring, MD: https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nos-techrpt01-global-regional-SLR-scenarios-US.pdf

Sea level rise increases the risks communities face from coastal flooding and erosion, which are caused by high waves[148], storm surge, high tides, rising groundwater, and extreme rainfall events. Saltwater intrusion from sea level rise into shallow coastal aquifers impacts coastal ecosystems,[149] shallow coastal groundwater wells, and underground infrastructure such as water and wastewater infrastructure, which may become corroded and leak contamination into freshwater and nearshore waters.[150]

Data Used in Climate Risk Analysis. The geospatial data used to analyze climate risk from coastal flooding with sea level rise are described in Appendix A, section Coastal Flooding and Erosion. These data were developed for the Hawaiʻi Sea Level Rise Vulnerability and Adaptation Report in 2017 when the worst-case projection for global sea level rise was 3.2 feet by 2100.[151] New sea level rise and coastal erosion modeling being conducted by the University of Hawaiʻi at Mānoa will integrate the latest planning scenarios.

[148] Vitousek, Sean et al. "Doubling of Coastal Flooding Frequency Within Decades Due to Sea-Level Rise." Scientific reports 7.1 (2017): 1399–9. Web.
[149] Befus, K. M. et al. "Increasing Threat of Coastal Groundwater Hazards from Sea-Level Rise in California." Nature climate change 10.10 (2020): 946–952. Web.
[150] Habel, Shellie et al. "Sea-Level Rise Induced Multi-Mechanism Flooding and Contribution to Urban Infrastructure Failure." Scientific reports 10.1 (2020): 3796–3796. Web.
[151] Hawaiʻi Climate Change Mitigation and Adaptation Commission 2017. Hawaiʻi Sea Level Rise Vulnerability and Adaptation Report. Prepared by Tetra Tech, Inc. and the State of Hawaiʻi Department of Land and Natural Resources, Office of Conservation and Coastal Lands, under the State of Hawaiʻi Department of Land and Natural Resources Contract No: 64064. https://climateadaptation.Hawaiʻi.gov/wp-content/uploads/2017/12/SLR-Report_Dec2017.pdf

Drought and Extreme Rainfall

Climate change together with climate variability contribute to long-term trends and highly variable conditions in drought and extreme rainfall events. Rainfall trends from 1920 to 2012 show a decrease in annual rainfall for all Hawaiian Islands, with the sharpest decline in the western part of Hawaiʻi Island.[152] However, extreme rainfall events on Hawaiʻi Island have become more frequent.[153] Extreme rainfall refers to the intensity of a rainfall event that delivers a high quantity of rainfall over a period of time. A storm event with daily precipitation of about 12 inches had a 20-year return period in 1960 but a 3- to 5-year return period in 2009.[154]

Rainfall patterns in Hawaiʻi are influenced by natural climate variability from the El Niño-Southern Oscillation (ENSO), the Pacific Decadal Oscillation, and the Pacific North American teleconnection pattern.[155] Extreme rainfall events increase in La Niña years and decrease in El Niño years.[156]

Droughts originate from a deficiency in rainfall, which can last months or years. Drought is a regular and natural component of the climate in Hawaiʻi with severe effects across many sectors statewide. The two worst droughts for the State of Hawaiʻi in the past century were 2007–2014 and 1998–2002, resulting in over $80 million in drought relief in the agriculture sector. On Hawaiʻi Island the 2007–2014 drought was worst drought of the past century. Droughts have become detectably more severe and longer lasting. Most droughts are associated with El Niño events.[157]

Wet-season precipitation is expected to decrease. (Figure A-13).[158] Dry areas will trend toward drier conditions in the future during both wet and dry seasons. Wet areas will trend toward small increases during the wet season. The exception is along and above the eastern slopes of mountains on all islands, where the trade winds dominate, such as the northeastern side of the Island of Hawaiʻi.

[152] Frazier, A. G., & Giambelluca, T. W. (2017). Spatial trend analysis of Hawaiʻian rainfall from 1920 to 2012. International journal of climatology, 37(5), 2522-2531. doi:10.1002/joc.4862

[153] Chen, Y. R., & Chu, P. S. (2014). Trends in precipitation extremes and return levels in the Hawaiʻian Islands under a changing climate. International Journal of Climatology, 34(15), 3913-3925. doi:10.1002/joc.3950

[154] Chen, Y. R., & Chu, P. S. (2014).doi:10.1002/joc.3950

[155] Frazier, A. G., Elison Timm, O., Giambelluca, T. W., & Diaz, H. F.(2017). The influence of ENSO, PDO [Pacific Decadal Oscillation] and PNA [Pacific North American teleconnection pattern] on secular rainfall variations in Hawaiʻi. Climate dynamics, 51(5-6), 2127-2140. doi:10.1007/s00382-017-4003-4

[156] Chen, Y. R., & Chu, P. S. (2014) doi:10.1002/joc.3950

[157] Frazier, A.G.; Giardina, C.P.; Giambelluca, T.W.; Brewington, L.; Chen, Y.-L.; Chu, P.-S.; Berio Fortini, L.; Hall, D.; Helweg, D.A.; Keener, V.W.; et al. A Century of Drought in Hawaiʻi: Geospatial Analysis and Synthesis across Hydrological, Ecological, and Socioeconomic Scales. Sustainability (2022), 14, 12023. https://doi.org/10.3390/su141912023

[158] Hawaiʻi Department of Transportation (2021). Hawaiʻi Highways, Climate Adaptation Action Plan, Exposure Assessments, https://hidot.Hawaiʻi.gov/wp-content/uploads/2021/07/HDOT-Climate-Resilience-Action-Plan-Exposure-Assessments-April-2021.pdf

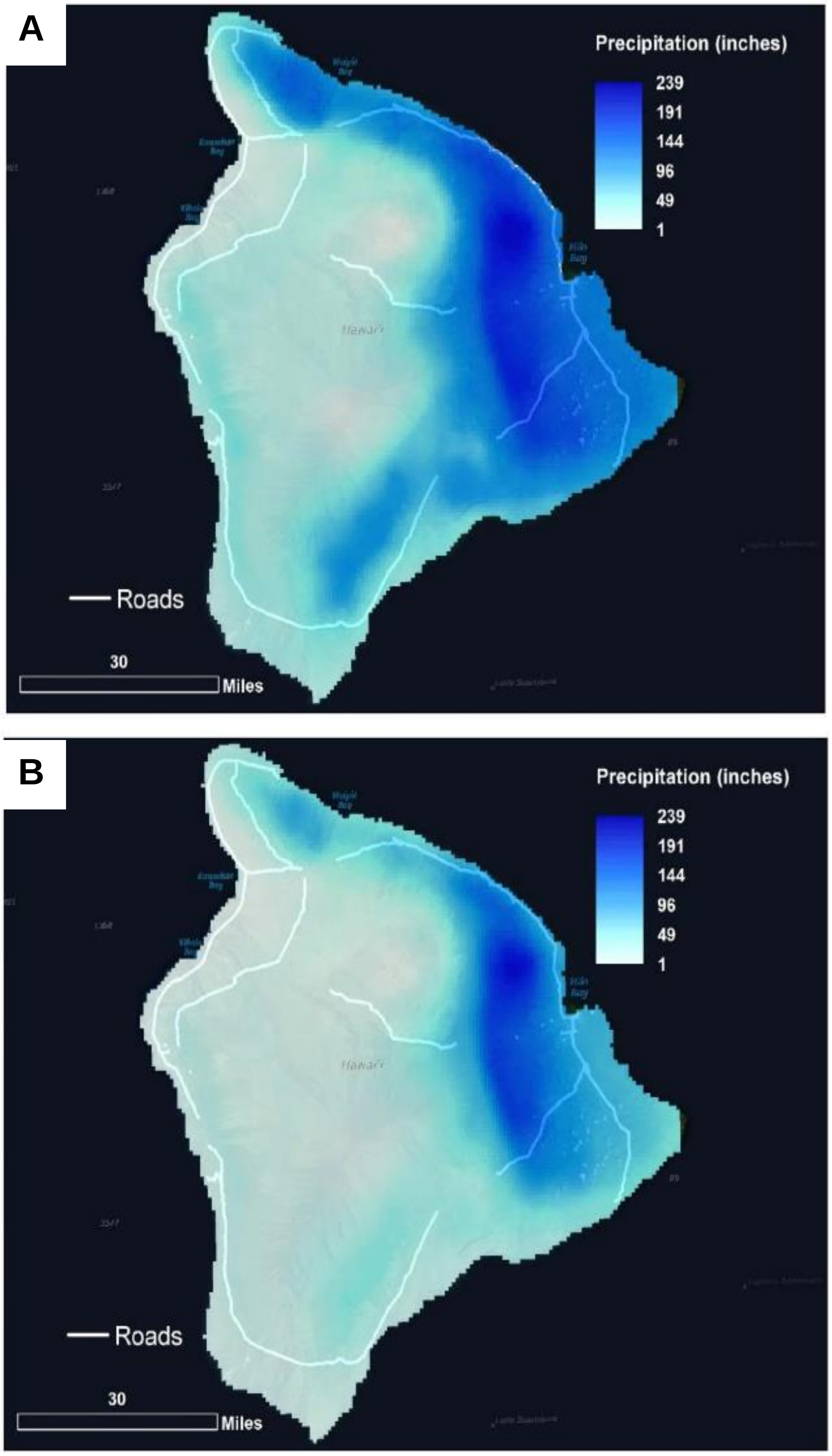

Figure A-13. (A) Historical precipitation values (seasonal data averaged across years 1978-2007) and (B) Future precipitation values at the end of the century during the wet season

Data Used in Climate Risk Analysis: The drought climate hazard was based on a 93-year analysis of changes in annual rainfall (percent per decade) from 1920 to 2012 for the Island of Hawai‘i (Figure A-14).[159] The sharpest downward trends, indicated with black hatching, are found on the western part of Hawai‘i Island. Future climate risk analysis should extend the rainfall trend through the most current decade.

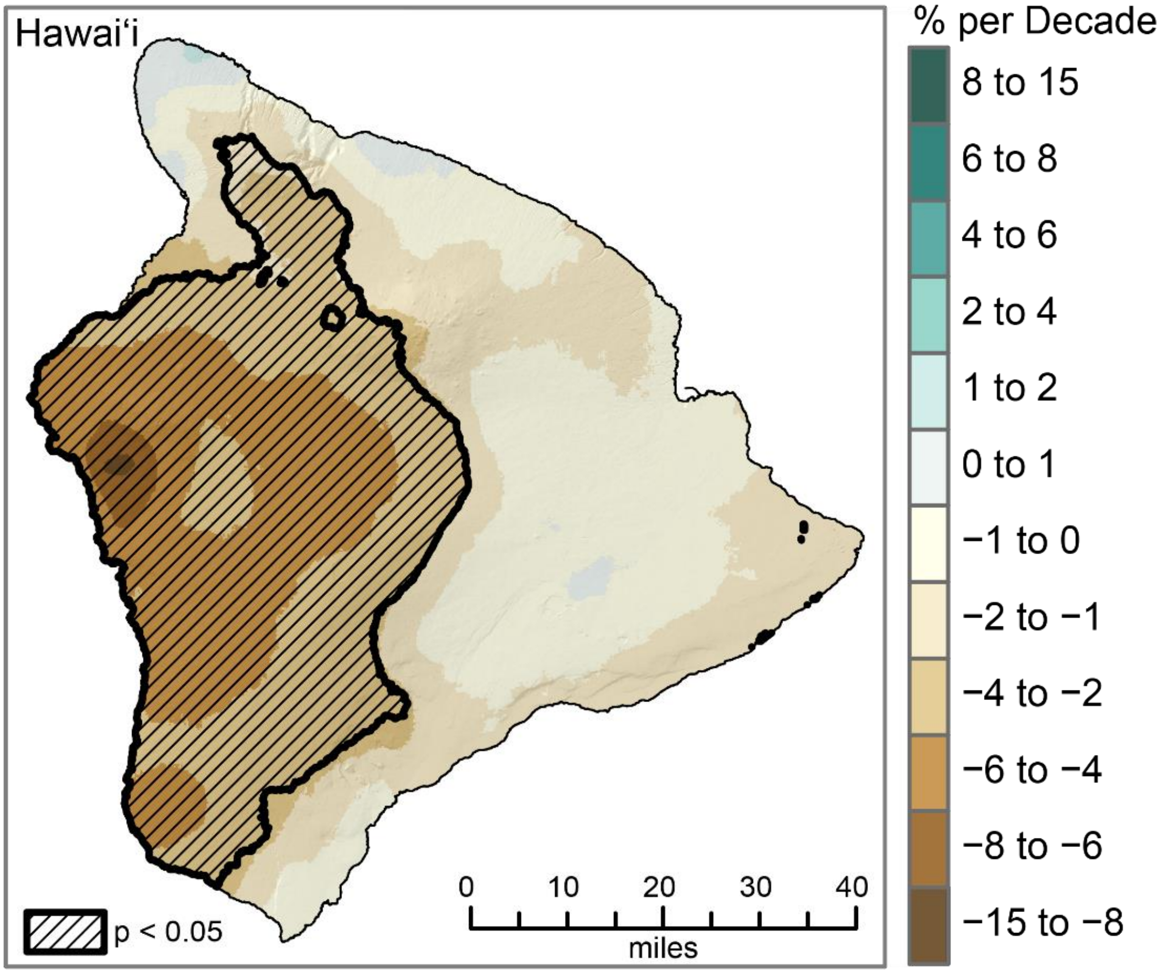

Figure A-14. Changes in annual rainfall (percent per decade) from 1920 to 2012 for the Island of Hawai‘i[160]

Riverine flood zones (FEMA DFIRM A/AE zones) (see Appendix A, section Riverine Flooding), mapped based on modeling of historical floods, were used as a proxy for extreme rainfall events. In a changing climate, extreme rainfall events will not be confined to these flood zones.

[159]Frazier, A. G., & Giambelluca, T. W. (2017). Spatial trend analysis of Hawai‘ian rainfall from 1920 to 2012. International journal of climatology, 37(5), 2522-2531. doi:10.1002/joc.4862

Landslides

Climate change is impacting storm patterns, increasing the probability of more frequent, intense storms with varying duration. Extreme rainfall events and storm surge can cause landslides and cliff failures. Warming temperatures also can increase the occurrence and duration of droughts, which increase the probability of wildfire, in turn reducing the vegetation that helps to support steep slopes. All of these changes and likely others would increase the probability for landslide occurrences.

A landslide is a mass of rock, earth or debris moving down a slope, caused by a combination of geological and climate conditions, as well as the encroaching influence of urbanization. Landslides are caused by one or more of the following factors:

- Change in slope of the terrain
- Increased load on the land
- Shocks and vibrations
- Change in water content
- Groundwater movement
- Frost action
- Weathering of rocks
- Removing or changing the type of vegetation on slopes

Landslides can be initiated by storms, earthquakes, fires, or volcanic eruptions and can be exacerbated by human residential, agricultural, commercial, and industrial development and associated infrastructure.

Data Used in Climate Risk Analysis. Medium and high landslide susceptibility zones (Class IV – X), developed by the Pacific Disaster Center and used in the Hawaiʻi State and Hawaiʻi County Multi-Hazard Mitigation Plan, were used in the climate risk analysis (Figure A-15). Landslide susceptibility zones are based on the following:

- Slope
  - Low Susceptibility – Slope less than 20 degrees
  - Moderate Susceptibility – Slope of 20 to 40 degrees
  - High Susceptibility – Slope greater than 40 degrees
- Geology
  - Low Susceptibility - Fresh volcanic rock at shallow depths
  - Moderate Susceptibility – Clay-rich surficial soils, weathered rock
  - High Susceptibility – Weak soft soils, ash deposits, mapped historic talus (rockfall deposits)
- Soil Moisture - derived from NOAA rainfall mapping of the island since regional groundwater and soil moisture data are unavailable island wide.

- Areas receiving more than 2,000 mm annual precipitation are considered to have wet soil; these areas are located primarily on the windward side of the island.
- Coastal areas below elevation 200 feet are considered wet due to potential groundwater seepage gradients from higher elevations, except in the arid Kona coast areas.

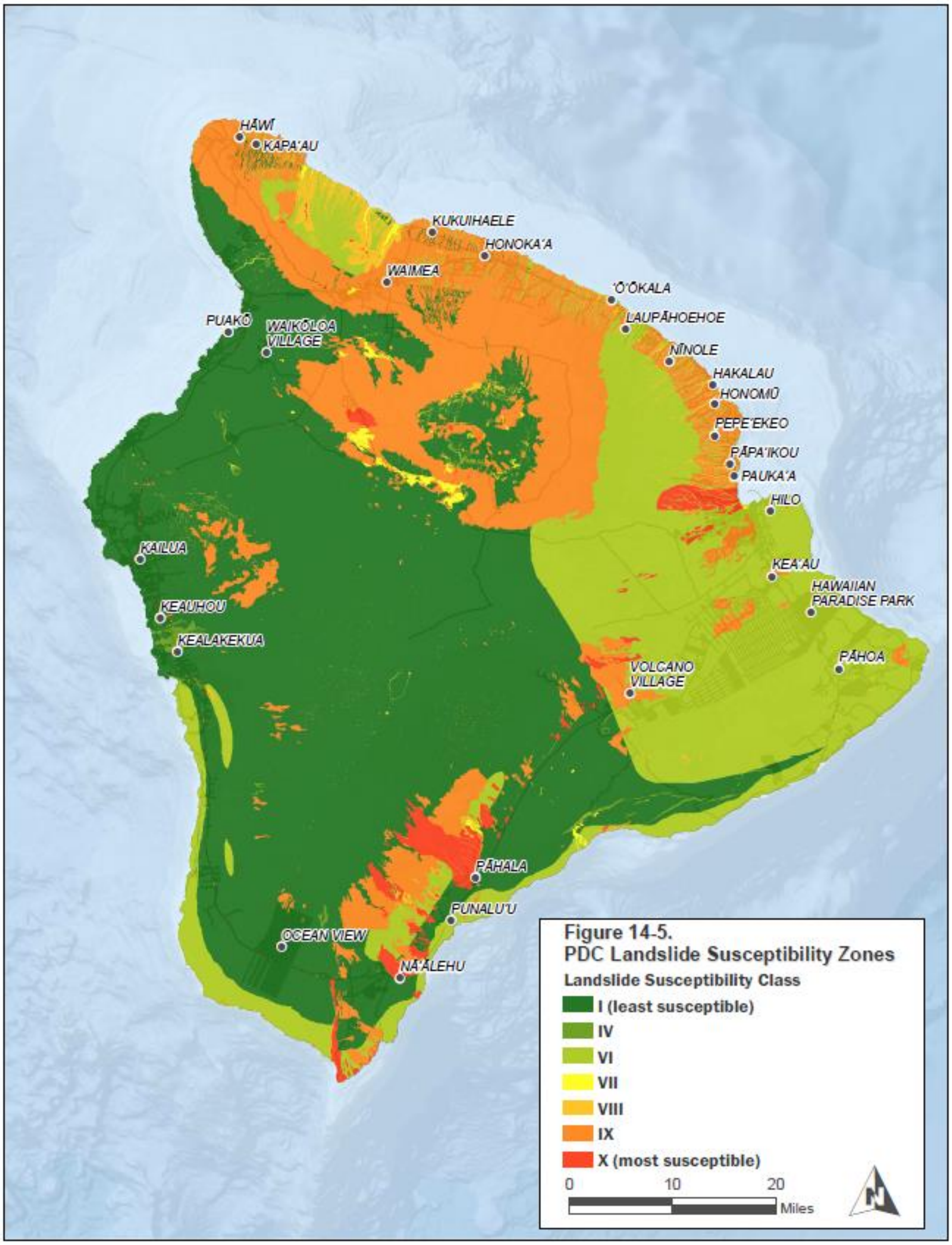

Figure A-15. Landslide susceptibility zones

Wildfire

The area impacted by wildfires in Hawaiʻi has increased fourfold in recent decades.[161] Climate, vegetation, and patterns of ignition are the main contributing factors for wildfire. Fire probability on Hawaiʻi Island will likely increase by the end of the century under the high global greenhouse gas emissions scenario (RCP 8.5). Increasing drought conditions with climate change will shift wildfire away from urban areas and grasslands with less fuel to ignite to higher elevation where native forests, which have evolved without regular lightning strikes, are sensitive to fire. Invasive species and land management factors further compound the impacts of wildfire.

