Social Vulnerability to Climate Change in Hawai‘i

Data, Indicators, and "Gap" Assessment

A Report to The State of Hawai‘i Climate Change Mitigation and Adaptation Commission

May 4, 2022

Makena Coffman
Director, Institute for Sustainability and Resilience
Professor, Urban and Regional Planning
Research Fellow, University of Hawai‘i Economic Research Organization

Suwan Shen
Associate Professor, Urban and Regional Planning

Maja Schjervheim
Climate and Energy Analyst
Institute for Sustainability and Resilience
University of Hawai‘i Economic Research Organization

UNIVERSITY of HAWAI‘I at MĀNOA
INSTITUTE for SUSTAINABILITY and RESILIENCE

Executive Summary

The State of Hawai'i Climate Change Mitigation and Adaptation Commission's statement on climate equity urges government entities in Hawai'i to:

- "Use a vulnerability framework that is appropriate for Hawai'i, and incorporate cultural responsiveness, reflect indigenous voices and customary law practices to identify any inequitable distribution of benefits, burdens and processes caused by climate change impacts and policy; and

- Recognize and address the inequitable distribution of benefits, burdens and processes, by incorporating equity considerations into their planning, policy development and implementation for climate change mitigation, adaptation and resilience (Hawai'i Climate Change Commission, 2019)."

To advance the mission of the Commission, this report presents conceptualizations for understanding the social dimensions of vulnerability to climate change as well as available data that represent climate change exposure, vulnerability and adaptive capacity. The aim of this project was to work with the Commission, its members and stakeholder groups, to understand how existing social vulnerability indicators (SVI) and other spatially-explicit climate-related data tools are currently being used to aid in decision-making for climate change adaptation. We provide a review of the application of SVI within existing climate change resilience-related planning documents as well as a review of best practices within peer-reviewed literature. We provide a landscape assessment of existing publicly available data, as well as identify data gaps, that relate to a range of SVI and climate change exposures. Climate change exposures are organized by those that happen suddenly (shocks) or more gradually (stressors). This assessment is used to create a "guide" for Commission actors, and others interested in regional-scale climate change vulnerability assessment, to build upon.

Key findings of the project are as follows:

- Studies find that composite indexes (i.e. those that aggregate multiple types of SVI) have the potential to skew information such that it can result in unproductive policy recommendations (Wood, 2021). Commission stakeholder members (the Commission's "Equity Hui") agreed that disaggregated data is more useful to better tailor inquiries. As such, we recommend working with multiple and disaggregated SVI to inform particular aspects of social vulnerability in relation to climate change impacts, rather than developing a statewide vulnerability index.
- There was general agreement in the feedback from Hui members on the "guide" that it would be most usefully provided in a centralized data hub. Multiple Hui members said that they would use this kind of SVI information in their work if it were more easily accessible, as it is often outside of organizational capacity to build and operationalize this kind of dataset internally. The next step for the guide should include both be an easy-to-use web interface for the purposes of quick data visualization, as well as a database that would enable more detailed, tailored analyses.

- Data should be made available in a spatial format (i.e. GIS) and at the lowest available spatial scale to best uncover geographical variations in vulnerability as they relate to climate change exposure.
- Though there is often broad acknowledgement of the importance of taking into account social vulnerability in climate-related decision-making in Hawai'i, there are sparse examples of doing so in detailed ways within existing climate-related adaptation planning. Multiple Hui members expressed that they would like to better operationalize SVI within their practices, but need capacity and expertise to analyze available information and build processes for integration of SVI into decision-making.
- A next step for the Commission could be to pursue working with a collective of state and county departments/agencies, perhaps organized around a heavily climate impacted sector (like transportation), to better understand the needs of specific departments and which SVI could be prioritized for sector-specific purposes.
- There are many data gaps as it pertains to understanding both climate change exposure and SVI.
    - Because social vulnerability to climate change can only be understood in the context of climate change to the degree that exposure data is precise and up to date, it is important to continually increase capacity for future climate forecasting, as exemplified in the recent release of the Hawai'i Climate Data Portal. An important exposure gap, for example, relates to data on heat extremes. The State and partner entities should continue to pursue the development of increasing and improved climate exposure data.
    - In regards to SVI, the conversations with Hui members and review of frequently used vulnerability indicators revealed multiple data gaps and concerns. Specifically:
        - Regarding more granular census data for Pacific Island ethnic groups, especially Native Hawaiians.
        - Data on homeowners and renter's insurance relative to various environmental hazards.
        - Comprehensive data describing housing characteristics that affects sensitivity to exposure.
        - Improved data on vulnerable infrastructure, compounding vulnerabilities (like communities served by few and vulnerable roadways), and broader adaptation efforts.
- Lastly, this project focused on identifying quantitative indicator-based approach to assessing social vulnerability to climate change, as an initial means of understanding the uneven distribution of climate-related impacts. An indicator-based approach helps to identify the characteristics, contexts and spatial distribution of vulnerability. While this is an important first step, there are notable limitations and thus should not be a singular approach. Specifically, public outreach and qualitative assessments will be necessary to make more informed and holistic decisions around social vulnerability and climate change impacts – particularly where quantitative data is incomplete, outdated, or simply fails to capture important measures of adaptive capacity. Moreover, identifying vulnerability itself is not enough to measure the impacts of climate-related policy and intervention. Thus, additional analyses will be important to understand and anticipate the impacts of climate-related policy action to ensure that the Commission's equity mission is truly met.

Table of Contents

List of Tables

List of Figures

I. Introduction

Climate change will have dramatic impacts to natural and human systems across the world (IPCC, 2021). Regional impacts of climate change in Hawai'i can already be observed, from increasing mean sea level to changing rainfall patterns (City & County of Honolulu Climate Change Commission, 2018; Keener et al., 2018). There is increasing understanding of regional climate change impacts and attention to identifying and quantifying changing local environmental hazard conditions. Important examples include sea level rise (SLR) exposure maps that represent multiple coastal hazards and the Hawai'i Climate Data Portal that provides detailed historical data on rainfall and temperature (Hawai'i Climate Change Mitigation and Adaptation Commission, 2021; Longman et al., In Preparation). Improved spatial granularity and projection capabilities regarding mounting climate-related environmental hazards critically underpin the ability of decision-makers - from government to community organizations to households - to take more informed actions in response to rapid environmental change. Directing governmental responses to climate change at a regional scale in an equitable manner prompts the need for additional tools that help to characterize the exposure, vulnerability and adaptive capacities of the diverse communities to which they serve.

The State of Hawai'i Climate Change Mitigation and Adaptation Commission consists of a multi-jurisdictional effort between 20 different departments, committees and counties. Its' mission statement lifts the concept of "equity" as one of the three key considerations that should guide all climate change response actions for the State - the other two being "clean" and "resilient." In its "Statement on Climate Equity," the Commission urges government entities in Hawai'i to:

- Use a vulnerability framework that is appropriate for Hawai'i, and incorporate cultural responsiveness, reflect indigenous voices and customary law practices to identify any inequitable distribution of benefits, burdens and processes caused by climate change impacts and policy;

  and

- Recognize and address the inequitable distribution of benefits, burdens and processes, by incorporating equity considerations into their planning, policy development and implementation for climate change mitigation, adaptation and resilience (Hawai'i Climate Change Commission, 2019).

To advance the mission of the Hawai'i Climate Change Mitigation and Adaptation Commission and its issued statement on equity, this report presents conceptualizations for understanding the social and economic dimensions of vulnerability to climate change as well as publicly available data that represent climate change exposure, vulnerability and adaptive capacity. The aim of this project was to work with the Commission, its members and stakeholder groups (called the "Equity Hui" by the Commission) to understand how existing social vulnerability indicators/indexes[1] (SVI) and other spatially-explicit climate-related data tools are currently being used to aid in decision-making for climate change adaptation. With a better understanding of how a variety of entities are (or are not) using existing tools, we provide a review of the application of SVI within existing climate change

[1] "Indicator" is defined herein as data that describes a particular aspect of vulnerability, while an "index" is an aggregate metric that combines more than one indicator into a single vulnerability score. Indexes and indices are both the plural of "index," and can be used interchangeably. We use "indexes" for consistency.

resilience-related planning documents as well as a review of best practices within peer-reviewed literature. We provide a landscape assessment of existing publicly available data, as well as identify data gaps, that relate to a range of SVI and climate change exposures. Climate change exposures are organized as those that happen suddenly (shocks) or more gradually (stressors). This assessment is used to create a "guide" for Commission actors, and others interested in regional-scale climate change vulnerability assessment, to build upon. The guide organizes relevant climate change exposure and social vulnerability data such that future work could operationalize its information into both an interactive online viewer as well as a more comprehensive database that is able to be tailored for specific analyses. This report and resulting guide offers an initial step towards conceptualizing the human dimensions of climate change impacts in Hawai'i.