Strong relations exist between drought, wildfire, and ENSO, with El Niño events typically leading to drier wet season conditions and greater area burned by wildfires. During El Niño years, high sea surface temperatures in the Equatorial Pacific Ocean lead to unusually warm and dry conditions over many fire-prone regions, increasing area burned and emissions from fire activity as well as socioeconomic, and environmental losses.[162] Heavy rainfall events prior to a drought season increase vegetation and risk of wildfire.[163] Drought and resulting dryness increase the likelihood of wildfire, which kills native plants while spreading fire-adapted, often fire-promoting, invasive grasses and shrubs.[164]

Climate change has the potential to affect multiple elements of the wildfire system: fire behavior, ignitions, fire management, and vegetation fuels. An increase in temperature coupled with a noticeable decrease in precipitation exacerbates droughts and has the potential to contribute to an increased frequency of wildfire. Hot dry spells create the highest fire risk. Increased temperatures may intensify wildfire danger by warming and drying out vegetation. When climate alters fuel loads and fuel moisture, forest susceptibility to wildfires changes. Climate change also may increase winds that spread fires. Faster fires are harder to contain, and thus are more likely to expand into residential neighborhoods.

Wildfires in Hawaiʻi are largely ignited by human activity such as smoking, campfires, equipment use, and arson. The potential for significant damage to life and property exists in areas designated as “wildland urban interface areas,” where development is adjacent to densely vegetated areas. Fires in these areas tend to behave differently from structural fires and are often more difficult to control and more damaging.

Wildfires can lead to secondary hazards such as landslides by stripping slopes of vegetation and exposing them to greater amounts of runoff. This in turn can weaken soils and cause failures on slopes. Major landslides can occur several years after a wildfire. Vulnerability to flooding increases due to the destruction of watersheds. Most wildfires burn hot and for long durations that can bake soils, thus increasing the imperviousness of the ground. This increases the runoff generated by storm events. Wildfires can cause direct economic losses in the reduction of harvestable crops and indirect economic

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161 Trauernicht, C. (2019). Vegetation—Rainfall interactions reveal how climate variability and climate change alter spatial patterns of wildland fire probability on Big Island, Hawaiʻi. The Science of the total environment, 650(Pt 1), 459-469. doi:10.1016/j.scitotenv.2018.08.347
162 Burton, C., Betts, R. A., Jones, C. D., Feldpausch, T. R., Cardoso, M., & Anderson, L. O. (2020). El Niño Driven Changes in Global Fire 2015/16. Frontiers in Earth Science, 8. doi:10.3389/feart.2020.00199
163 Trauernicht, C. (2019).doi:10.1016/j.scitotenv.2018.08.347
164 Pacific Islands Climate Science Center (2017). Ecological Drought in the Hawaiʻian Islands: Unique tropical systems are vulnerable to drought. (Report from the Pacific Islands Climate Science Center Workshop, March 6-8, 2017). Honolulu, HI.

losses in reduced tourism. Wildfires cause the contamination of reservoirs and destroy transmission lines.

Data Used in Climate Risk Analysis. The geospatial analysis of wildfire exposure was based on Communities at Risk from Wildfires maps, which delineate communities that share similar environmental conditions, land use characteristics, fuel types, hazards, and general wildfire issues, and provide fire risk ratings to characterize generalized hazards in each area community (Figure A-16).[165] Wildfire mapping differs from the other hazard mapping used in the exposure analysis as it does not show wildfire risk over the entire island, but only the risk in populated areas.

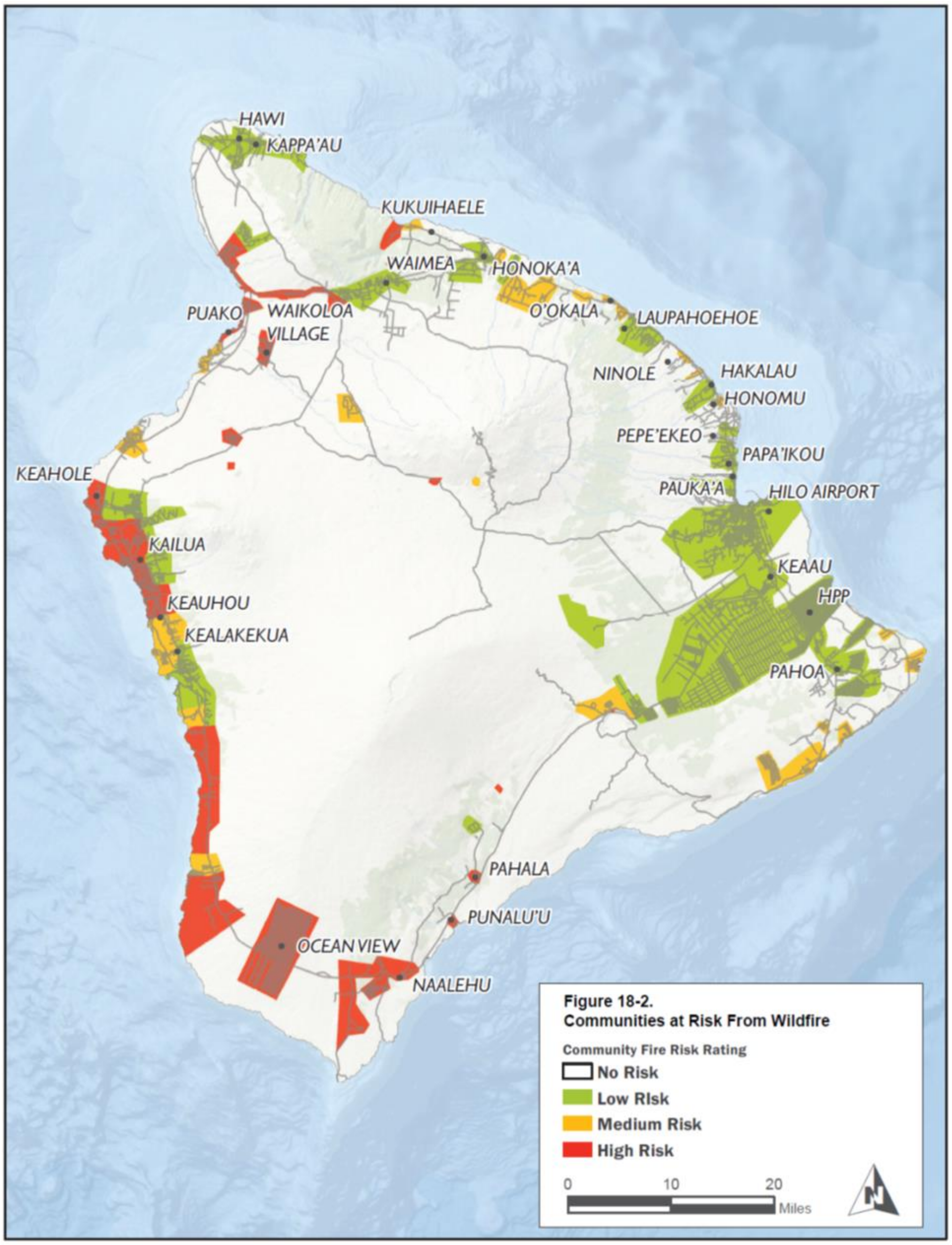


Figure A-16. Communities at risk from wildfire

[165] County of Hawaiʻi (2020) Multi-Hazard Mitigation Plan; data provided by Hawaiʻi Wildfire Management Organization

High Windstorms

A windstorm is any storm with a damaging or destructive wind component accompanied with little or no rain.[166] High trade winds, Kona winds, and tropical cyclone winds are types of windstorms that can affect Hawaiʻi County. Historical data shows that the probability for severe weather events such as high windstorms increases in a warmer climate. Wind is one of the costliest hazards to insured property, causing more damage than earthquakes or other natural hazards. Wind pressure, not wind speed, causes damage. Besides the high wind pressures exerted on structures during windstorms, and especially during tropical cyclones, windborne debris can be a major factor in causing damage. Such debris includes flying objects such as tree limbs, outdoor furniture, signs, roofs, gravel, and loose building components.

Data Used in Climate Risk Analysis. The geospatial analysis of high windstorms was based on the average wind speed measured at 50 meters above ground (Figure A-17).[167] Average wind speeds at 50 meters above ground include moderate (greater the 5 meters per second) and high (greater than 8.5 meters per second) severity. Projections of future wind speed are unavailable.

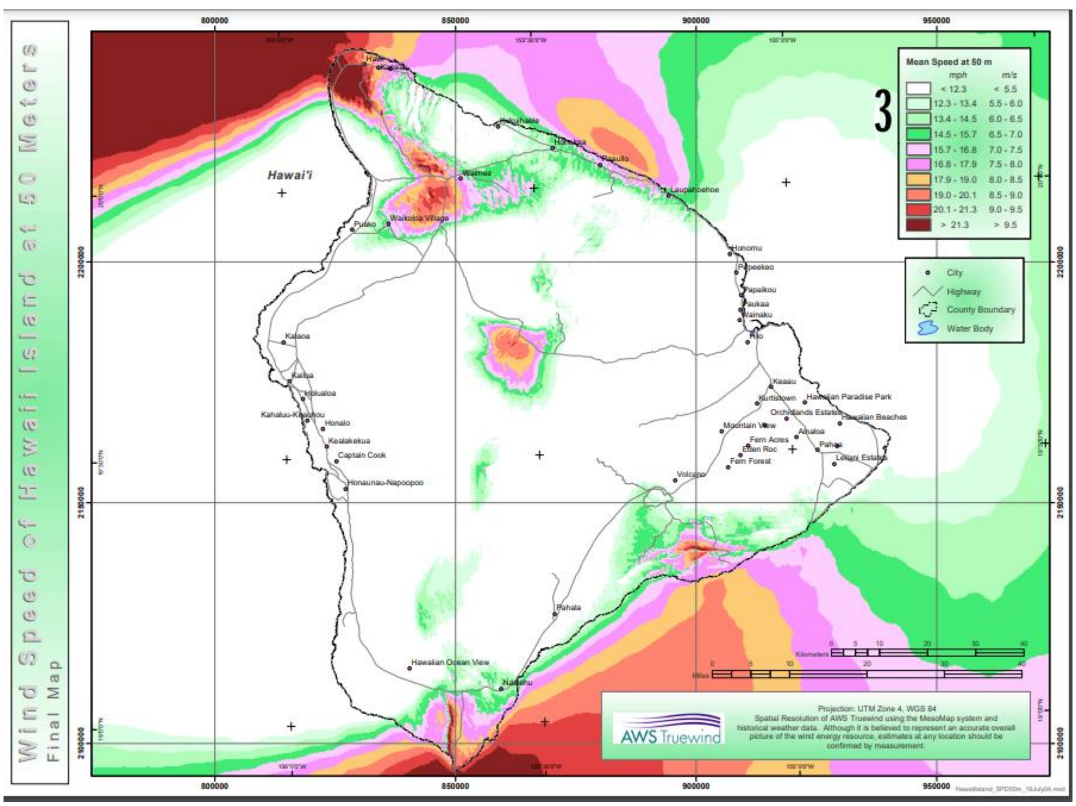


Figure A-17. Average wind speed at 50 meters elevation

[166] 42 U.S. Code § 15702 - Definitions
[167] Hawaiʻian Electric Company, Inc. (2019) https://www.Hawaiʻianelectric.com/documents/clean_energy_Hawaiʻi/renewable_energy_sources/Hawaiʻi_county_Hawaiʻi_island_SPD_50m_19_july_04.pdf

Riverine Flooding

Climate change is increasing the intensity of rainfall events, which in turn increases riverine and other types of land-based flooding such as flash floods and overland sheet flow. Prolonged rainfall results in an accumulation of water that may cause flooding that lasts several days, or even weeks. Factors influencing flooding include rainfall intensity and duration, topography, soil type, antecedent soil moisture, and ground cover. Four types of storms produce heavy precipitation and therefore floods: kona storms, frontal storms, upper level lows, and tropical cyclones. Increasing rainfall intensity will result in increased flooding and erosion along riparian areas and the shoreline.

Data Used in Climate Risk Analysis: Riverine flooding was based on 1 percent annual chance riverine flood zone (FEMA DFIRM A/AE zones). These maps depict the 1 percent annual chance and 0.2 percent annual chance flood events (Figure A-18)[168]. The flood studies that these maps are based on use historical records to determine the probability of occurrence and do not incorporate climate change. In a changing climate, flooding will not likely be confined to these areas.

Riverine flood zones are not mapped for all areas of the Hawaiʻi Island and do not extend or overlap with coastal flood zones as defined by FEMA (DFIRM V/VE zones). Riparian modeling is being conducted by the County and should be incorporated into future climate risk analysis.

[168] County of Hawaiʻi (2020) Multi-Hazard Mitigation Plan

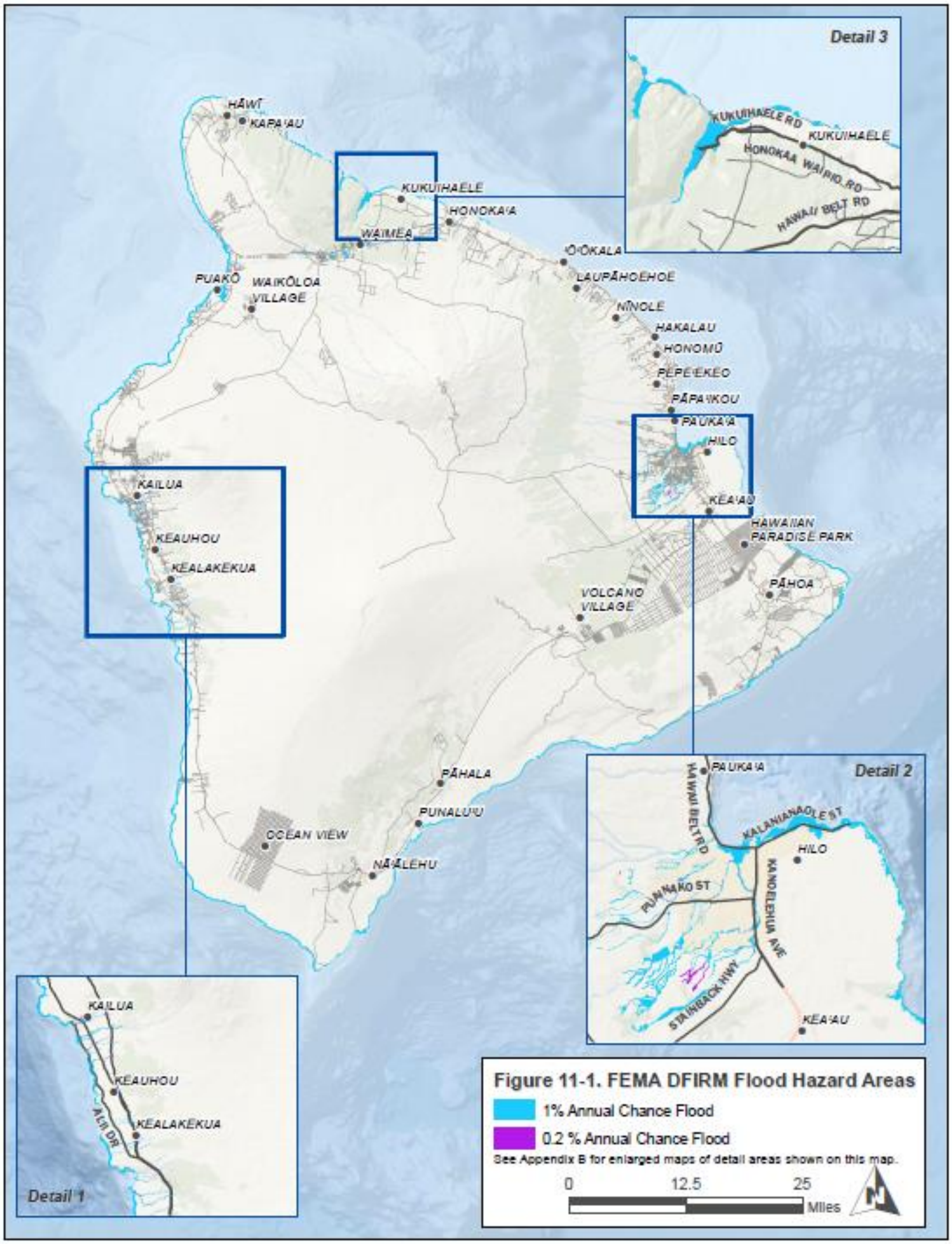
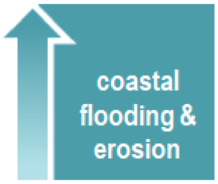


Figure A-18. FEMA DFIRM flood hazard areas

Coastal Flooding and Erosion



Sea level rise and other climate change hazards increase the frequency and extent of coastal flooding and erosion. Increasing coastal flooding and erosion result from high waves[169], storm surge[170], high tides[171], extreme rainfall events[172], and groundwater exacerbated by sea level rise and other climate hazards.

The increasing frequency of high tide flooding is being used as a trigger to implement climate adaptation. A rapid increase in high tide flood events in Hawaiʻi is expected in the mid-2030s (Figure A-19).[173] After the strong 2015 El Niño, Hawaiʻi experienced record-high sea levels in 2017, which contributed to recurrent flooding of coastal areas.[174]

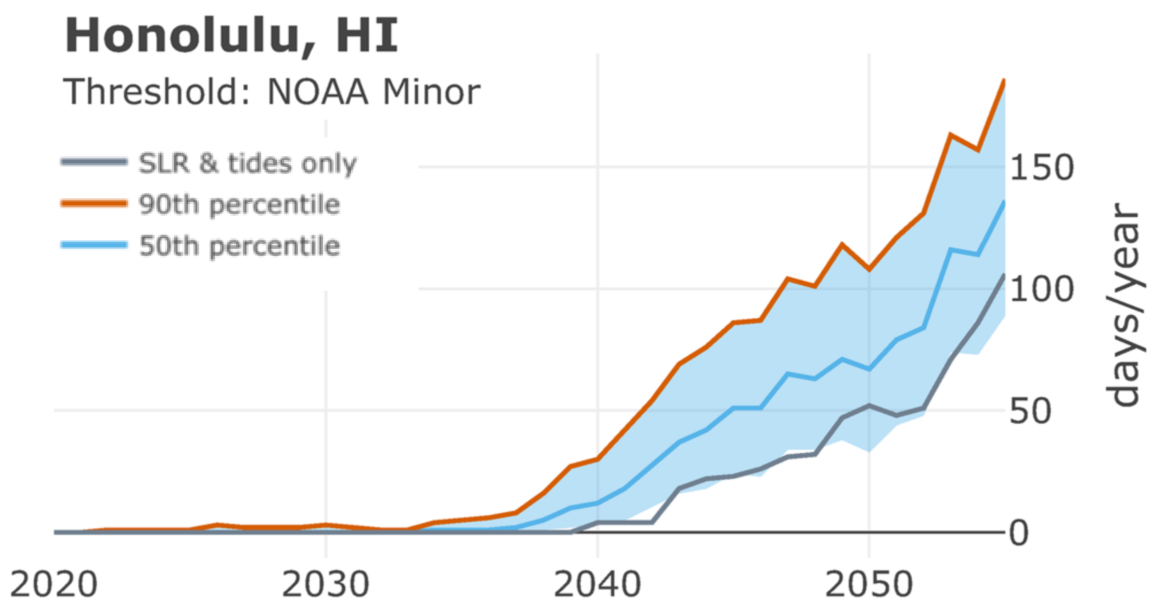


Figure A-19. Projections of annual counts of high-tide-flooding days for the NOAA Intermediate Sea Level Rise Scenario compared to expectations from sea level rise and tides alone.