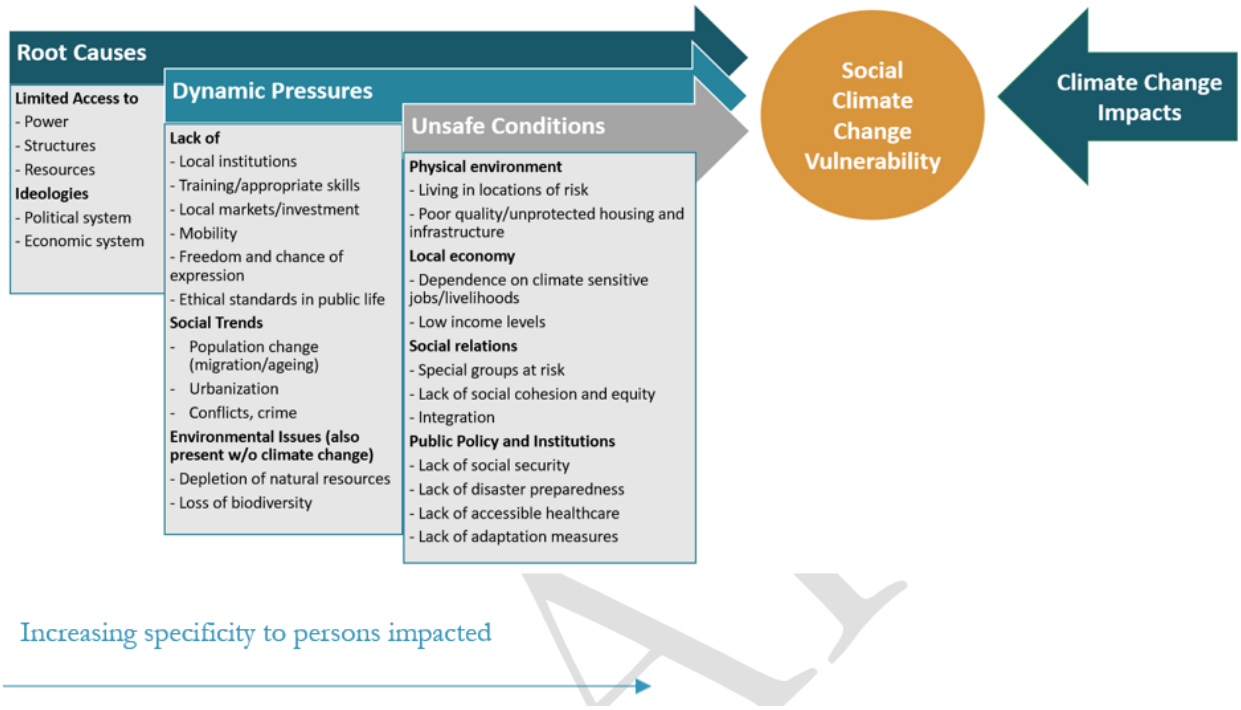
II. The Concept of Social Vulnerability

Rooted in the hazard research paradigm, the term "vulnerability" is widely acknowledged as a concept for understanding the conditions of people and the environment that enable a hazard to become a disaster (Adger 2006; Cutter, Boruff, and Shirley 2003; Kuhlicke et al., 2011; Blaikie et al., 1994). Cutter, Boruff, and Shirley (2003) summarized three major conceptual models in vulnerability research: 1) models that identify the environment that makes people or places vulnerable to severe natural hazards (i.e. what we often call "exposure") (Burton, 1993); 2) models that focus more on the social conditions that shape different societal resilience to hazards (i.e. what is often called "social vulnerability") (Blaikie et al., 1994); and 3) models that integrates the physical exposures and social vulnerability with an emphasis on their interaction in specific places (Cutter, Mitchell, and Scott, 2000, Cutter, 1996). These three approaches show how the field has evolved from earlier approaches that were more centered around solely physical events to better incorporating more people-centered drivers of vulnerability.

Following these tenets, empirical research has focused either on the unequal exposure of various groups to natural hazards or the unequally distributed capacity to prepare and respond to disasters. In particular, social vulnerability is often viewed as the product of social inequality that influences or shapes various groups' susceptibility to harm as well as their ability to respond (Spielman et al., 2020). However, while social vulnerability has become a buzzword that has been widely used for decades, there is still no consensus among scholars with regards to its concepts, approaches, and indicators (Kuhlicke et al., 2011). The major point of contention is the tension between capturing the root causes and/or broader context that contributes to the creation of vulnerability, and the ability to operationalize the concepts to support empirical testing and decision-making.

The most common conceptual framework for social vulnerability in the environment and development literature is derived from a political ecology perspective, which examines the role of human agency and attributes the drivers of vulnerability to the social, political, and economic pressures that limited individuals' actions and abilities to deal with disasters (Zimmerer and Bassett, 2003; Forsyth, 2004; Bebbington et al., 2008). Another well-known theoretical framework is the "pressure and release" model proposed by Blaikie et al. (1994). It is based on the concept that disaster occurs at the intersection between social vulnerability on one side, and natural hazards on the other, creating pressure that leaves people vulnerable to hazards. Accordingly, disaster is mitigated when pressure is "released" by reducing social vulnerability.

Figure 1. The Pressure and Release model: the progression of social vulnerability to climate change



Source: As shown in Breil et al. (2018), adapted from Blaikie et al. (2003).

As shown in Figure 1, the model tracks the formation of vulnerability from root causes (e.g. limited access to power, political ideologies) through dynamic pressures (e.g. lack of local institution, urbanization, loss of biodiversity) to unsafe conditions (e.g. residence at risk, dependence on climate-sensitive jobs, lack of social cohesion). As such, the model describes how vulnerability originates in more overarching and diffuse societal structures and is transferred to specific individuals via local institutions, policies, and trends. While the model helps to understand the social progression of vulnerability, it has been criticized for its failure to adequately address the interaction between the social and natural systems and is difficult to operationalize in empirical testing (Cutter et al., 2009). A more combined approach (Cutter, 1996) looks at both the risk/hazard and political ecology perspectives to describe the placed-based interaction between biophysical exposure and the overall determination of social costs of hazards.

The indicators of social vulnerability

Because of the dynamic nature of social vulnerability, there is no consensus regarding its precise meaning or indicators (Lee 2014; Adger and Agnew, 2004; Khan, 2012). Evaluating vulnerability varies substantially among disciplinary fields, depending on the geographical scale of interest and applications (Lee, 2014). Regardless of these differences, there are many efforts to develop indicators and indexes to measure social vulnerability (King and MacGregor, 2000; Tapsell et al., 2002; Cutter et al., 2003; Lee, 2014), following the tradition of indicator development within the social and environmental sciences with the intent to put social inequality and environmental justice into practice (Cutter et al., 2009; Lee 2014; Walker, 2009). While there are disagreements regarding the specific types of indicators that best represent the broad concepts of relevant factors, hazard researchers generally agree on the main factors that influence social vulnerability, characterized in

four main dimensions based on disaster response capacity: demographic characteristics, social and economic characteristics, community social capital, and public infrastructure and resources (Lee, 2014; Kuhlicke et al., 2011). The first two dimensions, demographic characteristics and socioeconomic characteristics include many measures of social class, which is often viewed as one of the largest contributors to social vulnerability (Burton and Cutter, 2008). Third and fourth dimensions include other marginalization factors that influence social vulnerability through a lack of access to resources, limited access to political power and representation, or economic marginalization (Cutter et al., 2003; Burton and Cutter, 2008; Singh et al., 2014). Factors such as employment, income, education, and housing tenure type combined with social capital, social dependence, access to services, and infrastructure availability have a significant influence on economic losses, injuries, fatalities and ability to recover from natural hazards (Cutter et al., 2003; Singh et al., 2014). Table 1 summarizes the factors and indicators that have been commonly used in social vulnerability studies (Lee, 2014; Cutter et al., 2009). It provides a list of relevant factors under each dimension, examples of indicators that quantitatively capture the concepts of such factors, as well as their relationship with social vulnerability. For example, under the first dimension, demographic characteristics, there are seven relevant factors, namely gender, age, race, population, growth, disability, and family structure. Some example indicators that represent these factors are number of female population in the area of interest, number of elderly population, percentage of minority population, and population density. As a generalization, more female population, elderly and youth, households with disabled members, more minority, high population density, high birth rate, more single parent household, and larger household size have been identified within previous studies to increase social vulnerability to disasters relative to employment, wages, family responsibility, cultural norms, and disaster recovery capacities (Cutter, 1996; Cutter et al., 2003; Lee 2014).

Table 1. Selected factors and indicators influencing social vulnerability

Dimension	Factors	Example Indicators	Effect on Social Vulnerability
Demographic Characteristics	Gender	Female population	Increase
	Age	Elderly and Youth under 18	Increase
	Race and/or ethnicity	% Minority	Increase
	Population	Population density	Increase
	Population growth	Birth rate	Increase
	Disability	Households with disabled members	Increase
	Family structure	% single parent households	Increase
		Large families	Increase
Social and economic characteristics	Socioeconomic status	poverty	Increase
	Income	Per capita income	Negative relation
	Education	% less than high school	Increase
	Employment	Unemployment rate	Increase
	Housing tenure	% homeowners	decrease
	Occupation	% agricultural workers	Increase
		% low skilled service jobs	Increase
Community social capital	Community development	Strength of social network	Decrease
	Place attachment	% houses rented or seasonal houses	Increase
	Special needs populations	Homeless, tourists, transients, nursing home residents	Increase
Public infrastructure and resources	Access to medical services	Higher density of medical establishments and services	Decrease
	Social dependence	% social security recipients	Increase
	Public infrastructure	Public infrastructure and resources that belong to the inhabitants	Decrease
	Safety	Quality of house	Decrease

Source: Cutter et al. (2009), Lee (2014).

It is worth mentioning again that there is no consensus regarding what is the best indicator to measure these factors, whether these factors can be quantified, how to quantify them, or what makes the best combination of measures to describe social vulnerability. There could be multiple indicators that can be used to represent the different aspects of a single factor, such as the family structure could be measured by percentage of single parent households, or the average household size, or both. There could also be overlap between key indicators (Wood, 2021). For example, some have argued that poverty, as a single variable, identifies vulnerability in a similar fashion to complicated vulnerability assessments that contain a broader set of indicators (Wood, 2021).

It is also worth noting that different from the quick onset hazards, there is less developed in the area of slow onset environmental hazards (i.e. "stressors") as it relates to vulnerability. The way that climate stressors affect the population is often incremental and therefore hard to detect until a tipping point is reached. More research is needed to advance the understanding of vulnerability to climate variability, especially how these slow-onset hazards interact with the vulnerable populations'

adaptive capacity and how social vulnerability to different climate impacts vary at a local scale (Cutter et al. 2009).