[169]Vitousek, S., et al. (2017) Doubling of coastal flooding frequency within decades due to sea-level rise: Nature Scientific Reports, https://doi.org/10.1038/s41598-017-01362-7.
[170] Rohmer, J., et al. (2019) Increased extreme coastal water levels due to the combined action of storm surges and wind waves. Geophys. Res. Lett. 46(8), 4356–4364.
[171] Thompson, P. R., et al. (2019). A Statistical Model for Frequency of Coastal Flooding in Honolulu, Hawaiʻi, During the 21st Century. Journal of Geophysical Research: Oceans, 124(4), 2787–2802. https://doi.org/10.1029/2018JC014741
[172] Habel, S., Fletcher, C., Anderson, T., & Thompson, P (2020) Sea-Level Rise Induced Multi-Mechanism Flooding and Contribution to Urban Infrastructure Failure. Nature Scientific Reports, 10: 3796 DOI:10.1038/s41598-020-60762-4
[173]Thompson, P. R., Widlansky, M. J., Hamlington, B. D., Merrifield, M. A., Marra, J. J., Mitchum, G. T., & Sweet, W. (2021). Rapid increases and extreme months in projections of United States high-tide flooding. Nature Climate Change, 11(7), 584-590. doi:10.1038/s41558-021-01077-8
[174] Long, X., Widlansky, M. J., Schloesser, F., Thompson, P. R., Annamalai, H., Merrifield, M. A., & Yoon, H. (2020). Higher Sea Levels at Hawaii Caused by Strong El Niño and Weak Trade Winds. Journal of climate, 33(8), 3037-3059. doi:10.1175/JCLI-D-19-0221.1

Data Used in Climate Risk Analysis: The geospatial analysis of coastal flooding was based on three types of coastal flood models:[175]

- Event-based coastal flooding based on historical events—the 1 percent annual-chance coastal flood event (FEMA DIRM V/VE Zones)
- Event-based coastal flooding with sea level rise—the 1 percent annual-chance coastal flood event with 3.2 feet of sea level rise (I%CFZ-3.2)
- Chronic coastal flooding based on passive inundation modeling—the Sea Level Rise Exposure Area with 3.2 feet of sea level rise (SLRXA-3.2)

A comparison of these three coastal flood models is shown by geographic extent (Figure A-20) and by parcels impacted (Table A-2). The greatest number of parcels exposed occurs with the 1%CFZ-3.2. For Hawaiʻi Island, coastal flooding with sea level rise was modeled only for passive inundation, with the highest sea level rise scenario at 3.2 feet by 2100. Without considering coastal erosion and wave runup with sea level rise, the Sea Level Rise Exposure Area with 3.2 feet of sea level rise (SLRXA-3.2) for Hawaiʻi Island underestimates the total land area exposed by 35 to 54 percent, depending on location and sea level rise scenario.[176]

Table A-2. Number of parcels exposed under different coastal flood hazard areas for Hawaiʻi County

Coastal Flood Hazard Areas	Description	Number of Parcels Exposed
1% Annual Chance Coastal Flood (DFIRM V/VE)	Depicts area with a 1% annual chance of coastal flooding (DFIRM V/VE zones) where wave heights could exceed 3 feet. Sea level rise not included.(Hawaiʻi State Flood Hazard Assessment Tool, 2017)	2,359
1% Annual Chance Coastal Flood Zone with 3.2 feet of Sea Level Rise (1%CFZ-3.2)	Depicts combined area of flooding in the V/VE Zones and modeled 1%CFZ-3.2 where wave heights could exceed 1.5 feet (Hawaiʻi State Multi-Hazard Mitigate Plan, 2018)	3,017
Passive Flooding with 3.2 feet of Sea Level Rise (SLRXA-3.2, 2100)	Depicts area inundated by passive flooding only. Hawaiʻi Island's Sea Level Rise Exposure Area with 3.2 feet of sea level rise (SLRXA-3.2) is based on modeling passive inundation with sea level rise (unlike the Islands of Maui, Oʻahu, and Kauaʻi which include three coastal hazards with sea level rise: passive flooding, annual high wave flooding, and coastal erosion). (Hawaiʻi State Sea Level Rise Viewer; 2017)	1,767

The Hawaiʻi County Multi-Hazard Mitigation Plan used the FEMA DFIRM V/VE Zones, based on historical flooding and the 1%CFZ-3.2 to quantify risks of coastal flooding that include waves and storm surge. For Hawaiʻi Island, these zones provide the best estimates of the extent of coastal flooding now and in the future.

[175]Spatial hazard layers from the County of Hawaiʻi (2020) Multi-Hazard Mitigation Plan
[176] Anderson, T. R., Fletcher, C. H., Barbee, M. M., Romine, B. M., Lemmo, S., & Delevaux, J. M. S. (2018). Modeling multiple sea level rise stresses reveals up to twice the land at risk compared to strictly passive flooding methods. Scientific reports, 8(1), 14484. doi:10.1038/s41598-018-32658-x

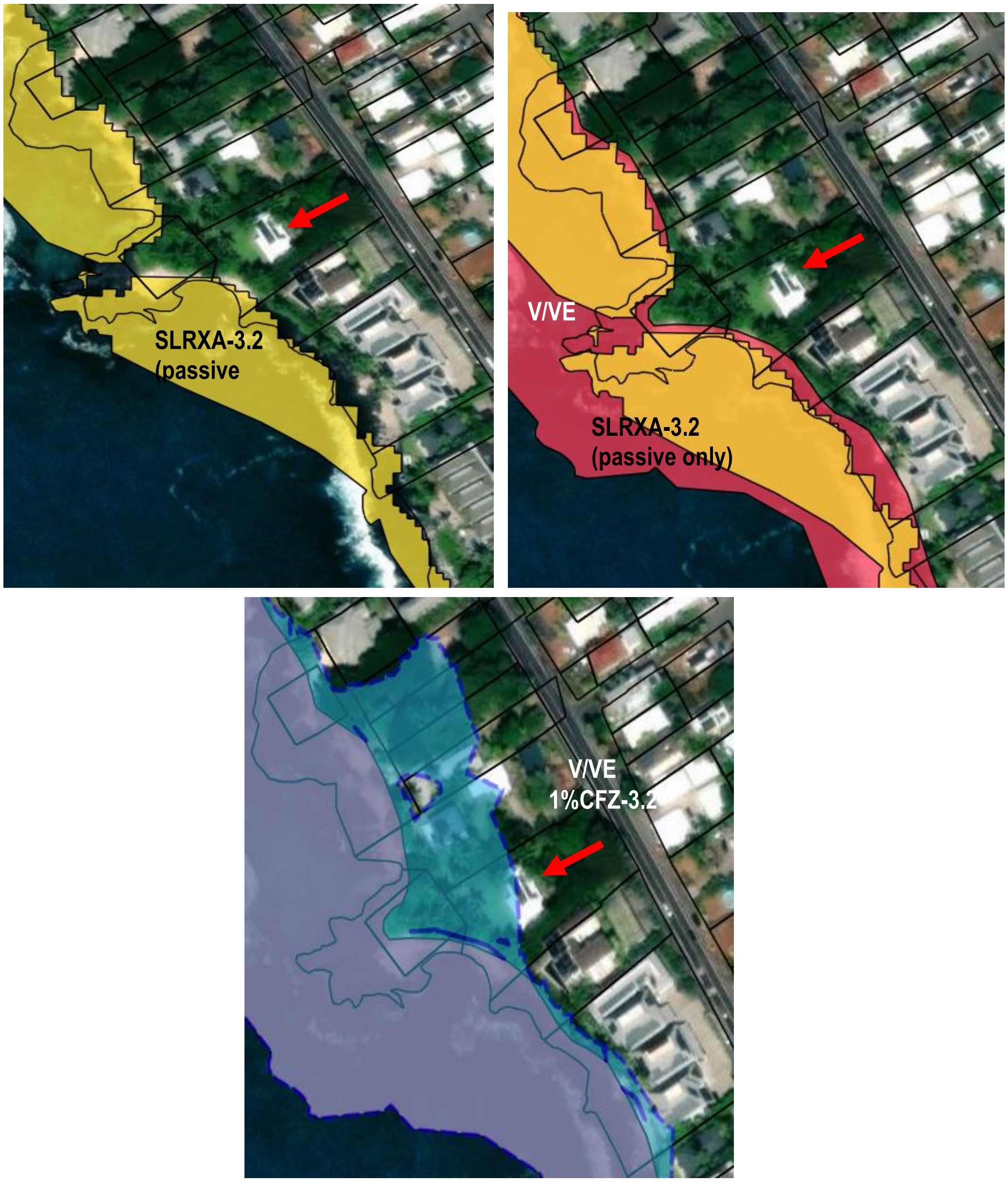


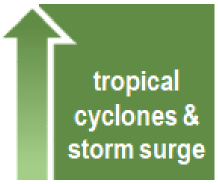
Figure A-20. Comparison of coastal flooding under different coastal flood hazard models in Kona, Hawaiʻi

It should be noted that riverine flood zones (FEMA DFIRM A/AE zones) do not overlap with coastal flood zones (FEMA FIRM V/VE zones) where rivers meet the sea. This results in an underestimation of the number of overlapping climate hazards in areas where a river meets the sea.

New studies are being conducted by the University of Hawaiʻi at Hilo and at Mānoa to model coastal flooding and erosion with sea level rise. A recent study by the University of Hawaiʻi at Hilo measured shoreline change and cliff failures in several pilot sites.[177] These data should be incorporated into the future climate risk analysis.

[177] Ryan Perroy, Eszter Collier, and Aloha Kapono (2022). Analysis to Establish Research-Based Shoreline and Riparian Setback Phase I: Identification, Mapping, and Analysis of Coastal and Riparian Hazard Vulnerabilities. University of Hawaiʻi, Spatial Data Analysis and Visualization (SDAV) Research Laboratory.

Tropical Cyclones and Storm Surge



Climate change is expected to increase the frequency and intensity of tropical cyclones around the Hawaiian Islands as the zone for tropical cyclone formation shifts poleward.[178] Warming ocean waters and rising sea level have the potential to strengthen the most powerful tropical cyclones.[179] Sea level rise can exacerbate the impacts of tropical cyclones and storm surge in multiple ways:

- Increasing the risk of storm surge-related flooding along the coast
- Expanding areas at risk of coastal flooding
- Increasing vulnerability of energy facilities located in coastal areas
- Flooding transportation and telecommunication facilities
- Causing saltwater intrusion into some freshwater supplies near the coasts

The 2014 hurricane season was highly active in terms of the intensity and frequency of hurricane events with a rare landfall of on Hawaiʻi Island (Figure A-21).[180] Increased sea surface temperatures and ocean heat content may have influenced three long-lived tropical cyclones in July and August of 2014: Hurricanes Genevieve, Iselle, and Julio.

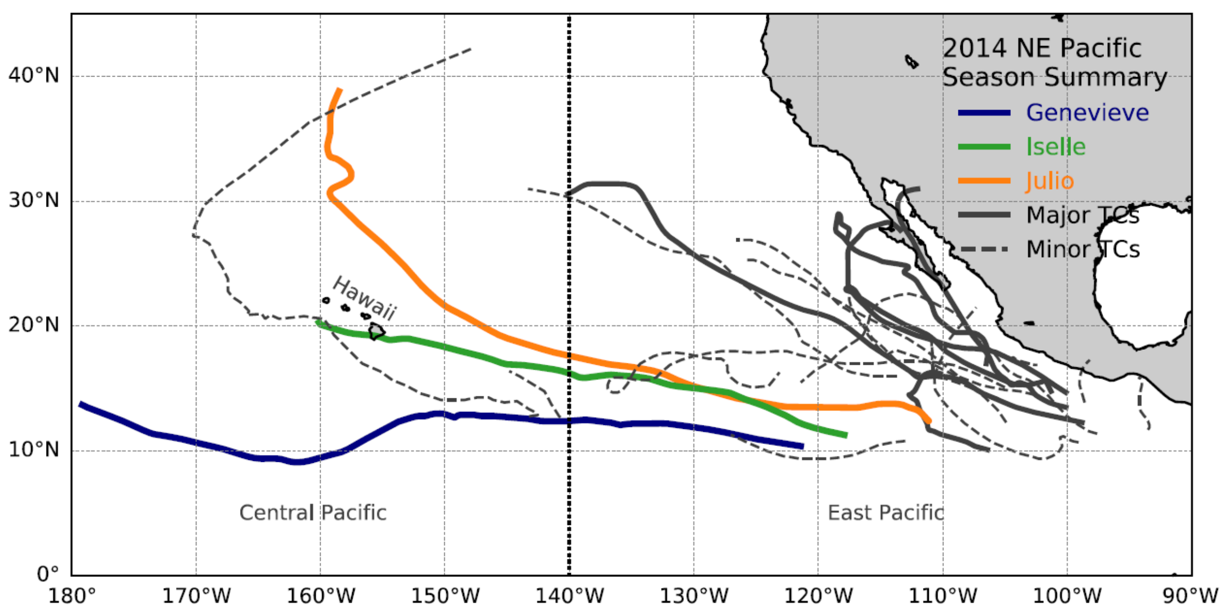


Figure A-21. Tropical cyclone tracks of the 2014 North Pacific hurricane season

[178] Murakami, H., Wang, B., Li, T. et al. (2013) Projected increase in tropical cyclones near Hawaiʻi. Nature Climate Change 3, 749–754. https://doi.org/10.1038/nclimate1890
[179] Knutson, T., et al. (2020) Tropical Cyclones and Climate Change Assessment: Part II: Projected Response to Human-made Warming, Bull. Amer. Meteor. Soc. (2020) 101 (3): E303–E322: https://doi.org/10.1175/BAMS-D-18-0194.1
[180] Ford, V. L., Walker, N. D., & Pun, I.-F. (2020). Anomalous Oceanic Conditions in the Central and Eastern North Pacific Ocean during the 2014 Hurricane Season and Relationships to Three Major Hurricanes. Journal of marine science and engineering, 8(4). Retrieved from doi:10.3390/jmse8040288

Tropical cyclones are among the most dramatic, damaging, and potentially deadly events that occur in the Hawaiian Islands. Hawaiʻi lies in the Central Pacific, which, on average, experiences four to five tropical cyclones every year. Almost all tropical cyclones in the Pacific basin form between June and November, a timeframe known as hurricane season. The threats caused by an approaching hurricane can be divided into three main categories:

- Storm Surge—Water that is pushed toward the shore by the force of the winds swirling around the storm. This advancing surge combines with normal tides to create a hurricane storm tide, which can increase the mean water level 15 feet or more. Storm surge is responsible for nearly 90 percent of all hurricane-related deaths and injuries. Waves and storm surges normally hit coasts ahead of high winds, as waves move faster than a hurricane advances.
- Wind Damage—The force of wind can quickly decimate the tree population, down power lines and utility poles, knock over signs, and damage or destroy homes and buildings. Flying debris can harm both structures and people. When hurricanes first make landfall, it is common for tornadoes to form, which can cause severe localized wind damage.
- Rainfall/Flooding—The torrential rains that normally accompany a hurricane can cause serious flooding. Locally intense rainfall may occur as the hurricane makes landfall. Whereas storm surge and high winds are concentrated around the "eye," the rain may extend for hundreds of miles and may last for several days, affecting areas well after the hurricane has diminished.

Other compounding hazards include landslides, flooding, coastal erosion, cliff failures, storms, and high surf. History has shown that the islands do not have to take a direct landfall from a cyclone to sustain a high level of damage.

Climate Risk Analysis: The geospatial exposure analysis for tropical cyclones and storm surge was based on hurricane winds (Figure A-22) and storm surge (Figure A-23) from a Category 4 storm scenario event with a storm track scenario deemed to be likely to have the greatest impact on people and infrastructure on the island.[181] The maximum wind gusts for the Category 4 scenario event modeled for the assessment range from 130 to 147 mph. Wind gusts of over 111 miles per hour were used in the climate risk analysis.

[181] Spatial layers from the Hawaiʻi County Multi-Hazard Mitigation Plan

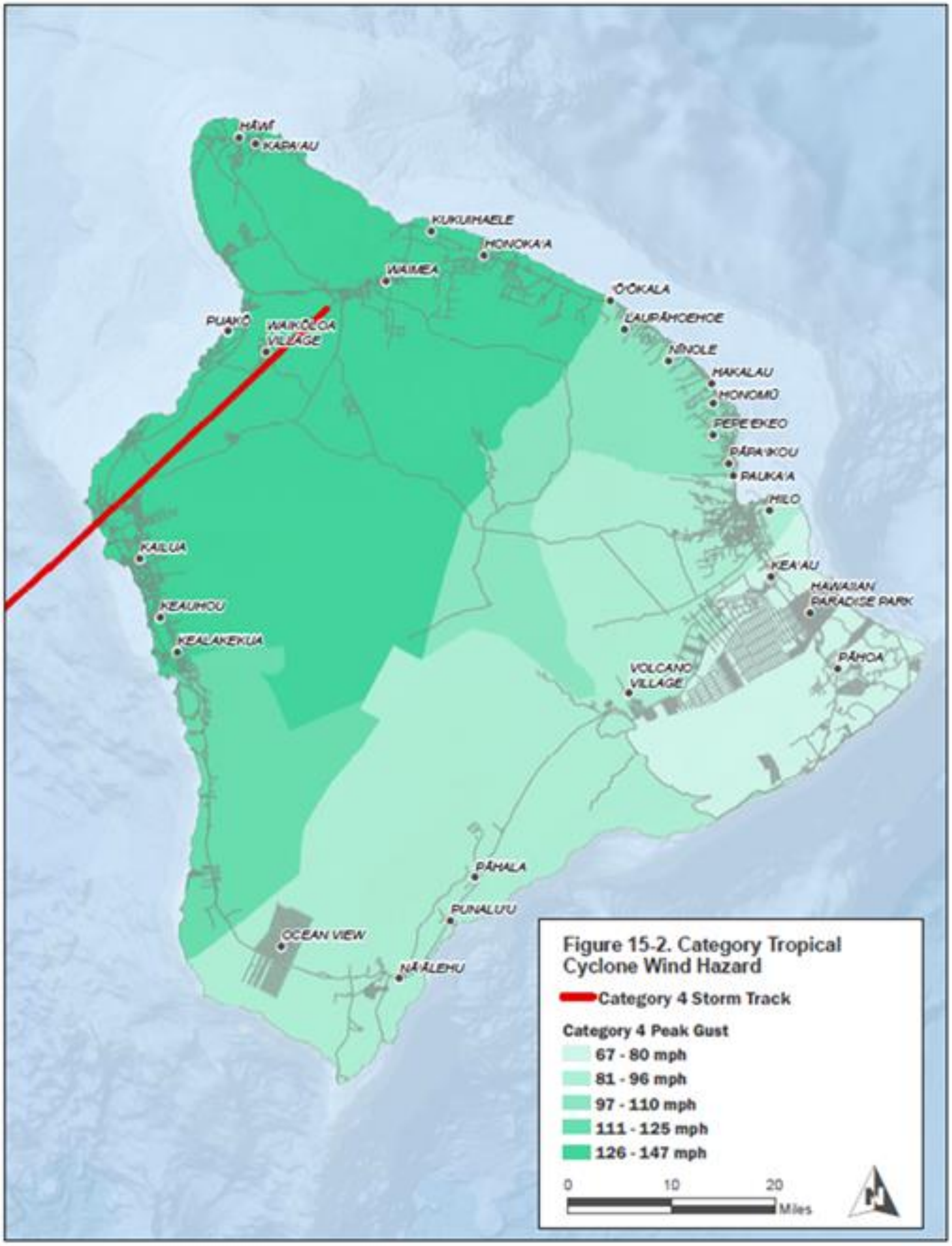


Figure A-22. Tropical cyclone wind hazard modeled for a Category 4 storm track

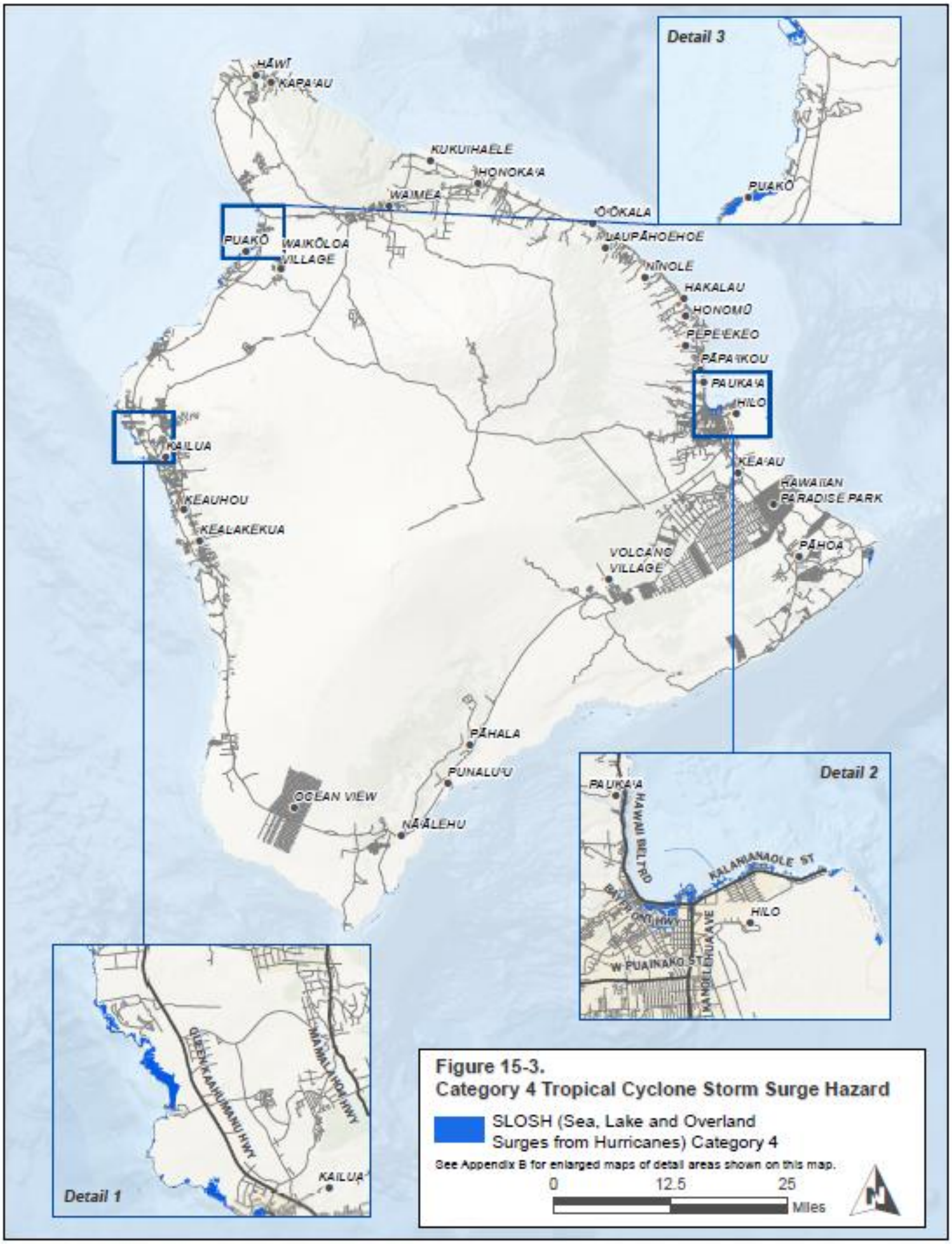


Figure A-23. Tropical storm surge hazard modeled for a Category 4 tropical cyclone

IPCC Sixth Assessment Report: Major Conclusions

The Synthesis Report of the IPCC Sixth Assessment Report (AR6) for Policymakers, released on March 20, 2023, summarizes the state of knowledge of climate change, its widespread impacts and risks, and climate change mitigation and adaptation efforts. Key findings are formulated as statements of fact based on scientific understanding. These statements, based on high or very high confidence levels, are reproduced here for reference.[182] The IPCC has concluded that there is a narrowing opportunity for climate resilient development (Figure A-24).

A. Current Status and Trends

A.1 Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850–1900 in 2011–2020. Global greenhouse gas emissions have continued to increase, with unequal historical and ongoing contributions arising from unsustainable energy use, land use and land-use change, lifestyles and patterns of consumption and production across regions, between and within countries, and among individuals (high confidence).

A.2 Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred. Human-caused climate change is already affecting many weather and climate extremes in every region across the globe. This has led to widespread adverse impacts and related losses and damages to nature and people (*high confidence*). Vulnerable communities who have historically contributed the least to current climate change are disproportionately affected (*high confidence*).

A.3 Adaptation planning and implementation has progressed across all sectors and regions, with documented benefits and varying effectiveness. Despite progress, adaptation gaps exist, and will continue to grow at current rates of implementation. Hard and soft limits to adaptation have been reached in some ecosystems and regions. Maladaptation is happening in some sectors and regions. Current global financial flows for adaptation are insufficient for, and constrain implementation of, adaptation options, especially in developing countries (high confidence).

A.4 Policies and laws addressing mitigation have consistently expanded since AR5. Global GHG emissions in 2030 implied by nationally determined contributions (NDCs) announced by October 2021 make it *likely* that warming will exceed 1.5°C during the 21st century and make it harder to limit warming below 2°C. There are gaps between projected emissions from implemented policies and those from NDCs and finance flows fall short of the levels needed to meet climate goals across all sectors and regions. (*high confidence*).

B. Future Climate Change, Risks, and Long-Term Responses

B.1 Continued greenhouse gas emissions will lead to increasing global warming, with the best estimate of reaching 1.5°C in the near term in considered scenarios and modelled pathways. Every increment of global warming will intensify multiple and concurrent hazards (high confidence). Deep, rapid, and

[182] IPCC (2023) Synthesis Report of the IPCC Sixth Assessment (AR6), Summary for Policy Makers (2023) https://report.ipcc.ch/ar6syr/pdf/IPCC_AR6_SYR_SPM.pdf

sustained reductions in greenhouse gas emissions would lead to a discernible slowdown in global warming within around two decades, and also to discernible changes in atmospheric composition within a few years (high confidence).

B.2 For any given future warming level, many climate-related risks are higher than assessed in AR5, and projected long-term impacts are up to multiple times higher than currently observed (high confidence). Risks and projected adverse impacts and related losses and damages from climate change escalate with every increment of global warming (very high confidence). Climatic and non-climatic risks will increasingly interact, creating compound and cascading risks that are more complex and difficult to manage (high confidence).

B.3 Some future changes are unavoidable and/or irreversible but can be limited by deep, rapid and sustained global greenhouse gas emissions reduction. The likelihood of abrupt and/or irreversible changes increases with higher global warming levels. Similarly, the probability of low-likelihood outcomes associated with potentially very large adverse impacts increases with higher global warming levels. (high confidence).

B.4 Adaptation options that are feasible and effective today will become constrained and less effective with increasing global warming. With increasing global warming, losses and damages will increase and additional human and natural systems will reach adaptation limits. Maladaptation can be avoided by flexible, multi-sectoral, inclusive, long-term planning and implementation of adaptation actions, with co-benefits to many sectors and systems. (high confidence).

B.5 Limiting human-caused global warming requires net zero CO_2 emissions. Cumulative carbon emissions until the time of reaching net-zero CO_2 emissions and the level of greenhouse gas emission reductions this decade largely determine whether warming can be limited to 1.5°C or 2°C (high confidence). Projected CO_2 emissions from existing fossil fuel infrastructure without additional abatement would exceed the remaining carbon budget for 1.5°C (50 percent) (high confidence).

B.6 All global modelled pathways that limit warming to 1.5°C (>50 percent) with no or limited overshoot, and those that limit warming to 2°C (>67 percent), involve rapid and deep and, in most cases, immediate greenhouse gas emissions reductions in all sectors this decade. Global net zero CO_2 emissions are reached for these pathway categories, in the early 2050s and around the early 2070s, respectively. (high confidence).

B.7 If warming exceeds a specified level such as 1.5°C, it could gradually be reduced again by achieving and sustaining net negative global CO_2 emissions. This would require additional deployment of carbon dioxide removal, compared to pathways without overshoot, leading to greater feasibility and sustainability concerns. Overshoot entails adverse impacts, some irreversible, and additional risks for human and natural systems, all growing with the magnitude and duration of overshoot. (high confidence).

C. Responses in the Near Term

C.1 Climate change is a threat to human well-being and planetary health (very high confidence). There is a rapidly closing window of opportunity to secure a livable and sustainable future for all (very high confidence). Climate resilient development integrates adaptation and mitigation to advance sustainable development for all and is enabled by increased international cooperation including improved access to adequate financial resources, particularly for vulnerable regions, sectors and groups, and inclusive governance and coordinated policies (high confidence). The choices and actions implemented in this decade will have impacts now and for thousands of years (high confidence).

C.2 Deep, rapid and sustained mitigation and accelerated implementation of adaptation actions in this decade would reduce projected losses and damages for humans and ecosystems (very high confidence), and deliver many co-benefits, especially for air quality and health (high confidence). Delayed mitigation and adaptation action would lock-in high-emissions infrastructure, raise risks of stranded assets and cost-escalation, reduce feasibility, and increase losses and damages (high confidence). Near-term actions involve high up-front investments and potentially disruptive changes that can be lessened by a range of enabling policies (high confidence).

C.3 Rapid and far-reaching transitions across all sectors and systems are necessary to achieve deep and sustained emissions reductions and secure a livable and sustainable future for all. These system transitions involve a significant upscaling of a wide portfolio of mitigation and adaptation options. Feasible, effective, and low-cost options for mitigation and adaptation are already available, with differences across systems and regions. (high confidence).

C.4 Accelerated and equitable action in mitigating and adapting to climate change impacts is critical to sustainable development. Mitigation and adaptation actions have more synergies than trade-offs with Sustainable Development Goals. Synergies and trade-offs depend on context and scale of implementation. (high confidence).

C.5 Prioritising equity, climate justice, social justice, inclusion and just transition processes can enable adaptation and ambitious mitigation actions and climate resilient development. Adaptation outcomes are enhanced by increased support to regions and people with the highest vulnerability to climatic hazards. Integrating climate adaptation into social protection programs improves resilience. Many options are available for reducing emission-intensive consumption, including through behavioral and lifestyle changes, with co-benefits for societal well-being. (high confidence).

C.6 Effective climate action is enabled by political commitment, well-aligned multilevel governance, institutional frameworks, laws, policies and strategies and enhanced access to finance and technology. Clear goals, coordination across multiple policy domains, and inclusive governance processes facilitate effective climate action. Regulatory and economic instruments can support deep emissions reductions and climate resilience if scaled up and applied widely. Climate resilient development benefits from drawing on diverse knowledge. (high confidence).

C.7 Finance, technology and international cooperation are critical enablers for accelerated climate action. If climate goals are to be achieved, both adaptation and mitigation financing would need to increase many-fold. There is sufficient global capital to close the global investment gaps but there are barriers to redirect capital to climate action. Enhancing technology innovation systems is key to accelerate the widespread adoption of technologies and practices. Enhancing international cooperation is possible through multiple channels. (high confidence).

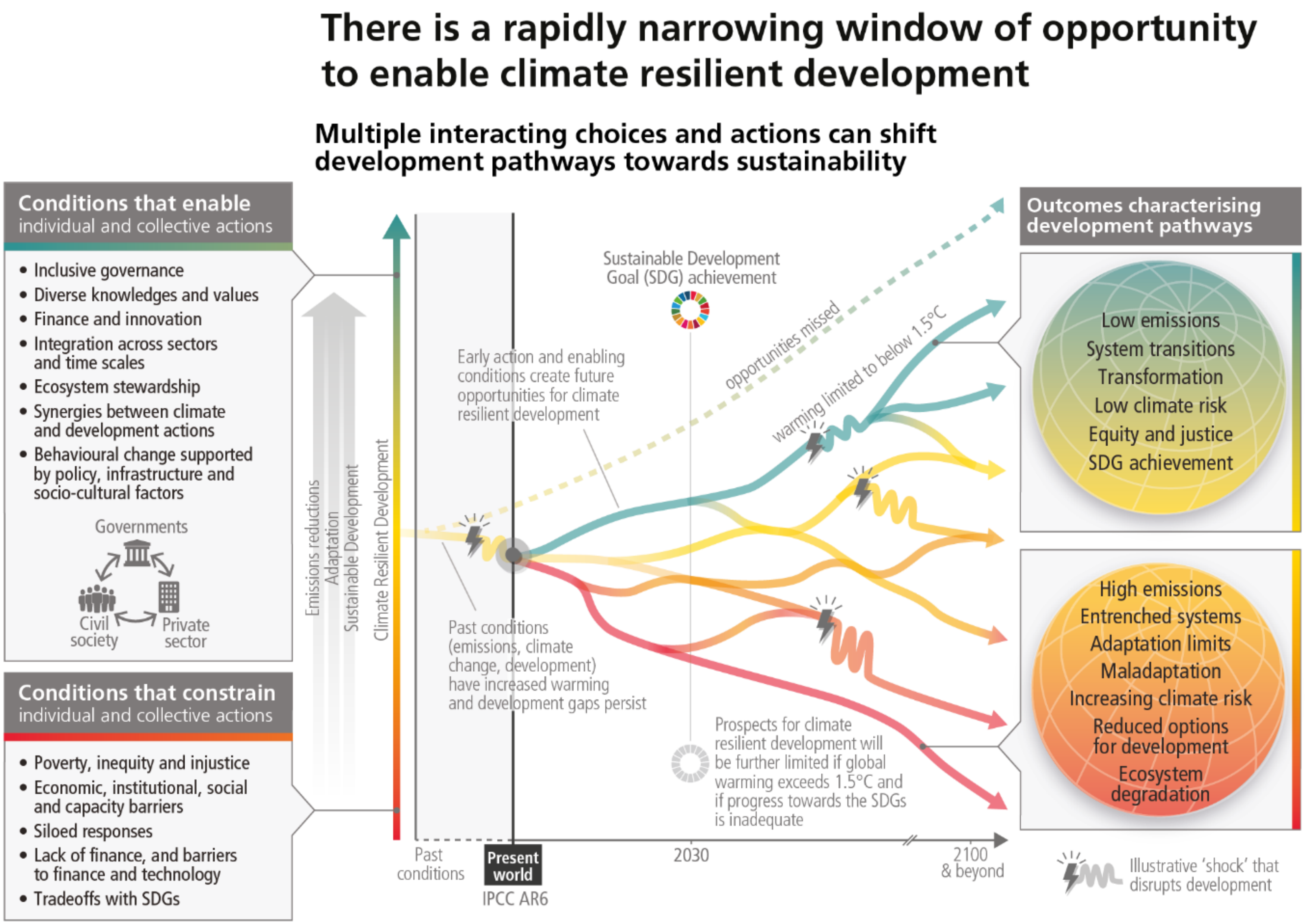


Figure A-24. Multiple interacting choices and actions that can shift development pathways to sustainability

APPENDIX B: CASCADE RISK ANALYSIS

A cascade risk analysis was also conducted based on the distribution of socially vulnerable populations by Census block group. The distribution of socially vulnerable populations was based on five vulnerability components (Figure B-2).[183]

The risk analysis determined the number of hazards to which socially vulnerable populations are exposed under each climate cascade, by Census block group. The cascade risk analysis framework is shown in Figure B-1. Risk analyses for Climate Cascades 3, 4, and 5 are based on climate hazards and incorporate the effects of multiple compounding hazards. For each of these climate cascades, evaluations were made to assess the risk the hazards pose to socially vulnerable populations.

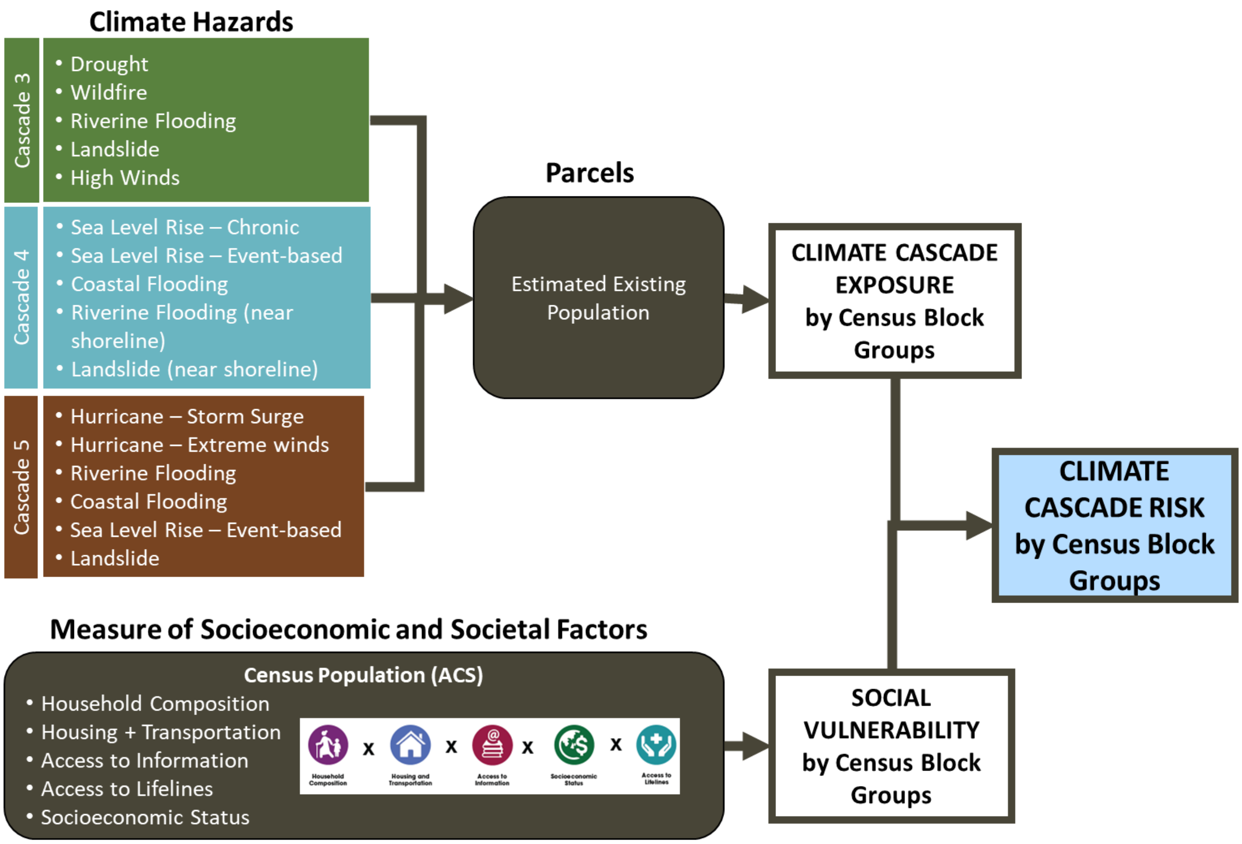


Figure B-1. Climate cascade risk analysis framework

The distribution of socially vulnerable populations by Census block group was determined using the Kīlauea Eruption Risk Assessment (KERA) methodology created for Hawaiʻi County by the Pacific Disaster Center for the Kīlauea 2018 eruption recovery effort (Figure B-2).[184] The KERA model used primarily Census data to assess the most vulnerable populations. It calculated a vulnerability score for

[183] Vulnerability analysis was based on the Kilauea Eruption Risk Assessment (KERA) methodology created for Hawaiʻi County by the Pacific Disaster Center for the Kilauea 2018 eruption recovery effort.
[184] The 2018 Kilauea eruption and lava flow changed the physical and social landscape of Puna. The area impacted by the lava flow was excluded from the climate risk assessment until updated hazard exposure model data and population data can be included.

each Census tract and Census block group. Five vulnerability components were explored, each with underlying metrics, to score locations based on their predisposition to impacts from disasters:

- Household composition
- Socioeconomic status
- Access to information
- Housing and transportation
- Access to lifelines

Vulnerable populations for climate change risk would be the same as those identified by KERA for volcanic risk. Therefore, the climate cascade risk analyses for this ICAP used the KERA scores for Census block groups, as shown in Figure B-2. Social vulnerability by Census block group is highest in Puna, Kaʻū (Ocean View), and Hilo.

Exposed population is measured based on percent area within cascade exposure areas. If 10 percent of a parcel is overlapping an exposure area, then 10 percent of the population is assumed to be exposed. Exposure score is based on a combination of all estimated exposed population within cascade hazard exposure types.

Overall community risk is calculated by combining a Census block group vulnerability and cascade exposure analysis of the population. Risk maps showing these results are included for Cascade 3 (Figure B-3), Cascade 4, (Figure B-4) and Cascade 5 (Figure B-5).

The following are key take-aways from the risk analyses for each climate cascade:

- **Cascade 3:** Census block groups with a high climate cascade risk (exposure to four or five hazards) are located in South Kohala, North and South Hilo, and Kaʻū (Figure B-3).
- **Cascade 4:** Census block groups with a high climate cascade risk (exposure to four or five hazards) are located in South Hilo, Puna, and North Kona (Figure B-4).
- **Cascade 5:** Census block groups with a high climate cascade risk (exposure to five or six hazards) are located in South Hilo, Puna, and North Kona (Figure B-5).