Additional Critiques and Limitations of Social Vulnerability Indicators and Indexes

Despite the prevalence of indicator and index development to capture social vulnerability to environmental hazards, there are plentiful and important critiques of this practice and application. First, quantitative metrics often fail to capture key aspects of social vulnerability and therefore overly collapse information such that it can be misleading. Based on Blaikie et al. (1994)'s model, many approaches presuppose a significant positive link between low socioeconomic status and high social vulnerability and hence employ conventional inequality indicators (e.g. age, income, gender, race, etc.) as proxy measures for social vulnerability. While these approaches offer a way to quantify social vulnerability and have practical benefits of raising awareness of these issues on the public agenda, it is difficult to reduce the complexity of system interactions to a collection of variables that rely exclusively on statistical (e.g. census) data (Cutter et al., 2009). Some concepts or relationships such as social networks, trust in government, local knowledge, culture, and traditions are extremely difficult to quantify and measure, if not unmeasurable at all (Cutter et al., 2009; Ranabir, Eghdami, and Singh, 2014; Kuhlicke et al. 2011). While other measures are straightforward and easy to quantify, they may create "false positives" and give rise to a stereotyped view of people's vulnerability (Kuhlicke et al., 2011). For instance, the age indicator may show all elderly people as vulnerable, but not all elderly populations are truly or equally vulnerable throughout the disaster event cycle. An indicator approach may therefore hinder the further assessment of the special needs within this group and in different disaster phases (Kuhlicke et al., 2011). Furthermore, while such taxonomic approaches could capture some of the unequally distributed capacities of groups to anticipate, cope with and recover from disasters, they offer little to understand the actual situation of such vulnerability (Wisner, 2013). For example, Wisner pointed out that while tourists and homeless are generally more vulnerable, their vulnerability depends on the specific hazards and specific circumstances, e.g. whether when the flood happens the tourist have access to a car, or whether the homeless living in fragile tents are facing flood emergencies or earthquakes. In this perspective, no single variables can capture social vulnerability, but rather it is a combination of factors that must be understood in societal context that produces vulnerability and quantitative measures alone often fall short.

Second, the geographical scale of the indicators is critical since the economic, demographic, and political factors that contribute to social vulnerability affect individuals at various geographical levels. Dwyer et al. (2004) classified the factors that contribute to social vulnerability into four levels: individual within household, community, regional, and administrative/institutional levels. The quantification of indicators and interpretation of social vulnerability are influenced by the selected geographical scale. For example, the percentage of elderly population at the neighborhood level would differ from that at the county level, generating different interpretations for the levels of social vulnerability. While many demographic and socioeconomic indicators are quantified based on census units, certain factors such as community development would manifest at a different scale that is not easy to measure (Lee, 2014). In addition, data at the individual or household level are sometimes more central to climate adaptation compared to the aggregated proxies from an actionability standpoint, given that individual and households are the scale at which hazard exposures and consequences are directly perceived and actions are taken (Tuccillo, 2020). Yet, data at such a granular geographical scale are often hard to collect and requires greater resources to analyze and apply (Tuccillo, 2020). The availability of data often impedes the selection of indicators, not only in

terms of the types of indicators but also the geographic unit and scale of analysis. This restricts the application of what might otherwise be a more comprehensive set of indicators (Cutter et al., 2009).

Third, the widely used measure of social vulnerability in the form of a single index has been critiqued as having fundamental theoretical flaws and internal inconsistency (Spielman et al., 2020). An index, i.e. combining multiple indicators, may diminish the significance of a single factor, ignore the relevancy of interconnected variables, and result in contradictory policy recommendations (Wood, 2021). For example, Spielman et al. (2020) showed that the integrated index based on principal component analysis in their study misaligned with the theory and demonstrated the opposite relationship between unemployment rate and overall vulnerability. This counterintuitive finding cast doubt on the theoretical consistency or construct validity of such index, or the degree to which an index measures what it claims to measure (Spielman et al.,2020). Spielman et al. (2020) suggests that the PCA-based index contributes little to our knowledge of the causes of social vulnerability, and could support maladaptive policy decisions. Rather than developing composite indexes, Spielman et al.(2020) suggests that it is better to simply communicate the covariance of indicators; for example, if renter-occupied households co-occur in places with high percentage of non-English speakers, this can be helpful for understanding and communicating specific types of risk as well as shaping approaches to public outreach.

Finally, the direction of the association between the commonly accepted indicators and the community's vulnerability depend on the type of hazard and is place-sensitive (Ilbeigi and Jagupilla 2020). To overcome these limitations, there is a call for place- and hazard-specific contextual measures of vulnerability (Wisner, 2013; Spielman et al., 2020). While the indicator-based taxonomic approach has more practical benefits to assess social vulnerability, it does not explain why and how those characteristics have come to be associated with an increased likelihood of injury, death, livelihood disruption, and greater difficulty in the recovery process in a specific place (Blaikie et al., 1994). Spielman et al. (2020) suggests to improve the process of indicator selection by integrating qualitative methods and local expert opinions. Wisner (2013) proposes two other approaches for a more sensitive view and thorough analysis of social vulnerability: the situational approach that recognizes complexity, change, and contingency, and contextual and proactive approach that let the community defines its own risks, vulnerabilities and capabilities.

III. Existing Social Vulnerability Indexes[2]

There are multiple publicly available SVI (mainly indexes) relevant to climate change in Hawai‘i. While some of the reviewed SVI were not designed to be used in a climate change context, all SVI contain data that could be used to evaluate social vulnerability to climate change in Hawai‘i if combined with climate exposure information. All of the following SVI assess social vulnerability in map form below the county level such that it is possible to consider the relative prevalence of vulnerabilities in various locations within each county. The following SVI were assessed, and are discussed below:

- CDC/ATSDR Social Vulnerability Index
- O‘ahu Social Vulnerability Index
- ALICE Map
- Dept. Of Energy’s Low-Income Energy Affordability Data Tool
- NOAA Coastal Flood Exposure Mapper
- FEMA National Risk Index
- EPA’s Environmental Justice Screening and Mapping Tool (EJSCREEN)

CDC/ATSDR Social Vulnerability Index

The Agency for Toxic Substances and Disease Registry created the Centers for Disease Control and Prevention Social Vulnerability Index (CDC SVI) to help emergency responders and public health officials identify communities that will most likely need assistance in the event of an emergency. This information guides the allocation of emergency preparedness funds, preparation of supplies, staffing of emergency responders, and prevention efforts. The CDC SVI ranks community vulnerability based on U.S. census tracts, which are subdivisions of counties. There are 351 census tracts within Hawai‘i. The index uses 15 census data indicators, known as social factors, to develop SVI scores. These social factors are then grouped into four themes. Each census tract receives an SVI ranking for each for the four themes and receives a combined ranking of all four themes. SVI scores range from 0 (lowest vulnerability) to 1 (highest vulnerability), reported as percentile ranking.

The 15 social factors and their related themes are:

- Below poverty
- Unemployed
- Income
- No high school diploma
- Aged 65 or older
- Aged 17 or younger
- Older than age 5 with a disability
- Single-parent household
- Minority
- Speaks English “less than well”
- Multi-unit structures

[2] This section is based on a whitepaper prepared by James McCallen (2021) available at https://climate.hawaii.gov/social-vulnerability-framework/.

- Mobile homes
- Crowding
- No vehicle
- Group quarters

The scores are derived from principal component analysis (discussed above) and are reported as a percentile ranking on the 0 to 1 scale. For example, Honolulu County has an overall SVI score of 0.472, which represents "low to moderate" level of vulnerability, while Hawai'i County has an overall SVI score of 0.577, which represents a "moderate to high" level of vulnerability. At the census tract level for Honolulu County, Census Tract 97.01 (representing Waianae) has an overall SVI score of 0.988, which represents a "high" level of vulnerability, while Census Tract 112.01 (representing Kailua), has an overall SVI score of 0.153, which represents a "low" level of vulnerability. The CDC SVI online tool ranks all U.S. census tracts or counties against each other and is thus more useful at the federal than at the state or county levels. However, Hawai'i specific Arc GIS datasets are available for download where tracts or counties are ranked against other tracts or counties in Hawai'i. The utility of such a broad composite index for designing specific interventions is likely limited.

O'ahu Social Vulnerability Index

The O'ahu Social Vulnerability Index (SOVI) displays social vulnerability for the island of O'ahu. With a few exceptions, SOVI indicators overlap considerably with those included in the CDC SVI, however, SOVI expands on the CDC SVI methodology by adding an additional "exposure to hazards" theme which includes Tsunami Evacuation Zones, Flood Zones, Hurricane Storm Surge, or Sea Level Rise Exposure Area (SLR-XA). These specific hazards are combined with the social vulnerability indicators into an Oahu-specific SOVI-score such that it is not possible to compare specific census tracts based on individual exposures. It is unclear how variables are weighted in terms of importance to the overall SOVI score.

ALICE Map

The ALICE (Asset Limited, Income Constrained, Employed) index was developed by Aloha United Way (Aloha United Way, 2020) and describes people whose income exceeds the federal poverty line but are still living paycheck-to-paycheck. This distinction is important because it describes the financial reality for many people in Hawai'i. According to Aloha United Way's "ALICE: A Study in Financial Hardship in Hawai'i," forty-two percent of Hawai'i households were struggling to get by pre-COVID-19, and fifty-nine percent of households faced severe financial hardship by the end of 2020. ALICE populations are among the most vulnerable in Hawai'i because their financial situations inhibit resiliency in the face of natural disasters or major life events. In addition to the ALICE index, the ALICE map includes data on total households, poverty (%), and internet access at the Census County Division (CCD) and Census Designated Place (CDP) levels. The indicators which are combined into the composite ALICE map are not individually accessible to the public.