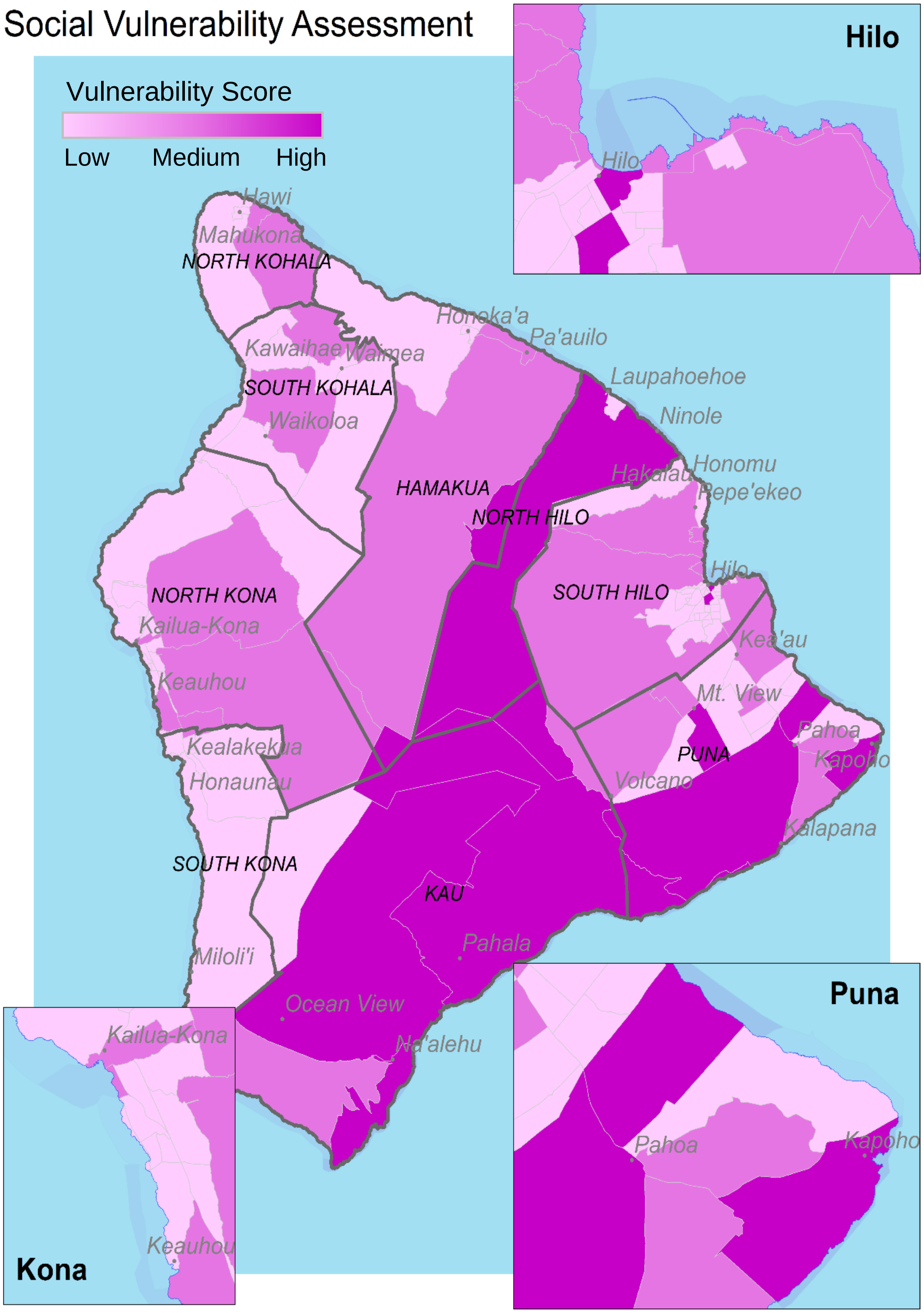


Figure B-2. Social vulnerability score by census block group

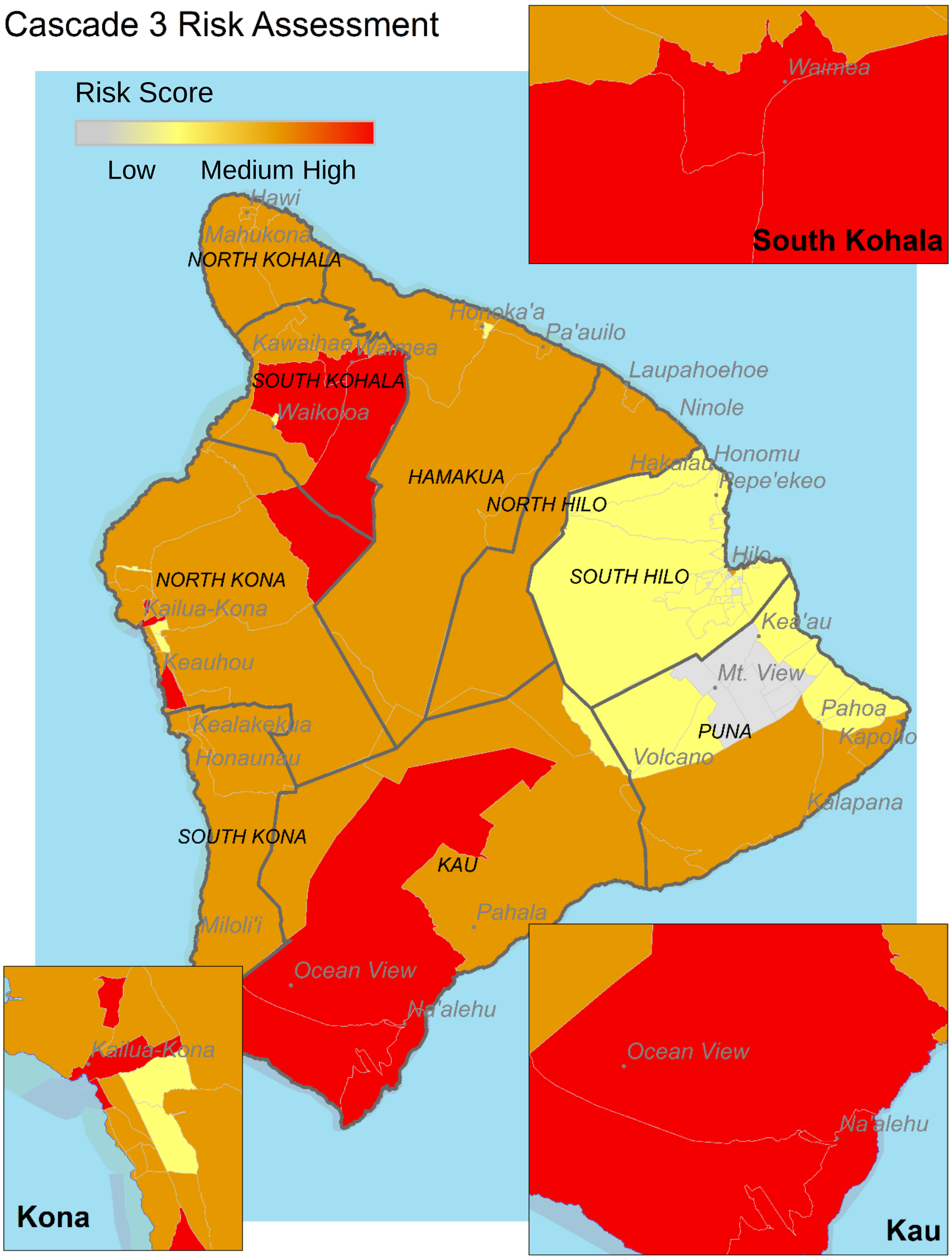


Figure B-3. Climate Cascade 3: Population at risk by census block group based on cascade exposure and social vulnerability

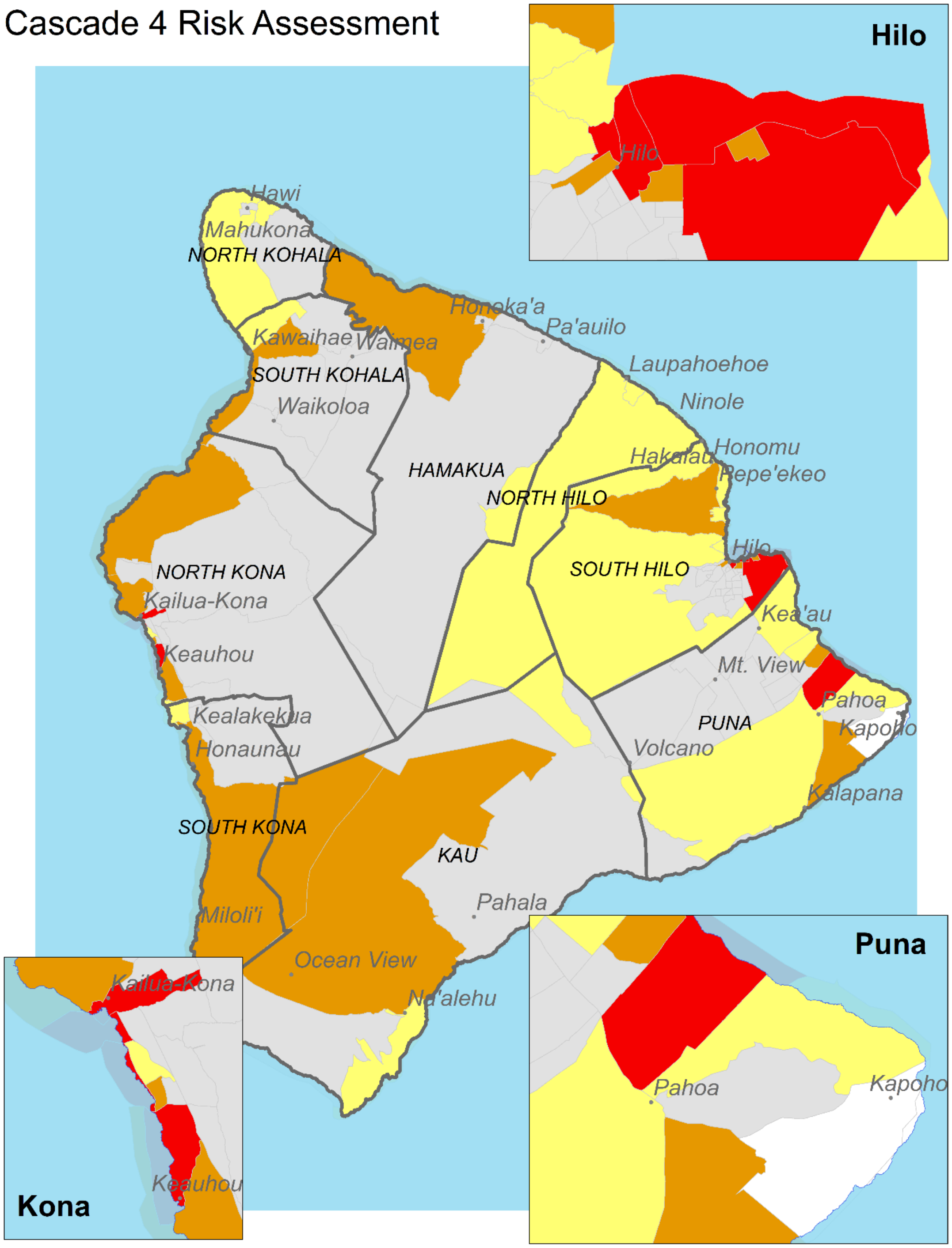


Figure B-4. Climate Cascade 4: Population at risk by census block group based on cascade exposure and social vulnerability

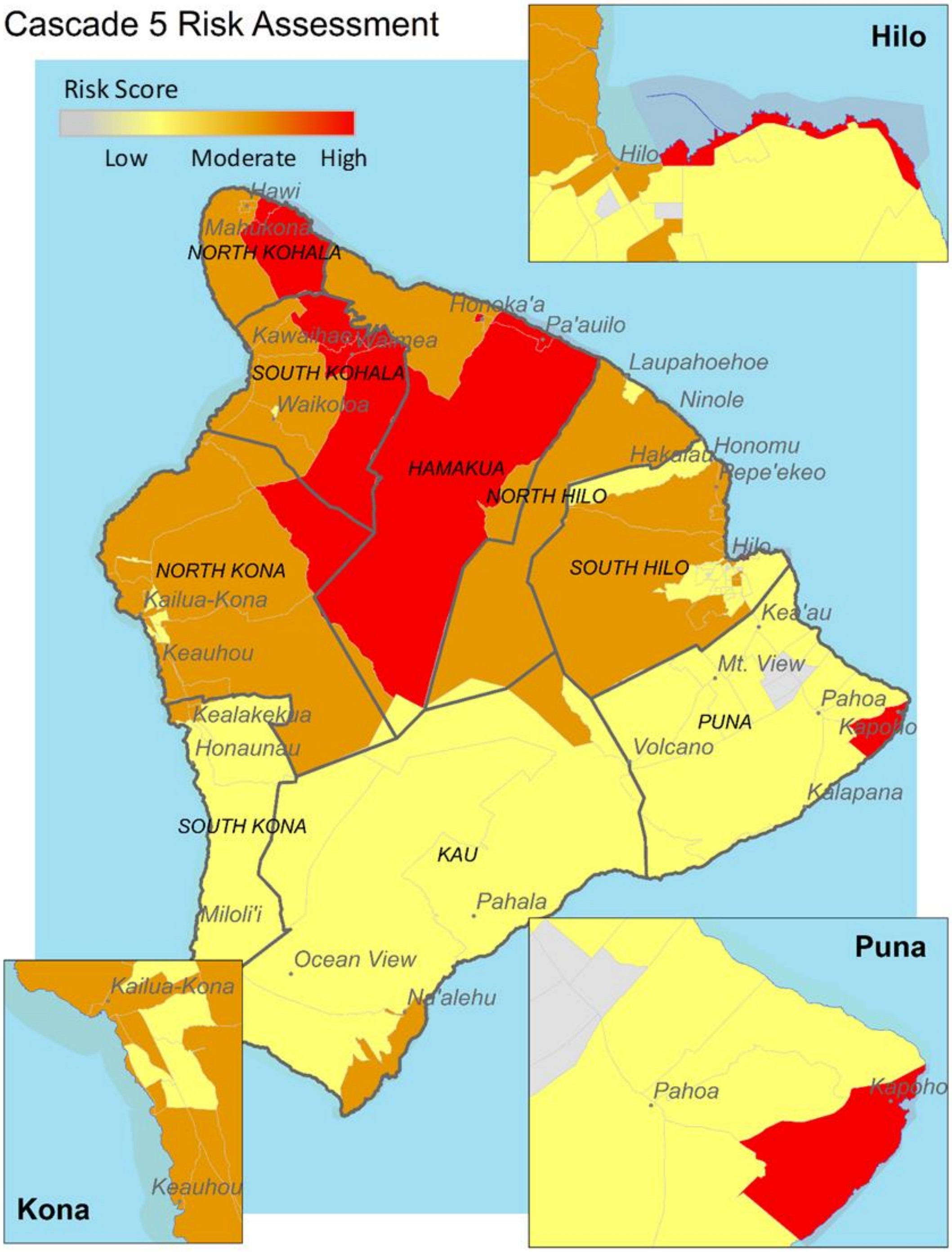


Figure B-5. Climate Cascade 5: Population at risk by census block group based on cascade exposure and social vulnerability

APPENDIX C: SURVEY RESULTS

Introduction

This survey was created as part of the Hawaiʻi County Integrated Climate Action Plan creation and outreach process. The Integrated Climate Action Plan for the Island of Hawaiʻi (ICAP) establishes a greenhouse gas emissions baseline, describes the impacts of climate change on natural hazard risks and community systems, and identifies both climate mitigation and adaptation actions that Hawaiʻi County and the community can take to reduce or minimize these effects. The ICAP effort is led by the County's Climate Action Team (CAT), which includes representatives from the Research & Development and Planning departments. The CAT works closely with a community Climate Action Working Group (WG), which advises the CAT on components of the plan, rallies citizen commitment and support, and sustains transparency throughout the process.

To understand community sentiment more fully around climate change causes, impacts, and priority actions, the CAT and WG worked together to create, distribute, and analyze a community sentiment survey around climate change. The purpose of this survey is 1) to help the County better understand communities' points of view on climate change to inform future engagement opportunities; and 2) to give the County a better understanding of how effective outreach efforts are and where improvement is needed to ensure that perspectives of underrepresented communities are included.

Methodology

The Climate Action Team used a survey on climate sentiment in the community from the Urban Sustainability Director's Network (USDN) platform. The team reviewed the survey template and made edits to the questions, including adding a demographics section and editing language based on issues that were pertinent to Hawaiʻi Island. The Climate Action Working Group gave feedback on the questions based on their expertise, including editing certain questions for bias. The survey was created on Google Forms and there were no paper copies printed and distributed. The survey was also created in English and was not translated into any other language. The survey was open and accepted responses from September 1, 2021, to March 1, 2022.

The survey received 1,079 responses. The survey was distributed through the County government networks, specifically the R&D and Planning Departments, and the Working Group network. The Mayor's office sent a press release. The survey was then distributed through three Big Island newspapers, including Hawaii Herald-Tribune, Big Island News Now, and West Hawaii Today, and through Hawaii News Now, KHON News, and Hawaii Business Magazine. The survey was also announced on the radio and was available through the R&D website. Working Group members also reached out to professors at UH-Hilo and high schools across the island. Professors and teachers distributed the survey to their classes at their own discretion. Three elected officials distributed the survey through their networks, including Representative Nicole Lowen, Councilmember Heather

Kimball, and Councilmember Rebecca Villegas. Through the Research & Development department specialist and Working Group networks, the survey was distributed to the following networks:

- Big Island Electric Vehicle Association
- Coral Reef Alliance
- Day Lum Rentals
- Hawaiian Electric users as a bill insert
- Hawaiʻi Energy
- Hawaiʻi Island Food Alliance
- Kohala Center
- Nextdoor Hāmākua
- South Kohala Coastal Partnership
- Terraformation
- Zero Waste Hawaiʻi

The first set of questions (1-4) asked about respondents' beliefs and concerns regarding climate change itself. These questions demonstrate public sentiment about the existence, severity, and threat of climate change. These questions also assess public sentiment about the prioritization of climate change relative to other issues.

The second set of questions (5-8) asked about respondents' personal knowledge of climate change and what is being done about it locally. This section also included questions about the causes and effects of climate change at a global and local scale. These questions demonstrate public knowledge about climate mitigation, climate adaptation, and related issues. This section also included a free response question to collect information about organizations and local initiatives that are addressing climate change.

The third set of questions (9-14) asked about responsibility for addressing climate change and reliable information sources about climate change. These questions demonstrate which sources respondents trust regarding climate change information. These questions also demonstrate which organizations and entities the public perceive should address climate change and which are already addressing climate change.

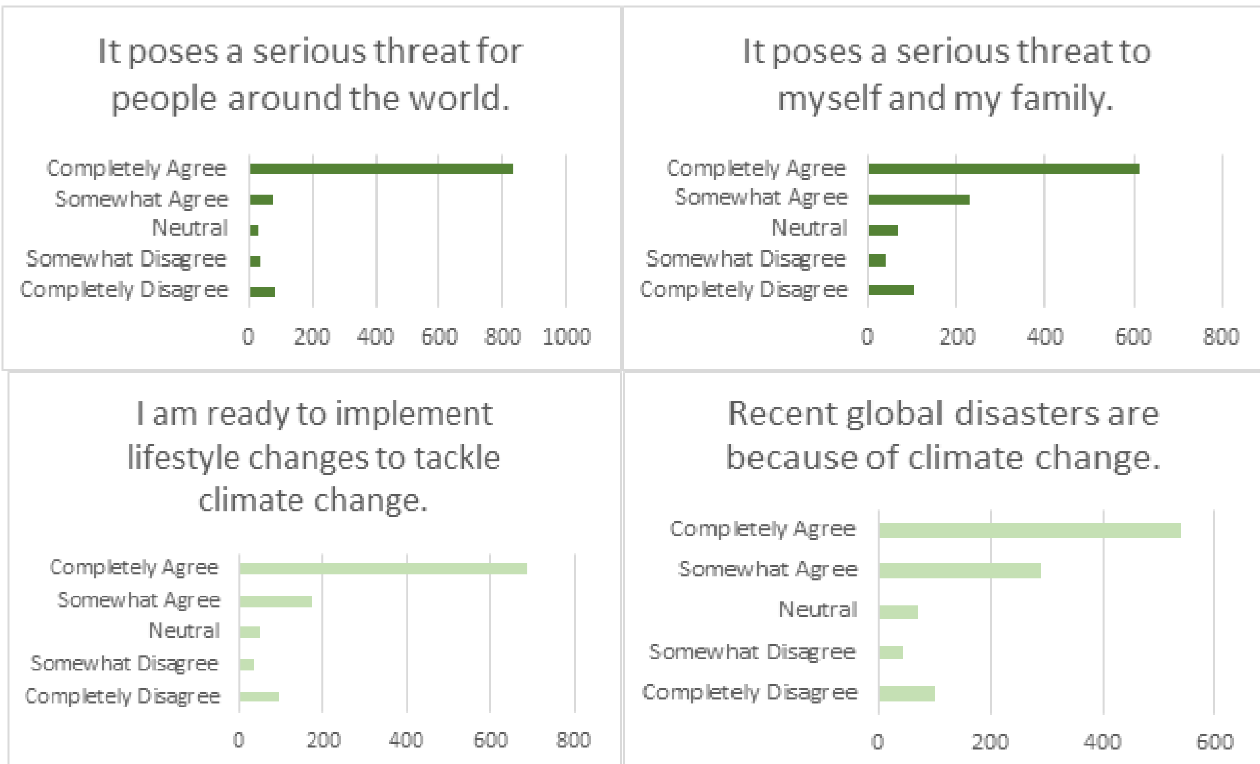
The fifth set of questions (15-19) asked about demographics. These questions were designed to demonstrate if the survey results are biased towards certain demographics. These questions determined places people hear about climate change, and where they would spread information about climate change. Some of the most popular answers for 13 included TV, newspaper, academic journals, school, friends and colleges, and social media. In question 14, common answers included the internet, school, the newspaper, friends, libraries, and social media.