Department of Energy's Low-Income Energy Affordability Data Tool (LEAD)

Known as LEAD, this tool visualizes and compares the energy burden (% of total income spent on energy, electricity and gas, needs) for census tracts and counties across Hawai'i (and the country). LEAD allows users to filter these comparisons based on area median income, percentage of federal

poverty level, household energy fuel type, and resident building age and type. Data are sourced from U.S. Census Bureau's American Community Survey 2016 Public Use Microdata Samples (5-Year Average, 2012-2016) and are calibrated to U.S. Energy Information Administration's electric utility (Survey Form-861) and natural gas utility (Survey Form-176) data.

NOAA Coastal Flood Exposure Mapper

The Coastal Flood Exposure Mapper, developed by the National Oceanic and Atmospheric Administration (NOAA), is based on NOAA's Roadmap for Adapting to Coastal Risk. The roadmap is a framework for participatory assessment of community vulnerability to coastal hazards and a guide to including coastal hazard risk and vulnerability data into local planning. The exposure mapper is a country-wide publicly accessible tool which includes data down to the neighborhood, but not parcel, level. The Exposure Mapper contains separate layers containing coastal exposure data as well as layers containing data on social vulnerability, critical infrastructure, and ecological resources. In addition to the separate exposure layers, the tool provides a "Coastal Flood Hazard Composite" layer, which shows the combined risk of coastal flooding, storm surge, and long-range inundation impacts in a given area (NOAA, n.d.a). The maps can be saved, shared, or downloaded; however, separate data layers are only available at their respective sources. The tool contains the following data layers that are relevant to climate change:

Exposure

- Coastal flood hazard composite layer
- High Tide Flooding
- FEMA Flood Zones
- Tsunami
- Storm Surge
- Sea Level Rise (0-10ft)

Enhanced exposure - infrastructure

- Development
- Critical Facilities
- Development Patterns

Enhanced exposure - ecosystem

- Natural Areas and Open Space
- Potential Pollution Sources
- Natural Protection
- Wetland Potential

Social vulnerability

- Population Density
- Poverty
- Elderly
- Employees

FEMA National Risk Index

The FEMA National Risk Index shows an overall risk index, a community resilience score, and displays expected annual financial and population loss for a range of exposures. It measures Community Resilience as the "ability of a community to prepare for anticipated natural hazards, adapt to changing conditions, and withstand and recover rapidly from disruptions." Both the social vulnerability and the exposure risk data/indicators are available at the census tract and county levels. Data are sourced from the U.S. Census and the Federal Emergency Management Agency (FEMA). The following are exposure indicators relevant to climate change in Hawai'i:

- Coastal flooding
- Drought
- Heatwave
- Hurricane
- Landslide
- Lightning
- Riverine Flooding
- Strong Wind
- Tornado
- Wildfire

EPA's Environmental Justice Screening and Mapping Tool (EJSCREEN)

EJSCREEN provides information about environmental health risk factors such as proximity to toxic sites and air particulate matter. Such environmental health risk factors can be a source of enhanced exposure during a climate change event. For example, toxic waste that may normally be relatively contained at their sites may spill during a flood event and become a health hazard for surrounding settlements. Like most of these tools, EJSCREEN sources social data from the U.S. census bureau. Environmental data are sourced from the EPA itself.

EJSCREEN contains the following environmental indicators:

- National-Scale Air Toxics Assessment (NATA) Air Toxics Cancer Risk
- NATA Respiratory Hazard Index
- NATA Diesel Particulate Matter (PM)
- Air PM
- Ozone
- Traffic Proximity and Volume
- Lead Paint
- Proximity to Risk Management Plan (RMP) sites
- Proximity to Hazardous Waste Facilities
- Wastewater Discharge Indicator (Stream Proximity and Toxic Concentration)

EJSCREEN contains the following demographic indicators:

- Percent Low-Income
- Percent People of Color

- Less than High School Education
- Linguistic Isolation
- Individuals Under Age 5
- Individuals Over Age 64

This index does not combine the environmental factors into a cumulative environmental score, but each environmental indicator is given its own environmental justice index (EJ index) per location. The "demographic index" is based on the average of two demographic indicators, Percent Low-Income & Percent Minority, and is used to calculate each environmental indicator's EJ index.

Key Takeaways from the Review of SVI

Most of these SVI combine multiple indicators into a composite index that provides a vulnerability rating or ranking. These indexes are intended to identify locations which are subject to multiple aspects of vulnerability and thus are likely to be at disproportionate risk if exposed to hazards. While assessing whether this is truly achieved is outside the scope of this report, the review of literature on best practices suggests that the application of indexes should be made with caution. Most notably, composite indexes can obscure important information via aggregation, as well as there is often little guidance as to how to interpret the vulnerability scores.

Unsurprisingly, existing SVI typically use data from the US census bureau and are therefore limited in spatial application below census designations (often the tract level). With 351 census tracts in the state, this could potentially obscure differences in social vulnerability at a more granular spatial scale depending on its application. For example, the FEMA National Risk Index rates the coastal flood risk for Hanalei Bay, which lies at sea level, as being the same as for Alakaʻi Swamp, which is located at about 5000ft elevation, because these two locations are within the same census tract. This will be a particular problem for islands with lower populations and fewer designated tracts; Lanaʻi, for example, only has one.

IV. SVI Uses and Needs in Hawai‘i

This section presents how existing SVI are currently being used in Hawai‘i as well as obstacles and data needs that impair the integration of SVI information into planning and decision-making in various state and county departments. The first section reviews a selection of plans at the state and county level, while the second section summarizes the data needs and obstacles to data incorporation identified in focus group conversations with Hui members.

Inclusion of SVI in Current Planning Documents in Hawai‘i

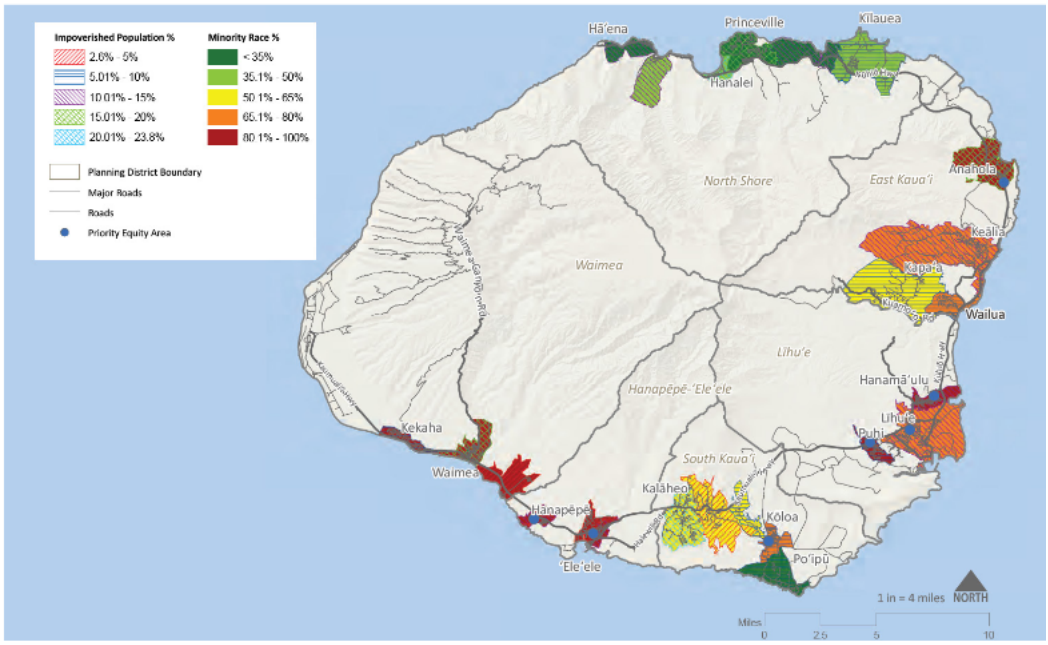
To understand how SVI has been used to inform climate-related planning processes in Hawai‘i (that could affect the climate change resiliency of various communities), we reviewed in total 16 plans and reports at the state, county and community levels (5 state plans, 8 county plans, 3 other) within Hawai‘i.[3] Of the plans reviewed, 10 (3 state plans, 6 county plans, 1 other) contained social vulnerability data and are discussed below.

Kaua‘i County General Plan, Kaua‘i Kākou

The *Kaua‘i Kākou* is the best example of inclusion of SVI among the reviewed plans. Kaua‘i released its updated general plan in 2018, which presents overarching vision and policy recommendations for long time planning and management of growth and development within the county. In 2019, the plan received the Daniel Burnham Award from the American Planning Association for its excellence in comprehensive planning, partly for its efforts to include policies that “support social equity amongst Kaua‘i’s ethnically diverse community” (American Planning Association, 2022).

[3] In addition to the plans discussed in this section, we reviewed six other plans which we found do not include quantitative information on social vulnerability:
- City & County of Honolulu General Plan (2021),
- Hawai‘i County General Plan (2005),
- County of Maui 2030 General Plan (2010),
- Department of Hawaiian Home Lands General Plan (2002),
- A Framework for Addressing Climate Change Adaptation in Hawai‘i (2009),
- East Honolulu, (1999, update in progress) and Central Oahu (2021) Sustainable Communities Plans.

Figure 2. Kaua'i HMP Social Equity Map



Source: County of Kaua'i Multi-Hazard Mitigation and Resilience Plan (County of Kaua'i, 2018). Used with permission.

The plan has four overarching goals, one of which is centered in equity and reads: "An Equitable Place, with Opportunity for All: Fostering diverse and equitable communities with vibrant economies, access to jobs, housing, and a high quality of life." As part of laying out this goal the plan includes a social equity map, as shown in Figure 2, which displays census designated places with high concentrations of minority households and households experiencing poverty. The spatial intersection of these two indicators is used to identify five "priority equity districts." While exemplary in many ways, the plan stops short at analyzing SVI in conjunction with changing environmental conditions.