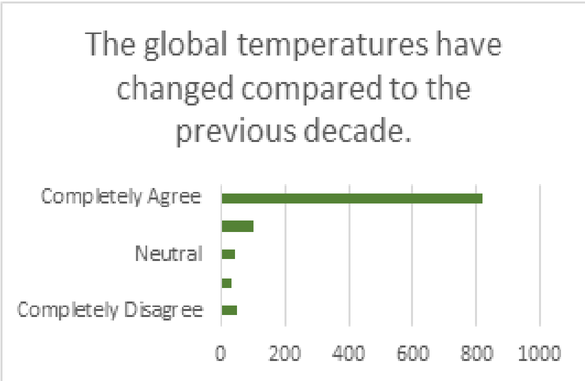
Results

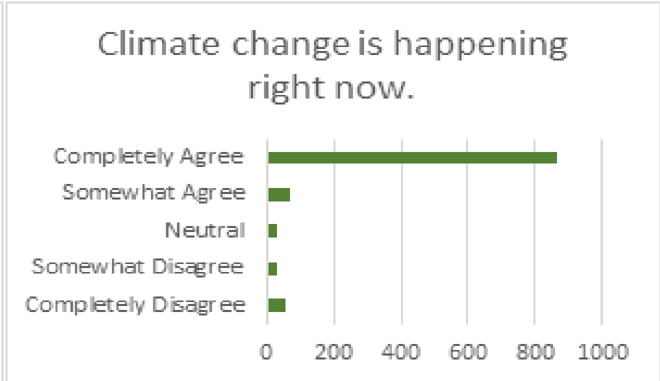
Questions 1 to 4: Climate Change Sentiment

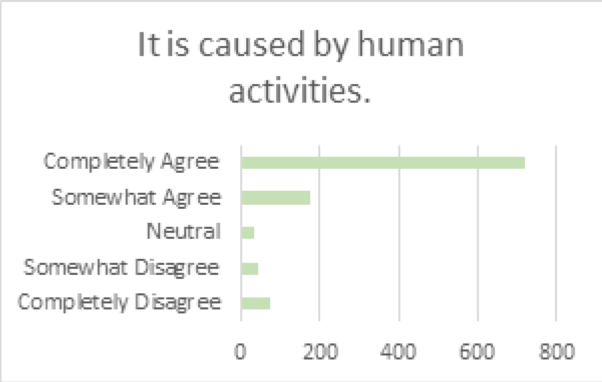
The first set of questions (1-4) asked about public sentiment about climate change. A large majority, 80%, believed that climate change is real and poses a serious threat to people around the world. A smaller percentage, 60%, believe that climate change poses a threat to their community and family. A similar majority, 83%, believed that temperatures have been rising and are caused by human activity.

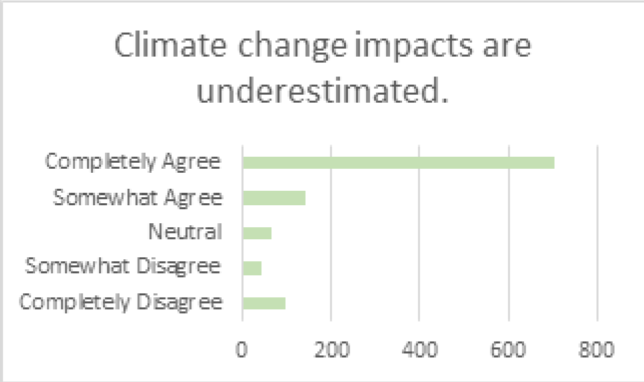
1. **Please state your level of agreement for the following statements regarding global warming/climate change.**





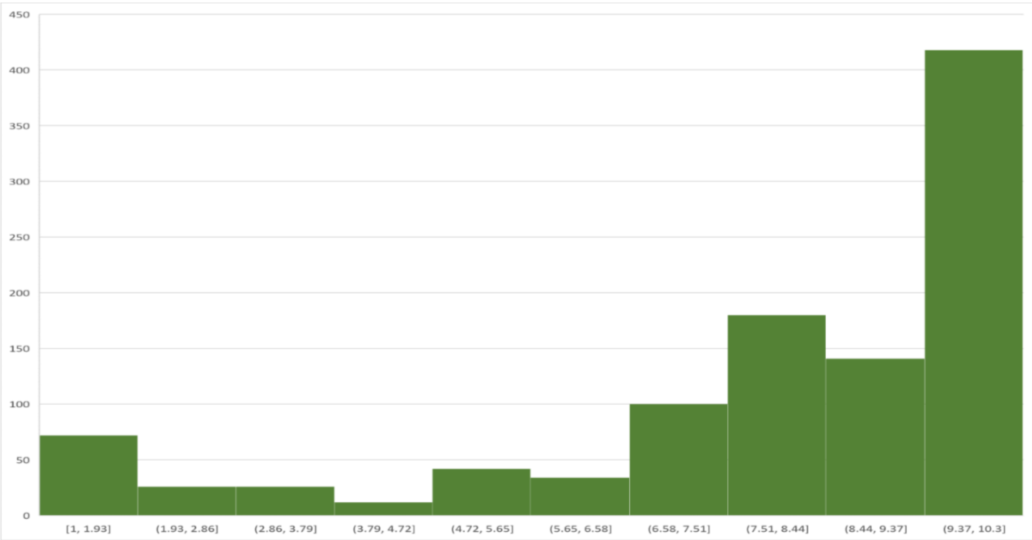






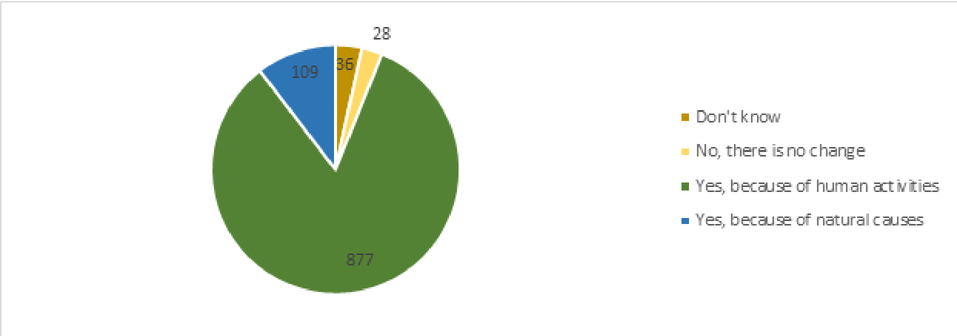
The results from Question 1, show that a large majority of respondents completely agree with the threats of climate change, with the highest percentages of agreement being that climate change poses a serious threat for people around the world (77%); climate change is happening right now (80%); and the global temperatures have changed compared to the previous decade (76%). These results also show that a higher percentage, about 20% more, of people completely agree that climate change poses a global threat than that it poses a personal threat to themselves and their family.

2. **On a scale of 1 to 10 please rate, how much do you believe climate change threatens your personal health and safety?**



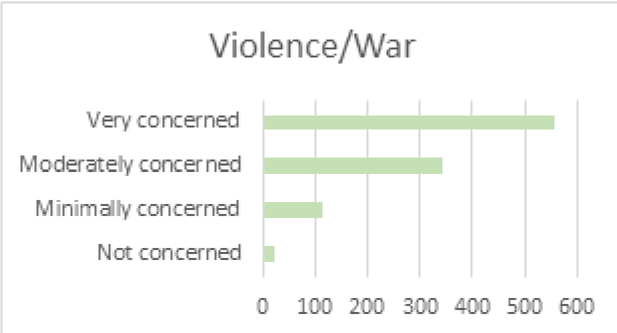
These results show that about 80% of respondents scored their belief that climate change is a threat to their personal health and safety as a 7/10 or higher. A small cluster of people, 6.9%, believed that climate change posed no threat (1/10) to their health and safety. The national average is 47%, according to a Yale Climate Study. [Yale Climate Opinion Maps 2021 - Yale Program on Climate Change Communication]

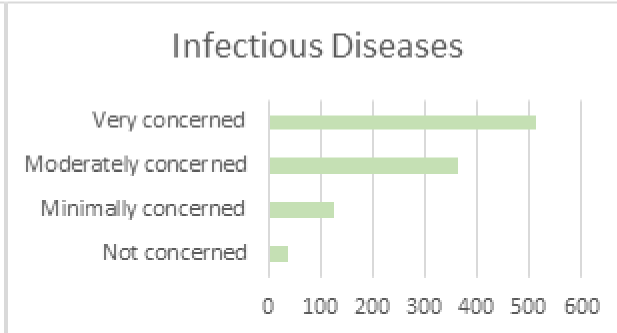
3. Do you believe the temperature on earth has been rising over the past decade?

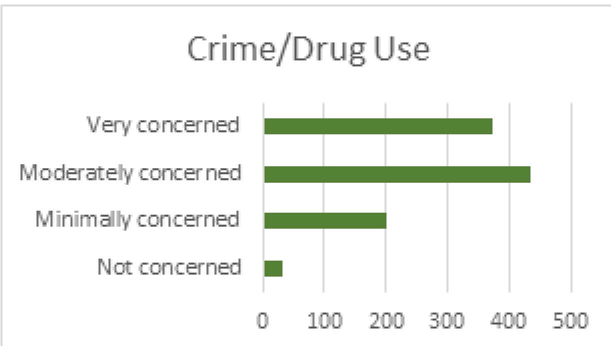


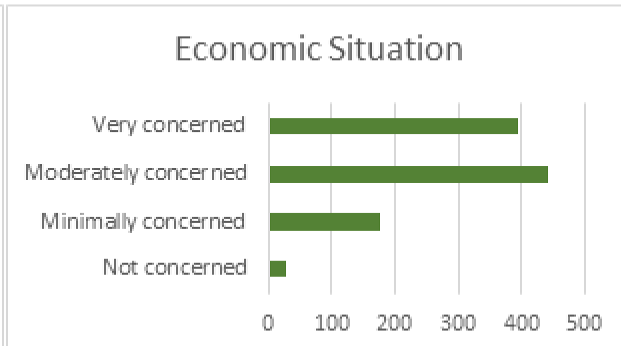
A large majority of respondents, 83.5%, believe that the temperature on earth has been rising over the past decade because of human activities.

4. Which issues are of more concern in your opinion?







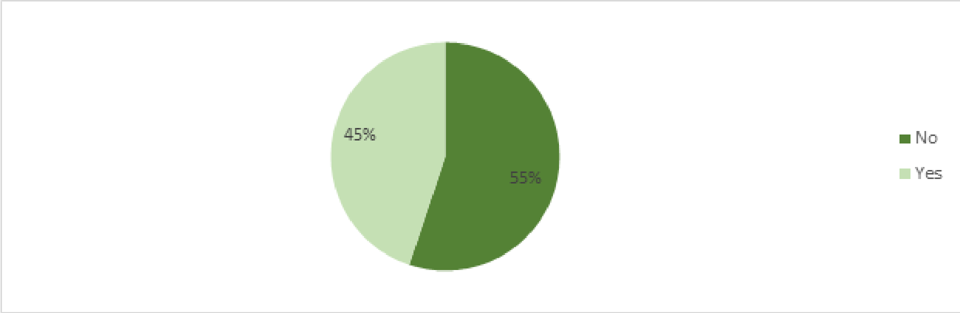


While most respondents agreed most of these problems were very concerning, a larger percentage of respondents ranked climate change as very concerning than ranking issues as very concerning. Climate change also has the highest percentage of respondents, ~8%, who are not concerned about it compared to every other issue. Behind climate change, the highest concerns were violence/war, poverty, and infectious diseases.

Questions 5 to 8: Climate Change Causes, Effects, and Local Initiatives

The second set of questions (5-8) asked about respondents' personal knowledge of climate change and what is being done about it locally. A slight majority, 55%, did not know about local policies taken to reduce climate change. A large majority (~82%) of people described their understanding of causes of climate change, like greenhouse gases, deforestation, and land use, as moderate to advanced. When asked about the importance of local issues, pollution of rivers and oceans and poor waste management were considered the most important.

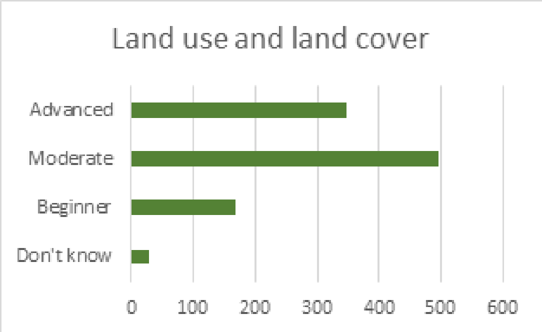
5. **Are you aware of any local policies or initiatives taken by various organizations to reduce climate change/global warming?**

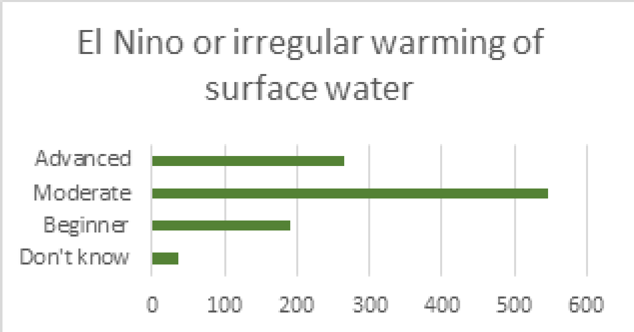


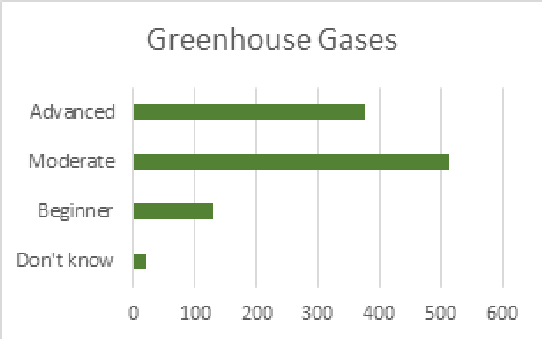
From question 5, while a very high number of respondents are concerned about climate change, a minority, 45%, of respondents know about local policies and initiatives that are being taken to address climate change. This may indicate that there is a gap in connecting communities with climate action resources or that more organizations are needed.

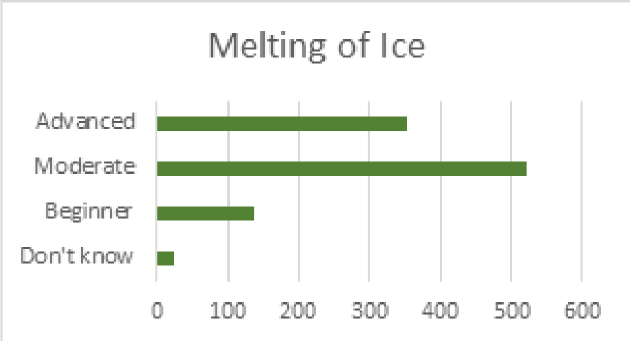
6. **Question 6 asked respondents to share and describe the local policies and initiatives they are aware of if they answered yes to question 5.** The full list of responses has not been included for the sake of privacy.

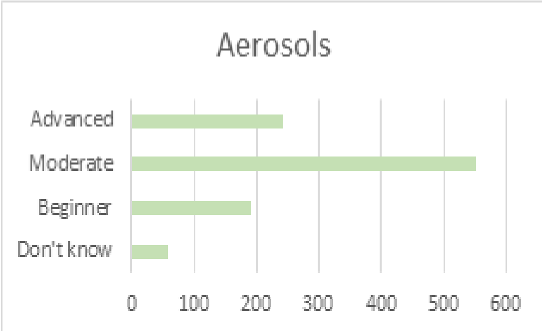
7. **How would you describe your understanding of these causes of climate change?**

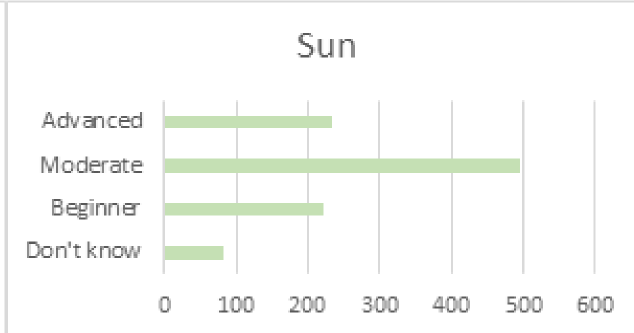


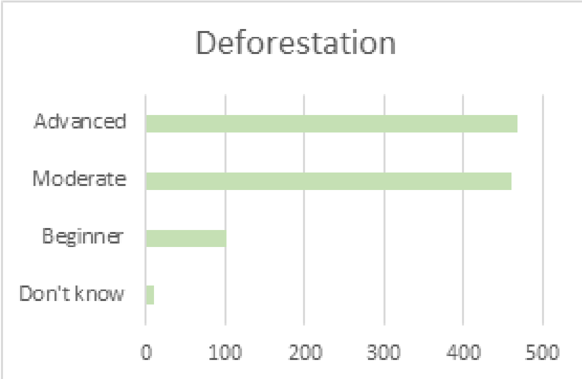






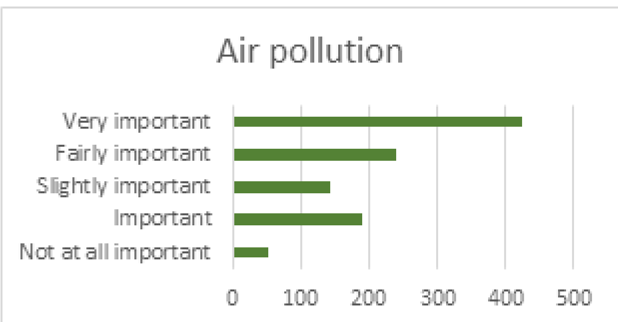


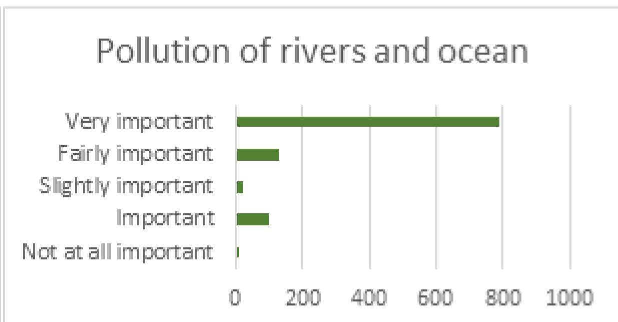


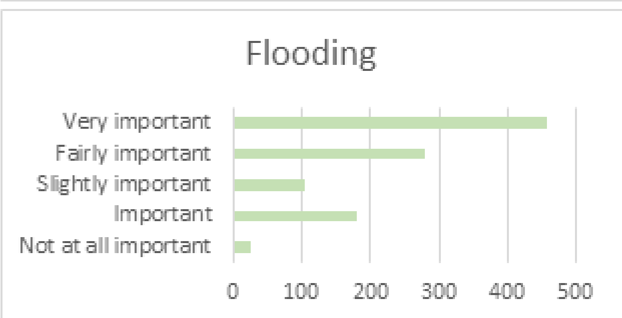


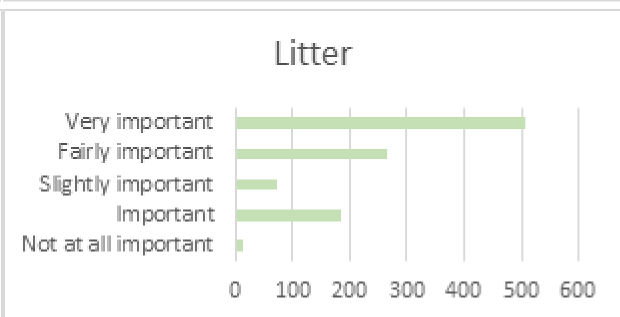
These results show that most respondents consider their understanding of the causes of climate change as moderate to advanced. For each category of knowledge, very few people, with an average of 16%, ranked themselves as beginners, and even fewer ranked themselves as having no knowledge.

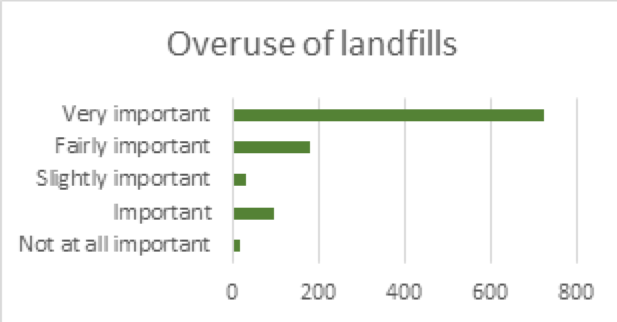
8. In your opinion, how important do you think the following issues are on a local scale?