State and County Hazard Mitigation Plans

The State and County Hazard Mitigation Plans (HMPs) are guiding documents for decision-making related to disaster preparedness and hazard mitigation within the state. In addition, hazard mitigation plans, updated at least every five years and approved by FEMA, are required to qualify for future FEMA funding in support of mitigation and disaster recovery efforts. The State's HMP was updated in 2018. Maui, City and County of Honolulu, and Hawai'i county-HMPs were updated in 2020, and Kaua'i County's HMP was updated in 2021.

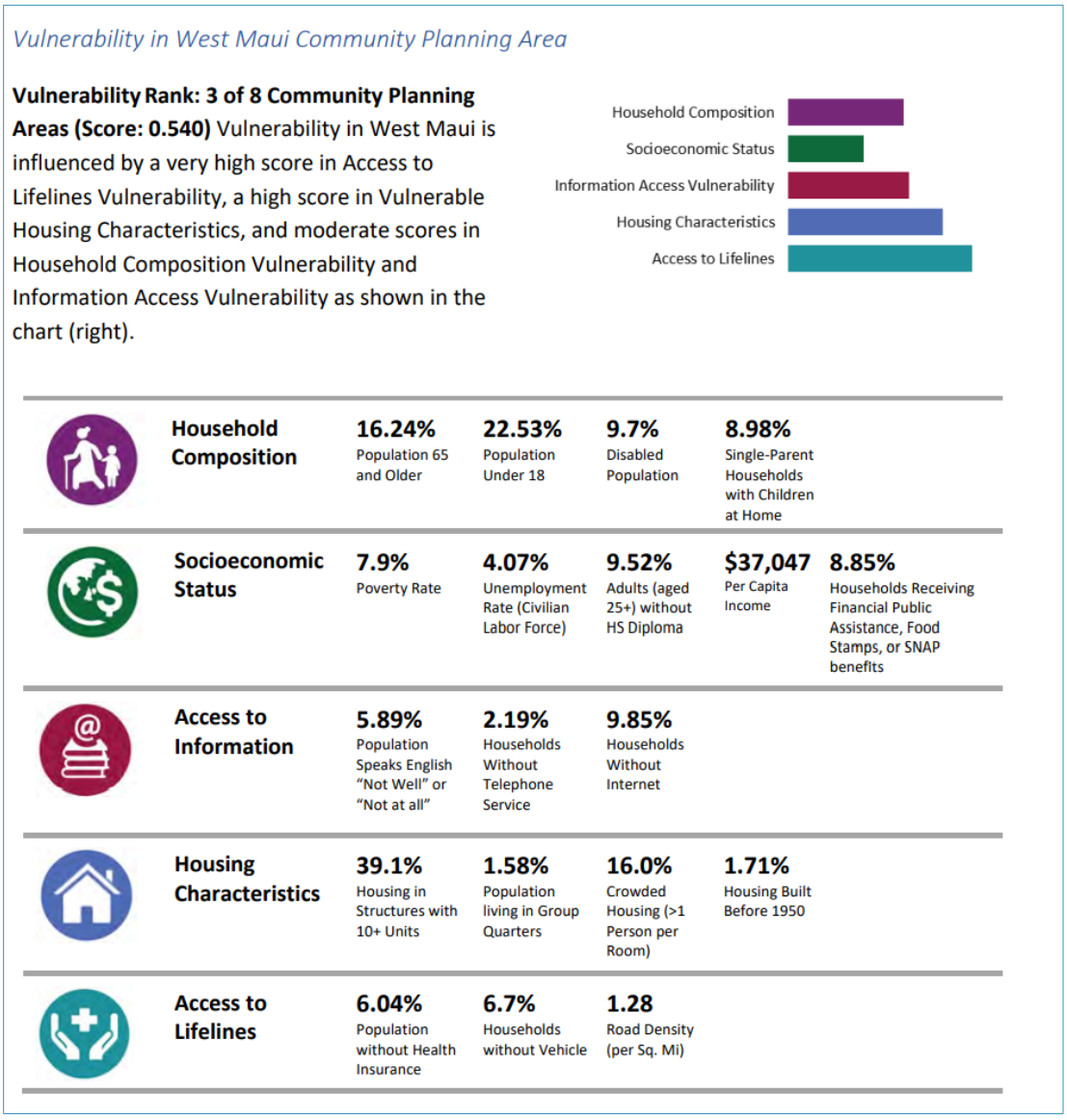
With the exception of the City and County of Honolulu, all County as well as the State HMPs discuss the importance of social vulnerability in disaster management to some degree. Table 2 summarizes the HMPs reviewed, the social vulnerability aspects considered within the plan, and the scale at which data is used.

Table 2. Spatial Assessment of Social Vulnerability Indicators in State and County Multi Hazard Mitigation Plans

Plan Jurisdiction	Social Vulnerability Aspects Considered	Indicator spatial granularity
State of Hawai'i	Disabilities Language barriers Race Homelessness Income	State (no spatial assessment)
City and County of Honolulu	Does not include any social vulnerability analysis	NA
Kaua'i County	Race Poverty	Census block group
Hawai'i County	Income	County (no spatial assessment)
Maui County	Household composition (single-parent, dependents, deaf and hard hearing) Socio-economic status Access to information (internet and telephone, language) Housing characteristics Access to lifelines (limited road networks and transportation access, and health insurance)	Community planning area

The Hawai'i County and State HMPs summarize data relevant to social vulnerability but only analyze the spatial distribution of social vulnerability at the state or county level. The Kaua'i and Maui HMP's summarize social vulnerability data at the census bock group and community planning area, respectively. The Kaua'i HMP also presents the "Social Equity Map," shown in Figure 2, which was developed as part of the County's general plan. According to the plan authors, an "equity lens" was used in the evaluation of risk and in the development of mitigation actions, and the plan proposes three actions that targets socially vulnerable groups. The Maui HMP provides vulnerability profiles for and ranks the community planning area against each other. An example of their social vulnerability profile is provided for West Maui community planning area in Figure 3. Notably, both Kaua'i and Maui plans analyze social vulnerability in isolation rather than in the context of climate change or other hazards, making it difficult to consider the exposure of locations with high prevalence of social vulnerability.

Figure 3. Vulnerability Assessment of the West Maui Community Planning Area from the Maui HMP



Source: Jamie Caplan Consulting (2020). Used with permission.

Hawai'i 2050 Sustainability Plan (2021)

The State of Hawai'i Office of Planning and Sustainable Development's Statewide Sustainability Program updated the Hawai'i 2050 Sustainability Plan in 2021. The plan is meant to be a strategic action plan for advancing state sustainability and climate change goals in the next decade. The plan puts substantial emphasis on equity and makes a conceptual link between social inequality and climate change. The plan provides some statewide data related to inequality and vulnerability, such as percentage of residents living in poverty, percentage of people living in food deserts, and percentage of residents lacking health insurance, as well as actions that are aimed at addressing these issues. However, it does not consider geographical differences in social vulnerability within the state nor does it make a data informed link between social vulnerability and climate change.

O'ahu Resilience Strategy

The "Ola" O'ahu Resilience Strategy was released in 2018 as part of the city's involvement in the 100 Resilient Cities project funded by the Rockefeller foundation. The City's Resilience Strategy has several references to "vulnerable residents" with some consideration of climate change but does not identify specific types of social vulnerability or location of these in regards to climate change or other planning considerations. The plan presents a strategy to collaborate through the Department of Community Services (DCS) with neighborhood preparedness groups to identify vulnerable residents in their communities who may require additional assistance and resources.

Sea Level Rise Vulnerability and Adaptation Report

The Sea Level Rise Vulnerability and Adaptation Report, mandated by Act 83 in 2014 (Hawai'i Climate Change Adaptation Initiative) and expanded by Act 32 in 2017 (Hawai'i Climate Change Mitigation and Adaptation Initiative), is a state-wide assessment of Hawai'i's vulnerability to sea level rise as well as recommendations to mitigate exposure and sensitivity to sea level rise. The report acknowledges the link between social vulnerability and sea level rise for each island and recommends that "priorities should be identified based on a number of social, cultural, economic, and environmental factors, aligned with shoreline protection and preservation priorities and in consultation with communities as part of the community development planning process." The report makes a start at this by quantifying impacted road miles and assessed land value.

Hawai'i Highways Climate Adaptation Action Plan and Mapping Tool

The Hawai'i Highways Climate Adaptation Action Plan (HDOT, 2020a) and the accompanying Exposure Assessment (HDOT, 2020b), was developed by the Hawai'i Department of Transportation (HDOT) to gain insight into how changing climate conditions are likely to impact the State's portion of the National Highway System (NHS). The findings of the assessments were visualized in a publicly available online mapping tool (available at https://hidot.hawaii.gov/resilience/). The tool contains six separate exposure layers relevant to climate change as well as three data layers containing assets within the state highway system as of 2020.

Climate change related exposure layers in the HDOT Asset and Hazard Assessment Tool:

- rock falls and landslides
- sea level rise
- storm surge
- annual high wave flooding
- coastal erosion
- wildfires

Asset data in HDOT Asset and Hazard Assessment Tool:

- roads
- culverts
- tunnels
- bridges

Similar to the Sea Level Rise Vulnerability and Adaptation Report, the HDOT adaptation plan and exposure assessment combines exposure data with infrastructure that could lead to unsafe

conditions but does not explicitly include social vulnerability information. However, mapping the susceptibility of certain segments of Hawai'i's road infrastructure to climate change can, in combination with social vulnerability data, importantly reveal areas of heightened social vulnerability to climate change.

Key Takeaways from the Review of SVI in Existing Plans

We find that multiple existing plans acknowledge the importance of considering social vulnerability in planning and decision-making; however, few do so in a systematic or data-driven way. Multiple plans state the importance of considering social vulnerability in decision-making related to climate change, general planning, or hazard mitigation. Few plans, however, include data or analysis of geographical differences in social vulnerability below the county level, and none of the reviewed plans make a direct link to social vulnerability in climate change or demonstrate how social vulnerability considerations are being incorporated into planning and next steps. This gap between intention and concrete incorporation of social vulnerability considerations to inform planning and implementation shows the importance of continuing to build tools that help to bridge this divide.

Hui Conversations – Uses and Perspectives of SVI

To gain a better understanding of current uses and needs for social vulnerability assessments and data use in a climate change context within Hawai'i, we engaged with the Equity Hui for feedback. This group was composed of members from state and county agencies, the utilities, academia, and non-profits. Identification of Hui members prior to this project are those that participated in the Commission's Equity Permitted Interaction Group. New members were invited based on NOAA's *Participants Checklist for Risk and Vulnerability Assessment Discussions* (NOAA, n.d.b). Appendix 2 provide a list of institutions that were invited to participate in the Hui.

A total of four Hui meetings were held. There were two large group meetings, and two small group meetings. The purpose of these conversations was to gain a better understanding of the benefits and shortcomings associated with the various tools such that any future efforts by the State in mapping social vulnerability can better target the needs of climate adaptation policy makers, implementors, and affected groups.

In the first large group meeting, a poll helped to identify Hui members that 1) have not applied existing SVI (as presented in section III) in their work and have had difficulties using the tools, and 2) have applied existing SVI in their work with some or no difficulty. In total, 25 Hui members had either used or considered using one or more of the SVI presented above, representing public sector, private sector, non-profits, and academia. The vast majority of members that had used existing SVI were public sector, predominately from various county departments and offices. Based on the responses, two small group conversations were organized. The organizations shown in Table 3 had representatives who participated in focus group discussions.

Table 3. List of Institutions Participating in the Hui Focus Group Meetings

Focus Group Participating Institutions
Department of Hawaiian Homelands
Office of Hawaiian Affairs
Department of Transportation
Department of Health
Oʻahu Municipal Planning Organization
City and County of Honolulu Department of Planning and Permitting
Maui County Office of Climate Change, Resiliency, and Sustainability
County of Kauaʻi Planning Department
City and County of Honolulu Office of Climate Change Sustainability and Resiliency
Hawaiʻi Data Collaborative
Ulupono Initiative
Hanalei Watershed Hui
Kauaʻi Island Utility Cooperative
Independent Consultant

There was demonstrated enthusiasm among Hui participants that there is a need for more and better statewide data on climate change impacts and related social vulnerability aspects. As one county representative expressed, counties are now using limited resources to try to get necessary data and a centralized effort could benefit many actors. Because the islands have similar data needs in relation to climate change and social vulnerability, it is likely a more efficient use of resources if data is collected and managed by the State. High-level SVI was stated to be of limited use for communities; however, it can be a medium for talking about climate change issues and ground truthing data in collaboration with communities. As such, the primary utility of climate change related SVI is to inform State and County decision-making around resource allocation.

Summary of Hui Small Group Conversations:

- *Most organizations used available environmental exposure datasets – and want more.* Environmental and climate-related exposure data was stated to be the most used information by Hui group members. Many voiced wanting more frequently updated information as well as for a wider range of environmental hazards (see below).
- *Some organizations used socio-economic data/indicators to inform their work – but not all.* The use of socio-economic indicators was also stated to be prevalent among Hui members and their organizations; however, one voiced that they explicitly do not consider this kind of data as their responsibilities and decision-making authority should focus on the physical information and remain unbiased to the characteristics of people in the area. Most voiced wanting to have better tools to more systematically incorporate social vulnerability information into their decision-making.
- *Few Hui members use the existing SVI to inform their work; however, they do use them as communication tools.*

Several Hui members, mainly from government but also civil society, expressed that the main benefit of existing climate change SVI is to inform state departments/agencies, larger organizations, and elected officials about the geographical and demographic distribution of climate change vulnerability. Several expressed that map-based SVI have been a useful tool to catalyze conversations about climate change with the public, as well as with decision-making entities that might not be deeply familiar with particular regions but have a variety of authorities that affect the area. Among the Hui members, existing SVI has been most useful to communicate outward. There are several notable organizations, like the O'ahu Metropolitan Planning Organization, however, that stated that they use SVI information to prioritize and select projects. In this case, SVI is used to inform internal decision-making.

- *SVI, in general, may have limited applications within communities themselves.* Several Hui members stated skepticism about the application of SVI at the community level: "we know our own community," and "what we need to know is the exposure." This conversation was specifically related to tight knit communities that are engaged in adaptation-related decision-making, with less said about larger communities that might not yet be engaged in adaptation or tend to be less organized with civil society groups.
- *To make SVI more useful, multiple modifications are needed.* There was overall agreement among Hui members that, though some of the existing tools are useful in state and county climate adaptation work, there are also limitations. To compensate for inadequate data access, some Hui members use the combination of several available data sources to infer existing conditions. Below summarizes Hui member suggestions for what would improve existing/future SVI tools:
    - *Spatial granularity.* Hui members said that many existing SVI are not available at a sufficiently granular spatial level to be useful for most planning and decision-making purposes, as averaging of data at a higher spatial level can obscure certain vulnerabilities. In particular, several Hui members noted barriers to using existing data for parcel and household level analysis, while others noted that this was not a likely application.
    - *Department-specific needs.* Different organizations identified different SVI needs, to enable analyses specific to their responsibilities. As such, Hui members suggested that data and indicators be separable (i.e. not presented solely in an index) such that tailored analyses can be done. As an example, the existing ALICE map has aggregated vulnerability information and Hui members thought it would be more useful if data could be separated.
    - *Updated exposure data.* Hui members expressed a strong need for more detailed and up-to-date environmental and climate-related exposure data. Hui members expressed interest in additional flood mapping (updating and going beyond the FEMA FIRM maps), and better information on heat extremes and its spatial dimensions. Hui members also expressed that available exposure data should be extractable in a spatial format such that users can overlay this with social indicators to reveal particularly vulnerable areas.
    - *Linking social vulnerability to exposure.* Hui members expressed a need to identify how specific types of environmental and climate-related exposures relate to indicators of both vulnerability and adaptive capacity, either in a readily available framework or as extractable data layers that can be applied for specific inquiries.
    - *Frequency of data updates.* All Hui members agreed that there's general need for more frequent data updates such that it becomes easier to evaluate the effect of interventions;

however, given that most socio-economic data come from the US census, there was also acknowledgement that there are large barriers to this.

- *Lack of capacity to process data.* Some Hui members expressed that data needs to be in a more readily available format to overcome departmental capacity constraints. This would include both visual formats (like an interactive web map) and database to support more specific analyses. Several voiced that agencies/departments often lack the capacity to operationalize their own SVI, though see the benefit of being able to do so if there was a centralized and shared effort.
- *Specific indicator needs voiced in Hui conversations were:*
    - Being able to quantify the historical trauma of certain communities, particularly for Native Hawaiians and how the climate crisis may be disproportionately impacting the indigenous population. Climate change is yet another event that threatens Native Hawaiian connection and access to the land. Due to changes in the census demarcations, Hui members stated concern that the ability to track how the Native Hawaiian population is faring will be lost.
    - Data that can map transportation related vulnerability, such as single access roads, that create neighborhood-scale vulnerability in particular hazard events.
    - Better publicly available information on road access and emergency exits.
    - Heat exposure data for all counties, at granular spatial scale. This is similar to what is currently available for O'ahu and shown within the SCOVI; however, the SCOVI represents data from only one day.
    - Data that would help map where climate adaptation investments have already been made into communities and the aggregate operating budget of nonprofits by location.
    - Sea level rise exposure data that:
        - better captures current erosion rates,
        - exists for the whole state in sufficient detail,
        - takes into consideration seawalls, and
        - captures interactions with ground water levels.

V. Climate Change and SVI Guide

Based on the totality of our work and findings presented above – a review of current literature on the use of social vulnerability data for in hazard impact assessment, conversations with Hui members on their use and perspectives of existing SVI, and a review of climate adaptation-related plans and their use of SVI – we developed an excel-based Climate Change and SVI Guide (hereby the "guide"). The purpose of the guide is to bring together multiple sources of climate change exposure information, organized as shocks and stressors, paired with relevant SVI. The guide also identifies data gaps that were identified as useful (either in the literature review or by Hui members) in the hopes that it might prompt future data gathering efforts. The guide is intended as an intermediary product that is the start of improving access and use of social vulnerability data in climate change related decision-making in the state. While it is outside the scope of this project, the next step would be to take the information within the guide to put it into a more user-friendly interface – both a GIS-based web map and a complementary database.

The guide is structured according to the concept that vulnerability is a combination of both sensitivity and exposure (Blaikie, 1997; Cutter et al. 2009; Lee 2014). Social vulnerability data was organized based on the conceptual framework presented in Figure 1 above, and with indicators selected based on a combination of Table 1 (Cutter et al., 2009; Lee, 2014), Hui conversations, and known public datasets. Climate change exposure information was conceptualized based on the "shocks" and "stressors" identified in the City and County of Honolulu Climate Change Commission's Climate Change and Financial Risk Guidance Document, as summarized in Table 4. (City & County of Honolulu Climate Change Commission, 2021).

Table 4. Climate Change Shocks and Stressors Included in the Guide

Shocks	Stressors
Sea level rise events	Chronic sea level rise and coastal erosion
Extreme weather	Precipitation
Heat waves	Heat stress
Landslides and rockfalls	Soil erosion

Shocks relevant to Hawai'i include sea level rise events (sudden impacts of sea level rise and associated wave overtopping and erosion), extreme weather events (including tropical cyclones, extreme rainfall and flooding, and high winds), heat waves (excessively hot marine or land temperatures), and landslides and rockfalls (downward movement of rock or earth). Stressors include chronic (passive) sea level rise and coastal erosion, changes in average precipitation levels, heat stress, and inland soil erosion. Climate change shocks and stressors were matched with social vulnerability data based on their temporal scales and structural impacts. Certain sensitivities, like poverty/income, are relevant to all types of exposures. Other sensitivities, however, are only relevant to specific shocks or stressors. Therefore, the guide makes recommendations by exposure type through eight exposure-specific tabs within the guide.