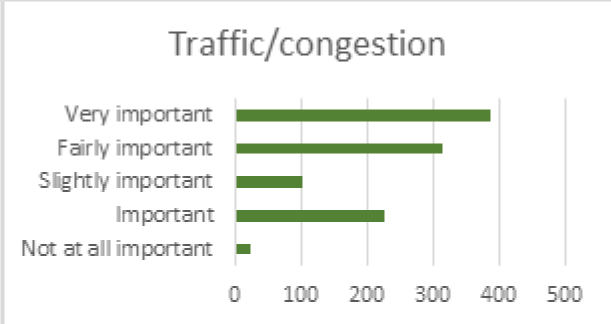


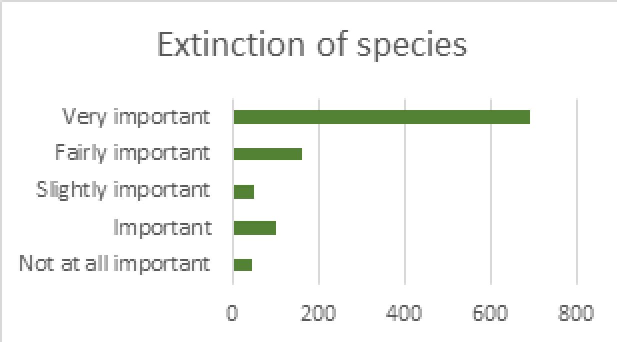


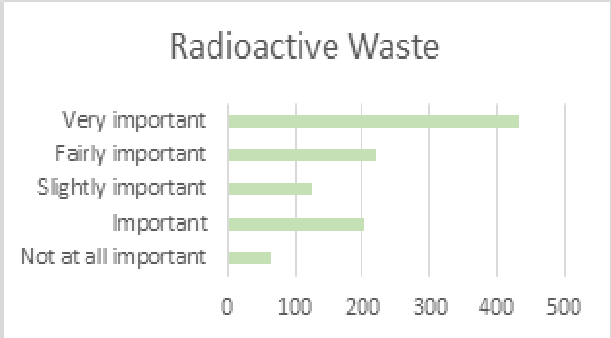


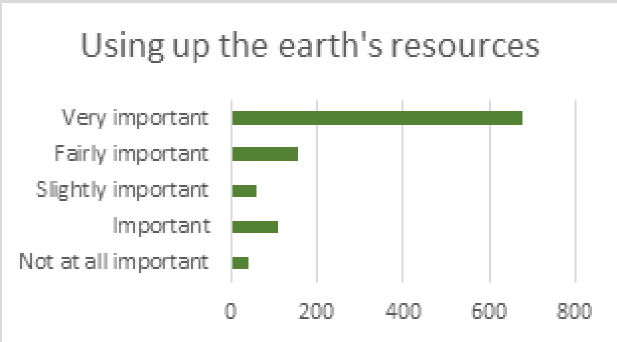


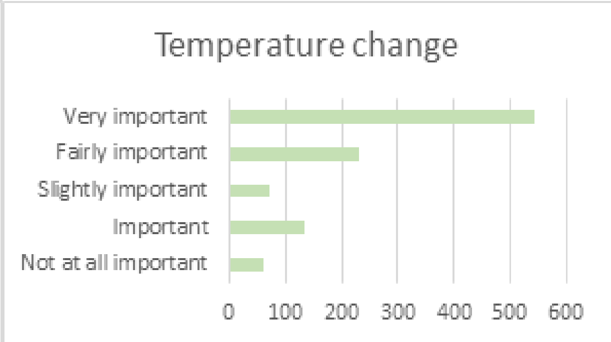


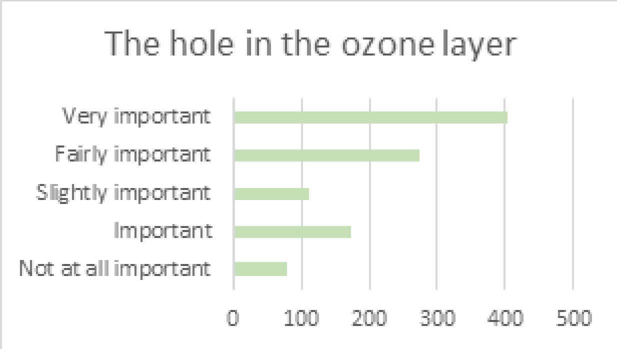


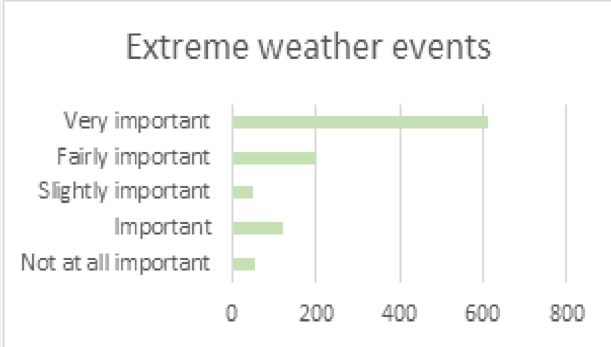










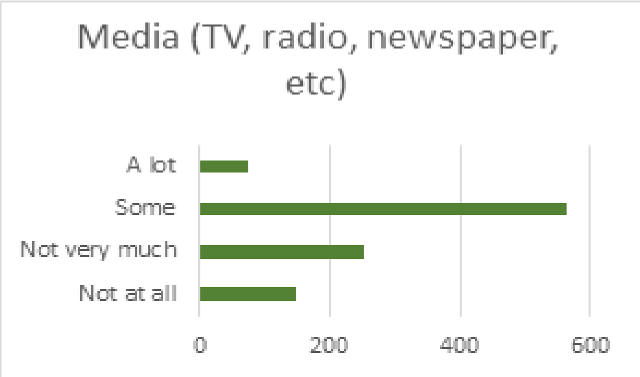


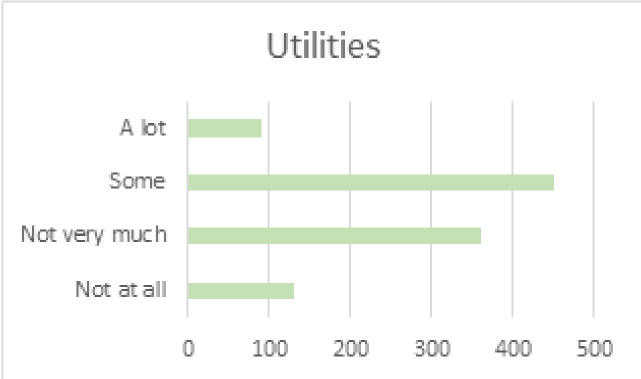
These results show that the issues of largest concern were pollution of rivers and the ocean, poor waste management, using up the earth's resources, extreme weather events, and extinction of species, as over 600 respondents ranked these issues as "very important." These took higher importance than temperature changes, flooding, litter, and air pollution. Traffic / congestion, radioactive waste, and a hole in the ozone layer ranked as least important. For every topic, the largest percentage of respondents ranked the topic as "very important."

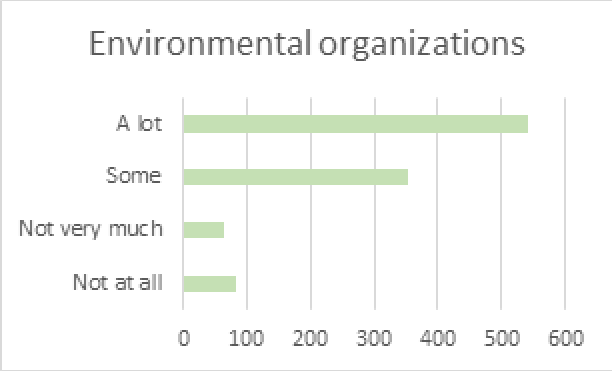
Questions 9 to 14: Climate Action Responsibility & Information Reliability

The third set of questions (9-14) asked about responsibility for change and trust of others when it comes to climate change. From the results, people have a very high trusts in scientists about climate change information, followed by environmental organizations. A majority believed that government, industries/businesses, and scientists have the highest amount of responsibility to address climate change. These questions determined places people hear about climate change, and where they would spread information about climate change. Some of the most popular answers for 13 included TV, newspaper, academic journals, school, friends and colleges, and social media. In question 14, common answers included the internet, school, the newspaper, friends, libraries, and social media.

9. How much would you trust information about climate change, if you were to receive it from the following?

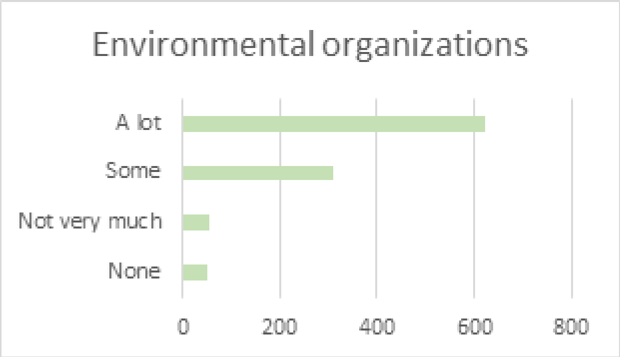


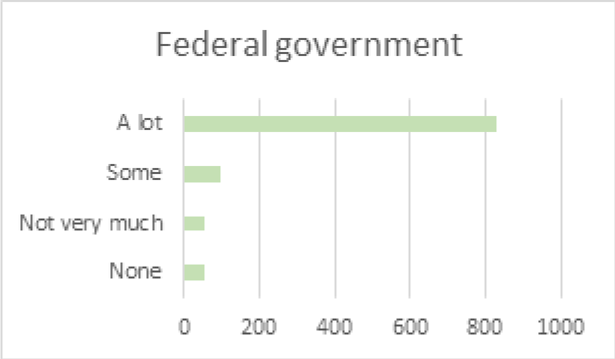


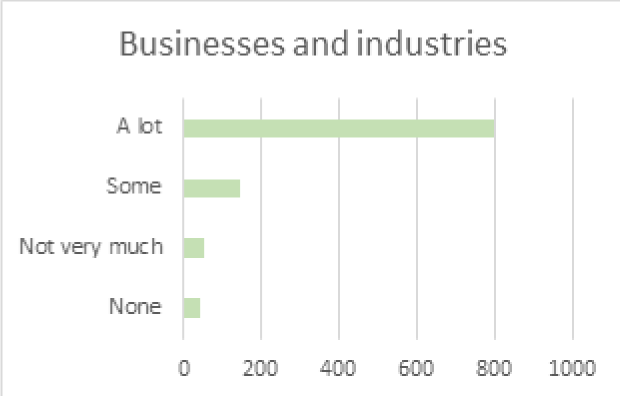


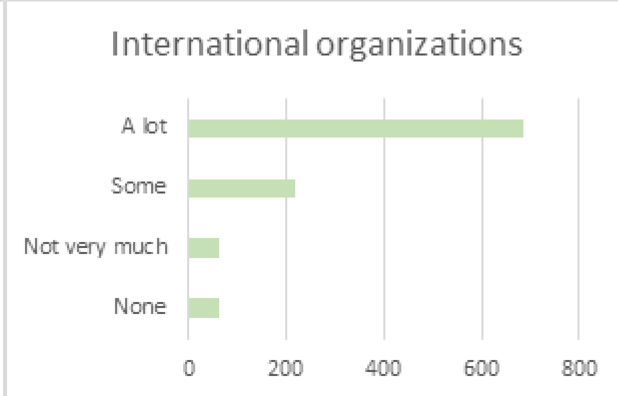
According to the answers, respondents have the highest trust in scientists when it comes to climate change information, after that "some" trust is spread across most of the other options, including family/friends, government, and media. Scientists also had the lowest amount of distrust from respondents. How much responsibility do you believe these organizations have to address climate change?

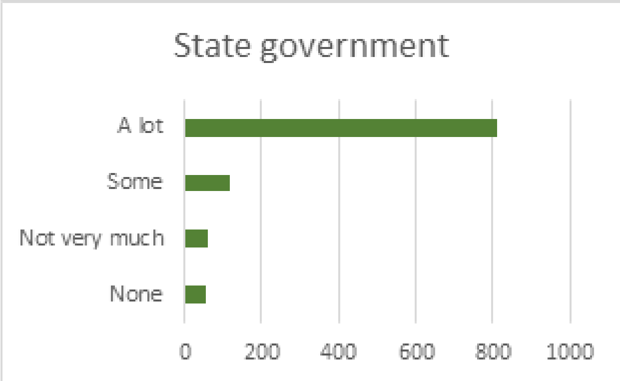
10. How much responsibility do you believe these organizations have to address climate change?

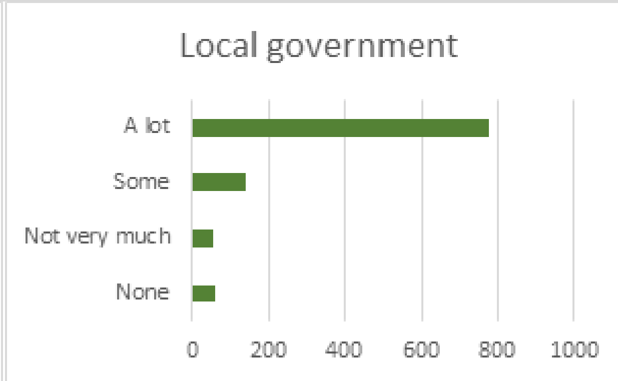


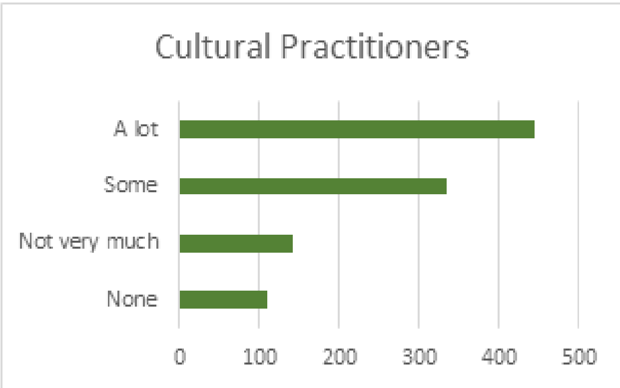


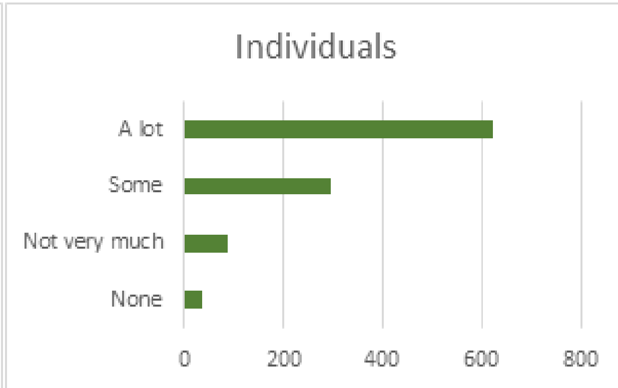


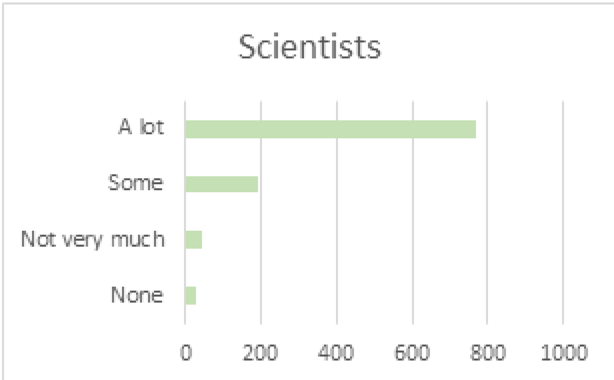






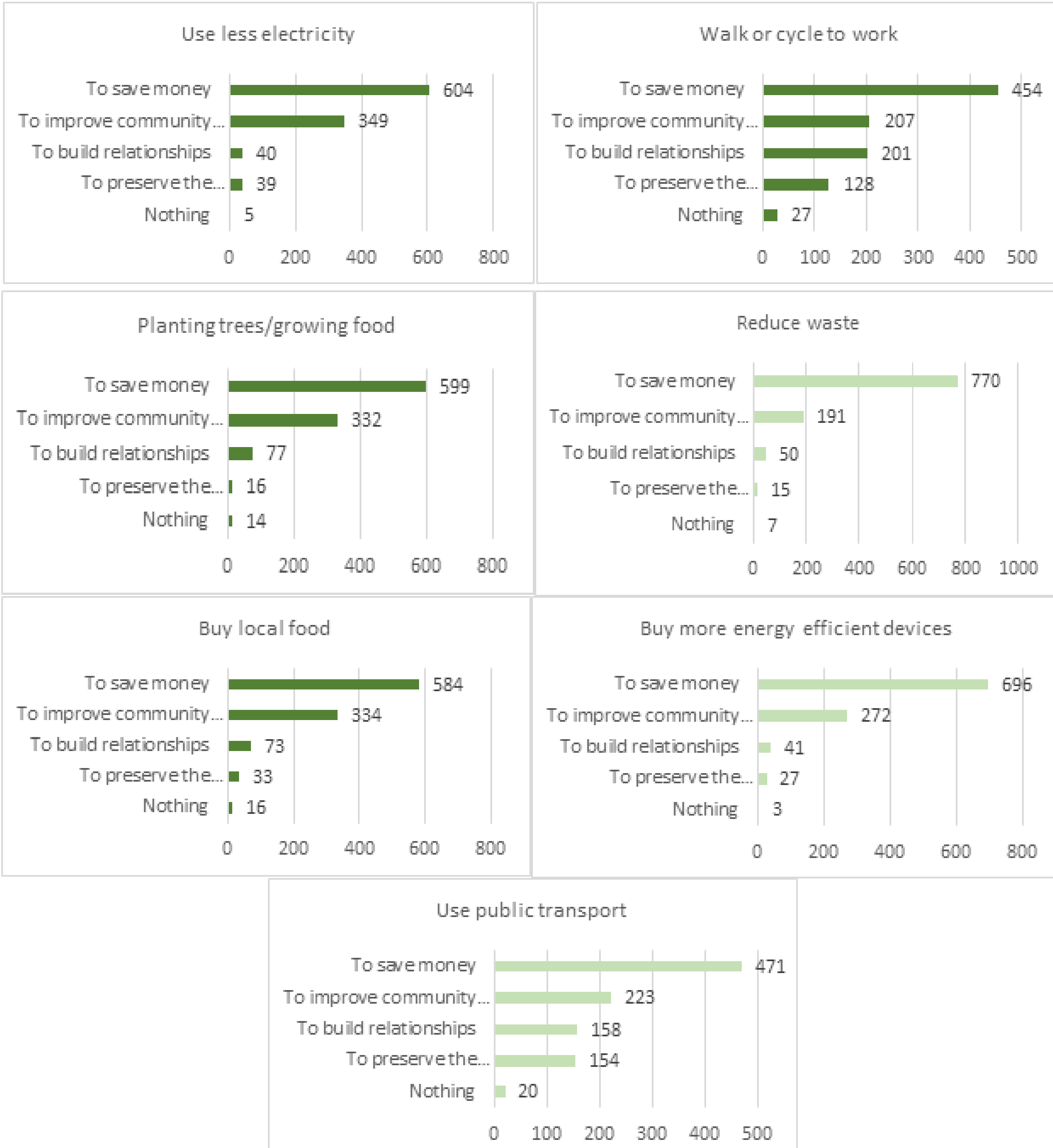






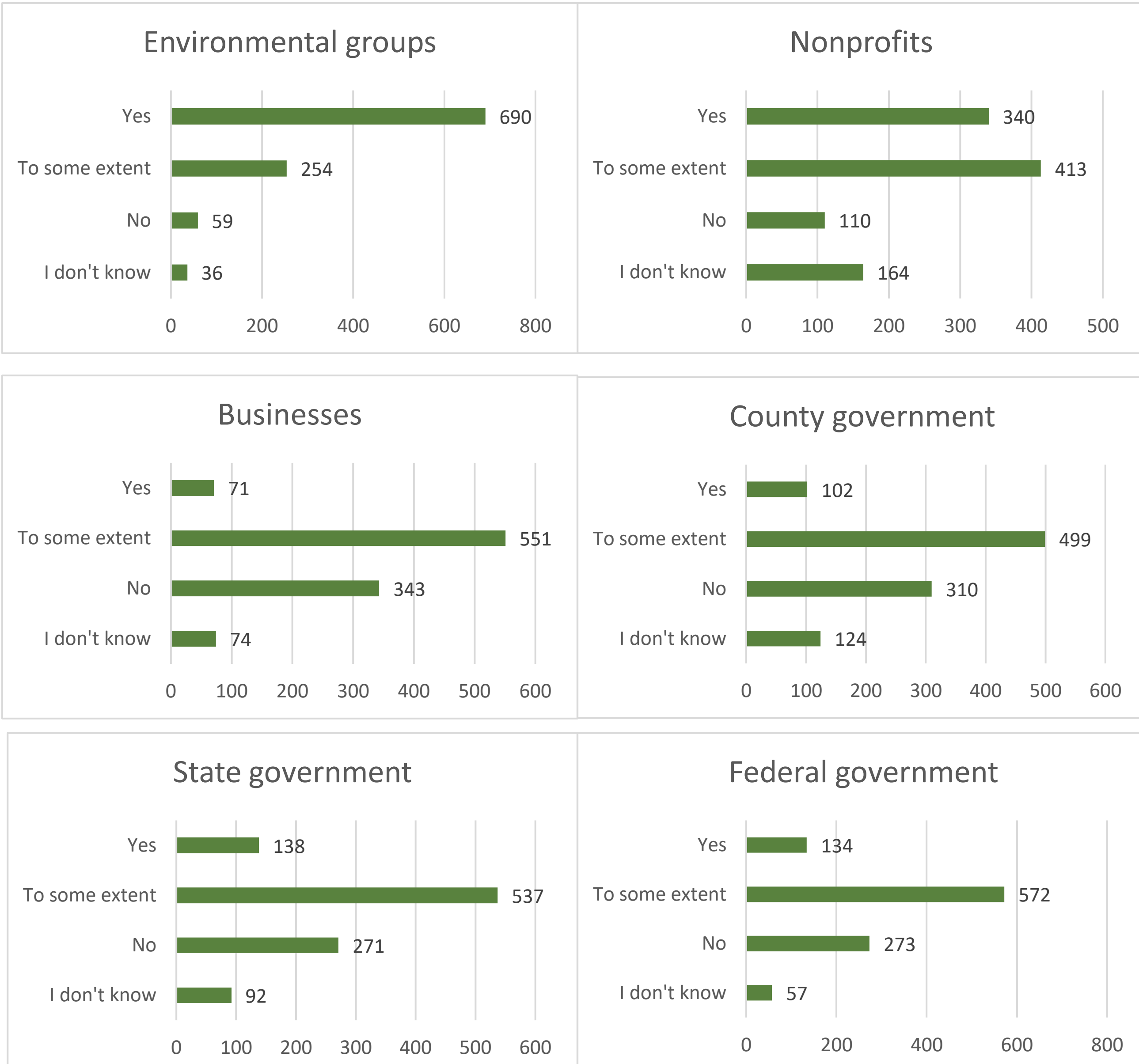
A majority believed that government, industries/businesses, and scientists have the highest amount of responsibility to address climate change, and individuals and cultural practitioners have the lowest amount of responsibility to address climate change.