Table 5 describes the unsafe conditions that are included in the guide and the use of associated indicator data, while Table 6 summarizes the relevance of these unsafe conditions to each shock and stressor. The first column of Table 5 displays the types of unsafe conditions that influence social vulnerability to climate change impacts. Within the excel sheet, each of these

categories contain links to one or more relevant indicator datasets. In general, and as illustrated in Table 6, there is a broader range of indicators that are relevant when considering vulnerability to shocks than stressors, because sudden onset events tend to be harder to proactively manage and thus require identification of immediate as well as longer term structural vulnerabilities. The indicators relevant to climate shocks should be used to identify shortcomings in disaster preparedness and areas or groups that are likely to need assistance before, during and after a sudden event. When assessing vulnerability to slow onset stressors, on the other hand, the goal is often to inform long-term planning such that existing patterns and trends can be steered towards more equitable and resilient outcomes.

Table 5. Description of the Types of Unsafe Conditions included in the Climate Change and SVI Guide

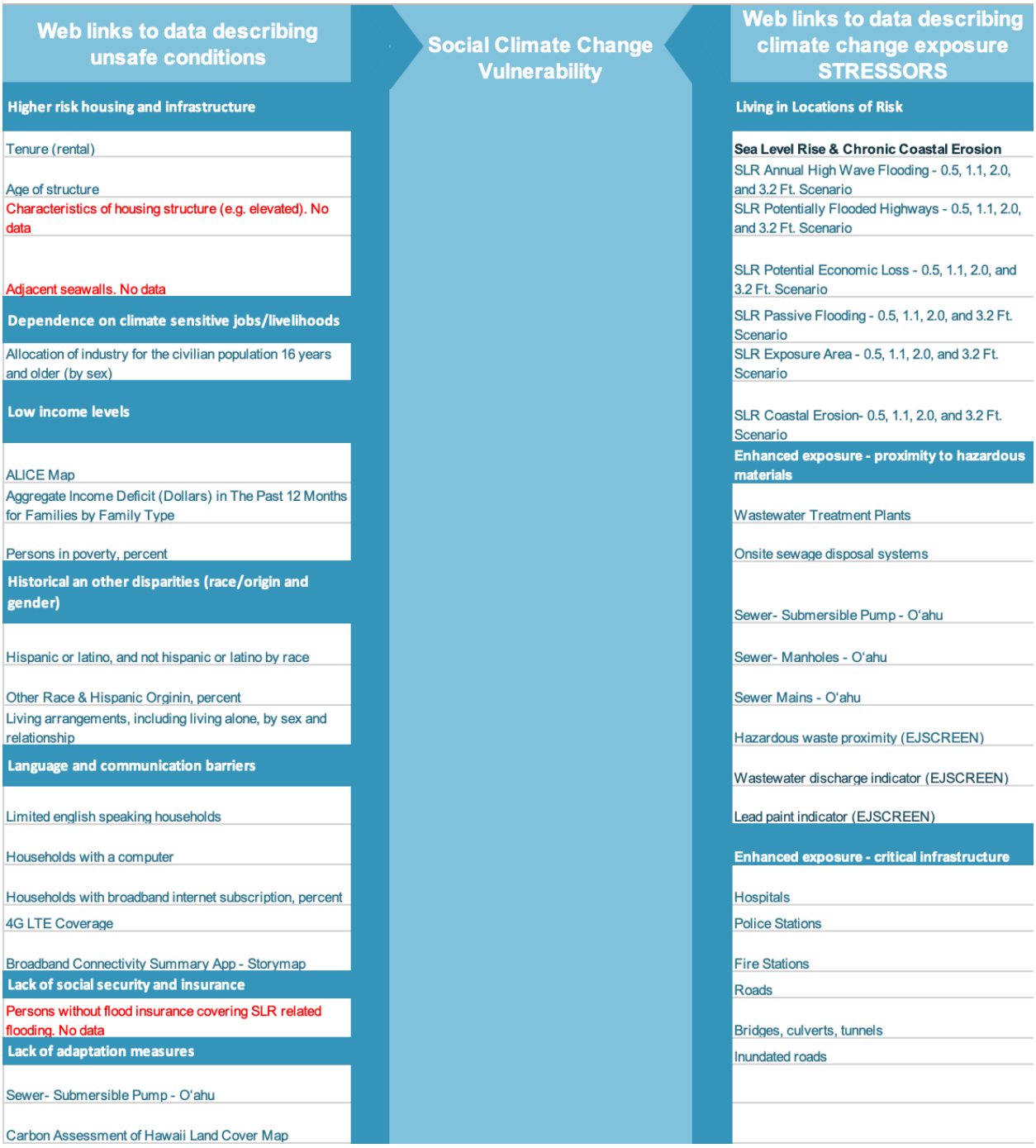
Types of Unsafe Conditions	**Description**
Higher risk housing and infrastructure	Indicators that describe living conditions, such as tenure, crowdedness, and characteristics of the housing structure.
Low-income levels	Indicators describing income and poverty.
Dependence on climate sensitive jobs/livelihoods	Locations of employment in jobs that are likely to be affected by climate change exposures, for example agriculture.
Special groups at risk	Indicators that help locate populations that are likely to be particularly vulnerable due to various medical/physical characteristics such as age, and locations of people in medical/care facilities.
Historical and other disparities	Indicators that describe current geographical distributions of historically marginalized groups including race, origin and gender.
Mobility constraints	Indicators that map the locations of communities/people that have inadequate access to means of transportation such as car ownership, or proximity to public transit.
Language and communication barriers	Indicators that help locate areas with a high number of people that are likely to have lower ability to receive or understand information about risk and possibilities for climate change adaptation and that may require facilitated communication and outreach means. Indicators include non/low-English speaking populations and broadband and cellular coverage.
Lack of social security and insurance	Indicators that describe the prevalence of people who are likely to have no or poor access to protection from direct or indirect financial loss related to a given hazard.
Access to critical infrastructure	Indicators that map the locations of communities/people that have inadequate access to critical infrastructure such as hospitals, police, and fire stations.
Lack of disaster preparedness	Data that can be used to map a shortage of security measures that can be utilized to mediate damage, injury, and loss of lives during and after an exposure event such as location of emergency shelters.
Lack of adaptation measures	Data that can be used to map a shortage of measures taken to manage or minimize risk of exposure to climate change.

Table 6. Relevance of Social Vulnerability Categories to Climate Shocks and Stressors in Hawai'i

Types of Unsafe Conditions	**Shocks**				**Stressors**			
	SLR events	Extreme weather	Heat waves	Landslides and rockfalls	Chronic SLR and coastal erosion	Precipi-tation	Heat stress	Soil erosion
Higher risk housing and infrastructure	X	X	X	X	X		X	X
Low-income levels	X	X	X	X	X	X	X	X
Dependence on climate sensitive livelihoods	X	X	X		X	X	X	
Special groups at risk	X	X	X	X			X	
Historical and other disparities (race/origin and gender)	X	X	X	X	X	X	X	X
Mobility constraints	X	X	X	X				
Language and communication barriers	X	X	X	X	X	X	X	X
Lack of social security and insurance	X	X	X	X	X		X	X
Lack of disaster preparedness	X	X	X	X				
Lack of adaptation measures	X	X	X	X	X	X	X	X
Access to critical infrastructure	X	X	X	X				

To illustrate the structure of the guide, Figure 4 shows a screenshot of the guide relevant to chronic sea level rise and coastal erosion. The guide contains links to available data mapping "unsafe conditions" (i.e sensitivity) on the left and links to available data mapping climate change exposures on the right. Data in these two columns can be used in combination to illustrate various aspects of social vulnerability to climate change. Titles with dark blue background represents major categories of social vulnerability or exposures, while titles with white background represent the availability of and web-links to individual datasets. Indicators highlighted in red mean that this is a data gap. While there is a plethora of data available that can be used to assess various aspects of social vulnerability to climate change in Hawai'i, the usefulness of these data sources depends on the specific application and the quality of the data – including how up-to-date and/or spatially detailed it might be. Appendix 1 contains a list of data sources included in the guide.

Figure 4. Climate Change and SVI Guide - Sea Level Rise and Chronic Coastal Erosion



VI. Recommendations for Next Steps

The impacts of climate change prompts new ways of conceptualizing human impacts and response. Planning for and adapting to expected impacts will require society-wide interventions that will result in a changing landscape of benefits and costs to certain groups and communities. It is important to make these interventions with a greater understanding of impacts and tradeoffs as it pertains to concepts of equity and protection of vulnerable populations – including the societal production of vulnerability. To do so requires developing new analytical tools, frameworks, and understandings of how people experience shifting burdens in the context of rapid environmental change. This project serves as a first step to better understand how SVI are being used in Hawai'i for climate-related decision-making, and conceptualizing how a comprehensive set of publicly available SVI can be understood relative to climate change shocks and stressors.

So that the Commission can see through its' equity-focused mission, our recommendations for next steps are as follows:

- The Commission should pursue the development of a user-friendly database and data-visualization portal based on the climate change and SVI guide presented herein.

- The Commission should pursue creating a pilot program, working with relevant departments and Commission entities, that focuses on operationalizing SVI to inform decision-making.

There was general agreement in the feedback from Hui members on the guide that it would be most useful if provided in a centralized data hub. Multiple Hui members said that they would use this kind of SVI information in their work if it were more easily accessible, as it is often outside of organizational capacity to build and process this kind of dataset internally. The next step for the guide should include both an easy-to-use web interface for the purposes of quick data visualization, as well as a database that would enable more detailed, tailored analyses. The database should preferably contain datasets in geospatial form as this will ease further analysis of how various social vulnerabilities interact with climate change exposures.