11. Which of the following reasons would motivate you to do the following activities?



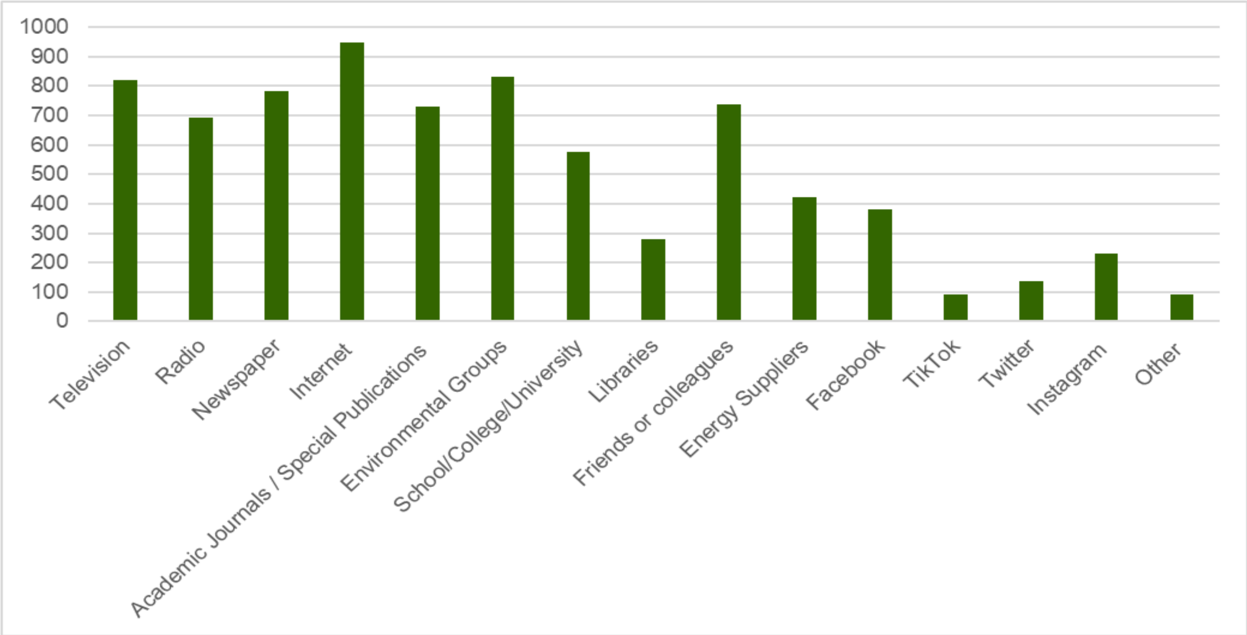
Respondents most commonly answered that they would be motivated to do the following actions to preserve the environment: use less electricity, buy more energy efficient devices, and reduce waste. People were less inclined to walk or bike to work or use public transportation for any of the given reasons.

12. Do you think the following entities are taking initiatives to reduce climate change?



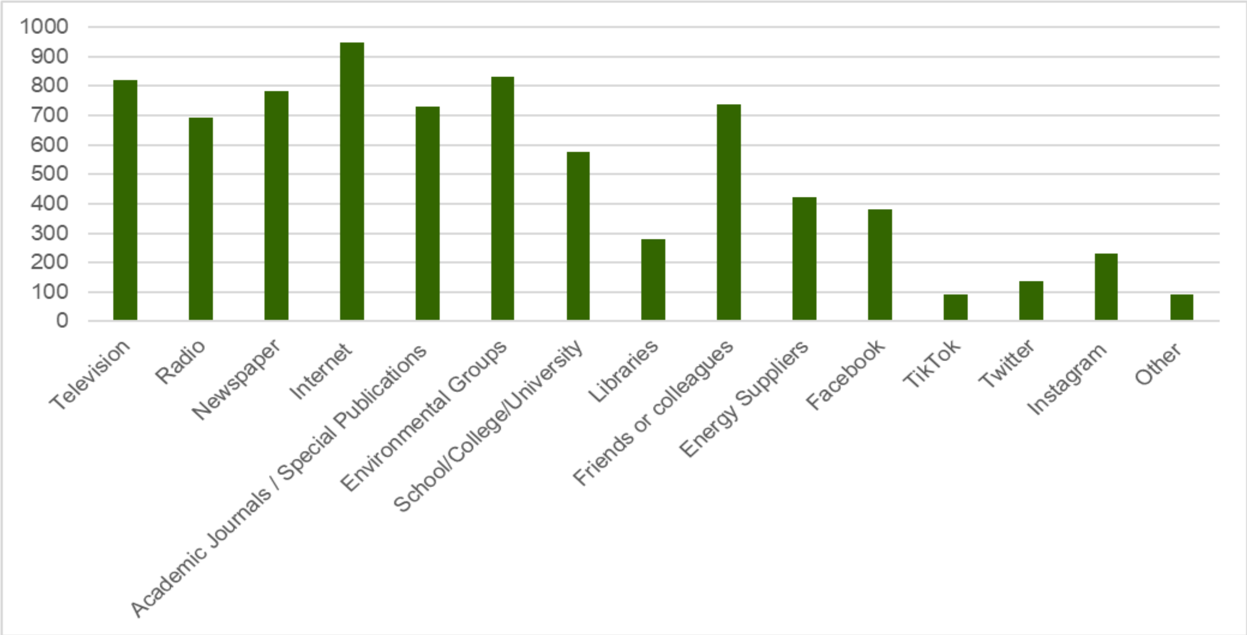
When asking about who they thought were taking initiative on climate change, environmental groups was the most common answer. Others like businesses and government were thought to only be taking initiative “to some extent.”

13. Where have you heard about climate change? Select all that apply.



Some of the most popular answers for 13 included TV, newspaper, academic journals, school, friends and colleges, and social media.

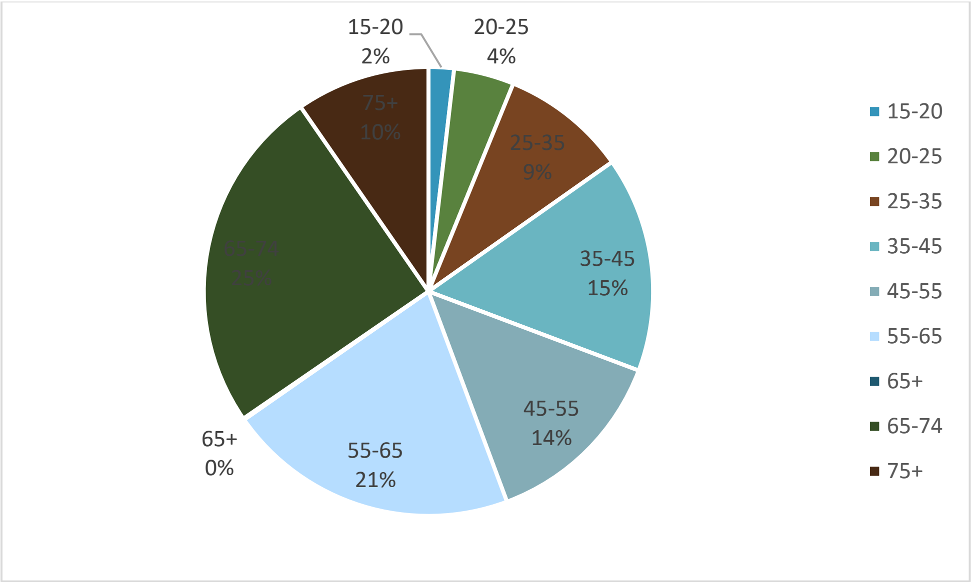
14. How would you increase awareness about climate change? Select all that apply.



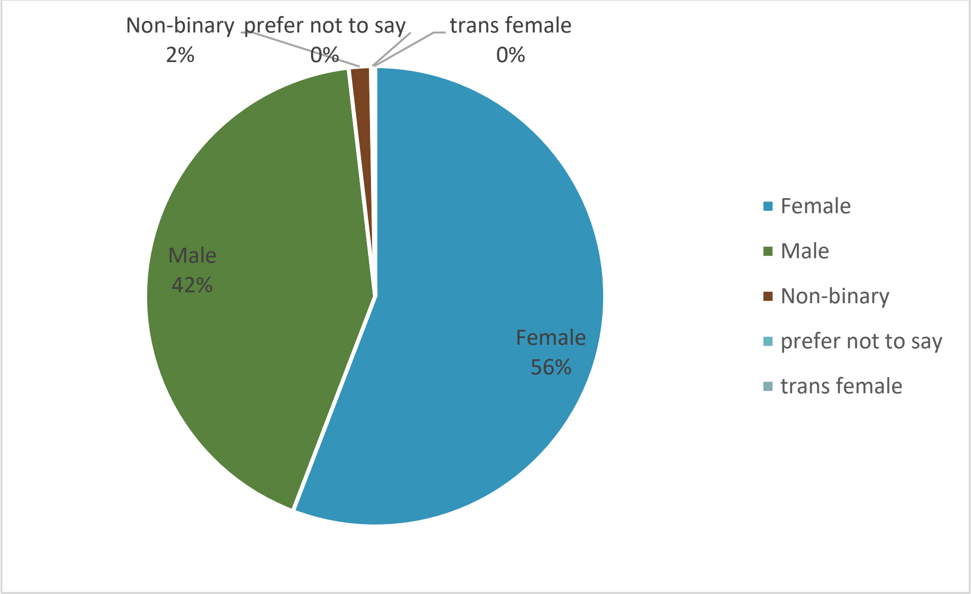
In question 14, common answers included the internet, school, the newspaper, friends, libraries, and social media.

Questions 15: Demographics

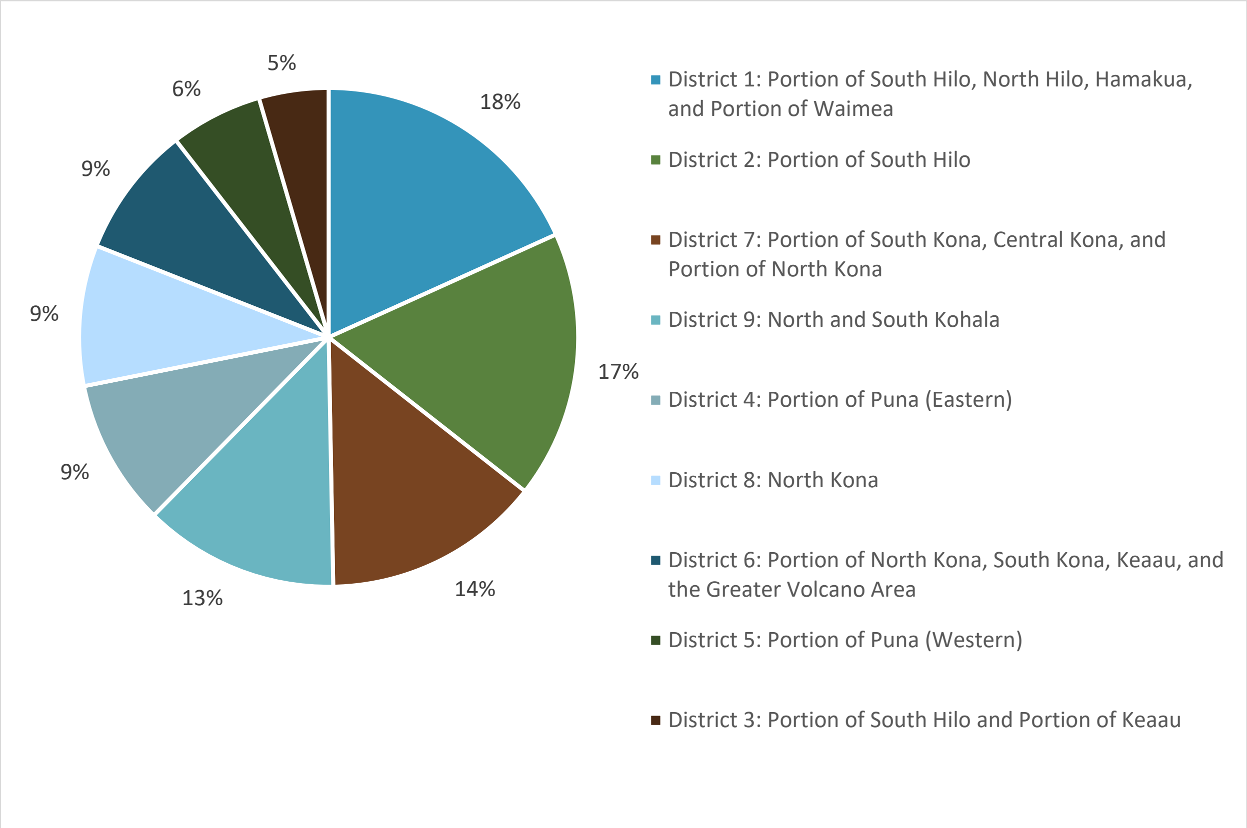
15. How old are you?



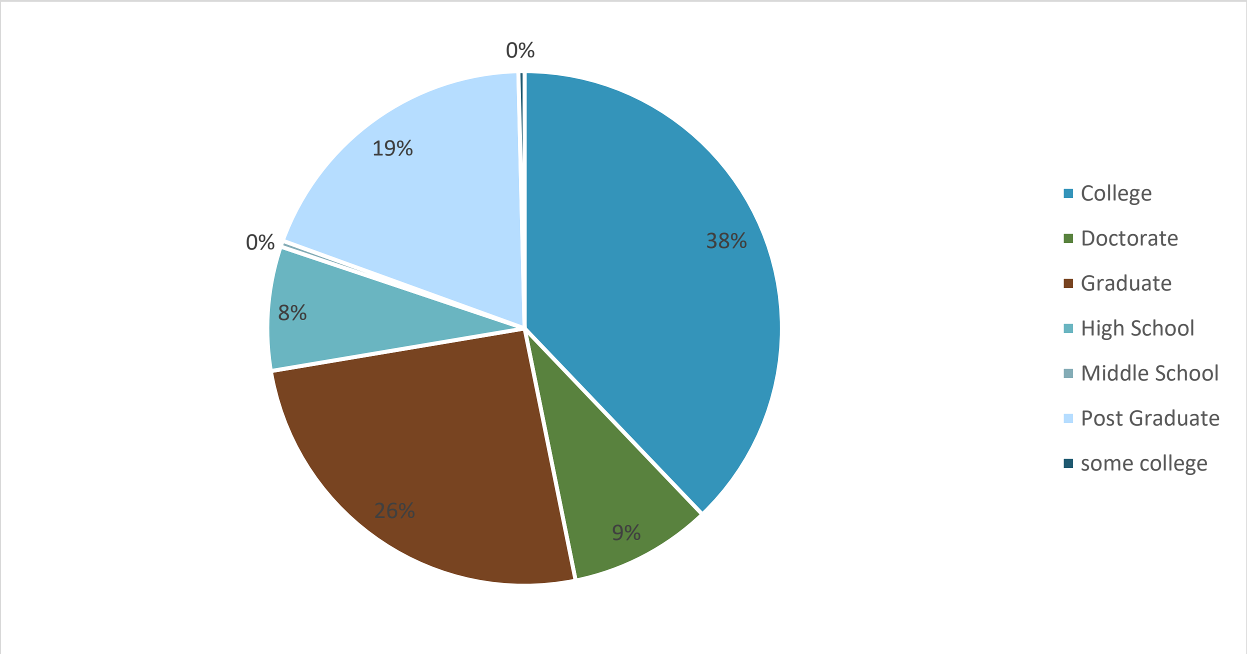
16. Gender



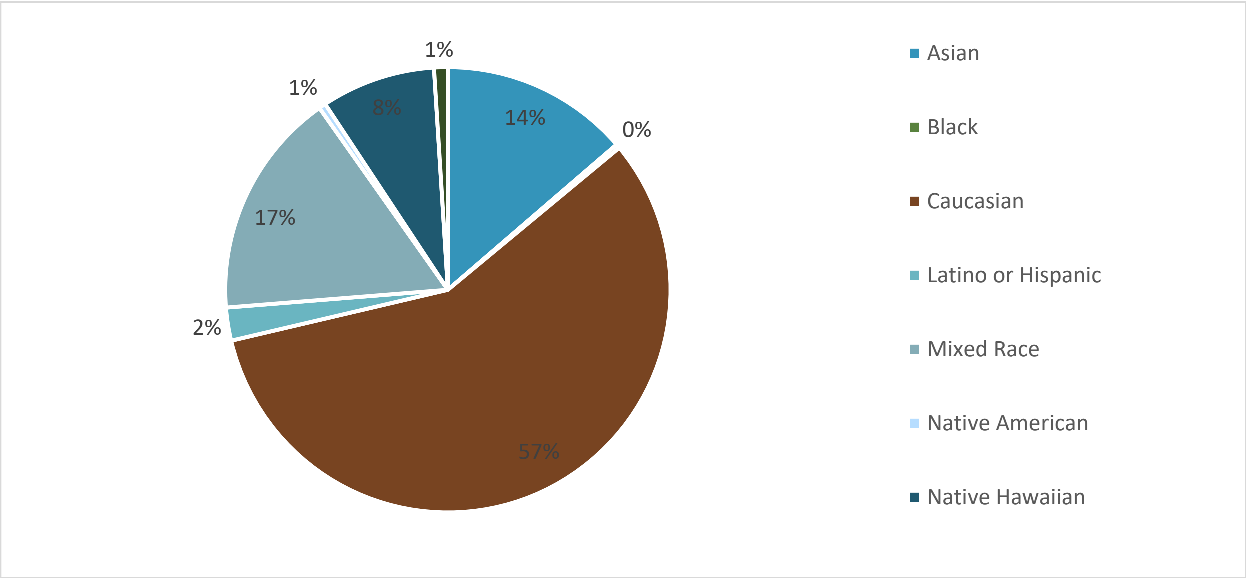
17. Which district do you live in?



18. What is your highest level of education?



19. What is your race?



Bias

From the demographic responses of the survey, it is clear there was bias in the answers. One of the most significant percentages was that 82% of respondents are college educated. In comparison, the US census reports that only 29.5% of residents on Hawaiʻi Island are college educated. As well, 59% of respondents identify as white, while the US census reports that only 34.3% of Hawaiʻi Island residents identify as white. This would imply that a majority of respondents were college educated white people, who do not accurately represent Hawaiʻi and its opinions on climate change as a whole. Therefore, it is important to acknowledge that these survey results will not be broadcasted as an island wide opinion on climate change.

A recent Yale study says that about 72% of people across the US believe in climate change, while about 80% of this survey responded believing in climate change. About 75% of respondents considered their knowledge of climate change causes “advanced” or “moderate”, indicating that the respondents are more knowledgeable about climate change and the island than the national average of people. Therefore, this would give bias towards the belief that climate change is real.

High-Level Conclusions

- A majority of respondents believe climate change is a threat to Hawaiʻi Island and themselves personally.
- Overuse of landfills, extinction of species, pollution of the Earth’s oceans and rivers, and using up the Earth’s resources were all identified as highly important issues by the majority of respondents.
- A vast majority of respondents believe local government has a responsibility to address climate change, but most respondents only have “some” trust in the information disseminated by governments on climate change.