Though existing online interactive maps are hugely important for better understanding exposure and thus fill important departmental needs (for example, the NOAA Coastal Flood Exposure Mapper at https://coast.noaa.gov/floodexposure/), they also have their limitations. Such online interactive maps typically only allow for simple overlay of a limited number of data layers and do not provide tools for further analysis (such as creating buffers around exposure areas or extracting datapoints where social vulnerability and exposure overlaps). Thus, we recommend the development and maintenance of a complementary database. Because research show that composite indexes have the potential to result in contradictory policy recommendations (Wood, 2021), and because various projects and purposes require specific data, we also recommend that the centralized database should allow for data/indicators to be presented and downloaded in a disaggregated way and at the most granular spatial scale available. Hui members generally seemed more interested in being able to use this data for specific inquiries rather than working towards developing a statewide vulnerability index.

Conversations with Hui members also elucidated the need for moving forward pilot projects and programs that showcase how SVI can be used to inform decision-making. Examples of use of SVI

in Hawai'i for equity considerations in climate-related decision-making to date are quite broad – with the exception of several organizations that used SVI to assess the allocation of grants. Multiple Hui members expressed that they would like to better operationalize SVI within their practices, but need capacity and expertise to build the tools and processes for its use. A next step for the Commission could be to pursue working with a collective of state and county departments/agencies, perhaps organized around a heavily climate impacted sector (like transportation), to better understand the needs of specific departments and which SVI could be prioritized for sector-specific purposes.

This project focused on identifying quantitative indicator-based approaches to assessing social vulnerability to climate change as an initial means of understanding the uneven distribution of climate-related impacts. While an important first step, there are notable limitations and should not be a singular approach. In most cases, public outreach and qualitative assessments will be necessary to make more informed decisions around social vulnerability and climate change impacts – particularly where quantitative data is incomplete, outdated, or simply fails to capture important measures of adaptive capacity. Moreover, identifying vulnerability itself is not enough to measure the impacts of climate-related policy and intervention. Thus additional analyses will be important to understand and anticipate the impacts of climate-related policy action to ensure that the Commission's equity mission is truly met.

VII. References

Adger, W. N., & Agnew, M. (2004). "New indicators of vulnerability and adaptive capacity" (Vol. 122). Norwich: Tyndall Centre for Climate Change Research.

Adger, W.N. (2006). "Vulnerability." *Global Environmental Change* 16 (3):268-281.

Aloha United Way (2020). ALICE in Hawai'i: A Financial Hardship Study. https://www.unitedforalice.org/methodology

American Planning Association (2022). *Daniel Burnham Award for a Comprehensive Plan—Kaua'i County General Plan, Kaua'i Kākou*. American Planning Association. Available at: https://www.planning.org/awards/2019/kauai/

Bebbington, A.J., Dani, A.A, De Haan, A., and Walton, M. (2008). Institutional pathways to equity: Addressing inequality traps: World Bank Publications.

Blaikie, P., Cannon, T., Davis, I. and Wisner, B. (1994). At risk: natural hazards, people's vulnerability and disasters: Routledge.

Burton, I. (1993). The Environment as Hazard: Guilford press.

Burton, C., & Cutter, S. L. (2008). "Levee failures and social vulnerability in the Sacramento-San Joaquin Delta area, California." *Natural Hazards Review*, 9(3), 136-149.

City & County of Honolulu Climate Change Commission (2021). Climate Change and Financial Risk Guidance Document. https://resilientoahu.org/s/CLIMATE-CHANGE-AND-FINANCIAL-RISK_7-20_FINAL.PDF

City and County of Honolulu (2019). *Ola O'ahu Resilience Strategy*. Available at: https://resilientoahu.org/resilience-strategy

County of Hawai'i (2005). *General Plan*. Available at: https://hidot.hawaii.gov/harbors/files/2014/04/Plans_CtyHawaii-General.pdf

County of Kaua'i (2021). *County of Kaua'i Multi-Hazard Mitigation and Resilience Plan*. Kaua'i Emergency Management Agency. Available at: https://kauai.gov/Mitigation

County of Maui (2010). *2030 General Plan Countywide Policy Plan*. Available: https://www.mauicounty.gov/DocumentCenter/View/11132/Final--Countywide-Policy-Plan--Complete?bidId=

County of Kaua'i (2018). Kaua'i Kakou Kaua'i General Plan. Prepared by County of Kaua'i and SSFM International. Available at: https://www.ssfm.com/project/Planning/

Cutter, S.L. (1996). "Vulnerability to environmental hazards." *Progress in Human Geography* 20 (4):529-539.

Cutter, S.L, Boruff, B.J. and Shirley, W.L. (2003). "Social vulnerability to environmental hazards." Social Science Quarterly 84 (2):242-261.

Cutter, S.L., Christopher T.E., Webb, J.J. and Morath, D. (2009). "Social vulnerability to climate variability hazards: A review of the literature." *Final Report to Oxfam America* 5:1-44.

Cutter, S.L., Mitchell, J.T. and Scott, M.S. (2000). "Revealing the vulnerability of people and places: A case study of Georgetown County, South Carolina." *Annals of the Association of American Geographers* 90 (4):713-737.

Dwyer, A., Zoppou, C., Nielsen, O., Day, S., & Roberts, S. (2004). Quantifying social vulnerability: a methodology for identifying those at risk to natural hazards.

Forsyth, T. (2004). Critical Political Ecology: the Politics of Environmental Science: Routledge.

Hawai‘i Climate Change Mitigation and Adaptation Commission (Hawai‘i Climate Change Commission) (2019). *Final Statement On Climate Equity.* Available at: https://climate.hawaii.gov/wp-content/uploads/2021/02/Commision-Statement-on-Climate-Equity-FINAL.pdf

Hawai‘i Climate Change Mitigation and Adaptation Commission (2017). *Hawai‘i Sea Level Rise Vulnerability and Adaptation Report* (No. 64064; Issue 64064). State of Hawai‘i Department of Land and Natural Resources, Office of Conservation and Coastal Lands.

Hawai‘i Climate Change Mitigation and Adaptation Commission (2021). *State of Hawai‘i Sea Level Rise Viewer*. Version 1.05. Prepared by the Pacific Islands Ocean Observing System (PacIOOS) for the University of Hawai‘i Sea Grant College Program and the State of Hawai‘i Department of Land and Natural Resources, Office of Conservation and Coastal Lands, with funding from National Oceanic and Atmospheric Administration Office for Coastal Management Award No. NA16NOS4730016 and under the State of Hawai‘i Department of Land and Natural Resources Contract No. 64064. http://hawaiisealevelriseviewer.org.

Hawai‘i Department of Transportation (HDOT) (2021a). Hawaii Highways Climate Adaptation Action Plan. https://hidot.hawaii.gov/blog/2021/07/26/hawaii-highways-climate-adaptation-action-plan-and-hazard-tool-available-online/

Hawai‘i Department of Transportation (HDOT) (2021b). Hawaii Highways Climate Adaptation Action Plan—Exposure Assessments. https://hidot.hawaii.gov/blog/2021/07/26/hawaii-highways-climate-adaptation-action-plan-and-hazard-tool-available-online/

Ilbeigi, M., andJagupilla, S.C.K. (2020). “An Empirical Analysis of Association between Socioeconomic Factors and Communities’ Exposure to Natural Hazards.” *Sustainability* 12 (16):6342.

Jamie Caplan Consulting (2020). *Maui County Multi-Hazard Mitigation and Resilience Plan*. Maui Emergency Management Agency. Available at: https://www.mauicounty.gov/1832/Multi-Hazard-Mitigation-Plan

Keener, V. W., Helweg, D., Asam, S., Balwani, S., Burkett, M., Fletcher, C. H., Giambelluca, T., Grecni, Z. N., Nobrega-Olivera, M., Polovina, J., & Tribble, G. (2018). *Chapter 27: Hawai`I and Pacific Islands. Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II*. U.S. Global Change Research Program. https://doi.org/10.7930/NCA4.2018.CH27

Khan, S. (2012). “Vulnerability Assessments and their Planning Implications: a Case Study of the Hutt Valley, New Zealand.” *Natural Hazards*, 64(2), 1587-1607.

King, D., & MacGregor, C. (2000). “Using Social Indicators to Measure Community Vulnerability to Natural Hazards.” *Australian Journal of Emergency Management*, 15(3), 52-57.

Kuhlicke, C., Scolobig, A., Tapsell, S., Steinführer, A. and De Marchi, B. (2011). “Contextualizing social vulnerability: findings from case studies across Europe.” *Natural Hazards* 58 (2):789-810.

Lee, Y.J. (2014). “Social vulnerability indicators as a sustainable planning tool.” *Environmental Impact Assessment Review* 44:31-42.

McCallen, J. (2021). *An Overview of Various Social Vulnerability Tools for a Climate Ready Hawai‘i.* Prepared by James McCallen, Climate Ready Hawaii VISTA under guidance of Anukriti Hittle, Coordinator, Hawaii Climate Commission & Suwan Shen, Ph.D., AICP, Associate Professor, University of Hawai‘i at Mānoa. Available at: https://climate.hawaii.gov/wp-content/uploads/2021/10/An-Overview-of-Various-Social-Vulnerability-Tools-for-a-Climate-Ready-Hawai%E2%80%98i_Final.pdf

National Oceanic and Atmospheric Administration (NOAA). (n.d.a). Coastal Flood Exposure Mapper—Frequent Questions. https://coast.noaa.gov/data/digitalcoast/pdf/flood-exposure-faq.pdf

National Oceanic and Atmospheric Administration (NOAA). (n.d.b). Participants Checklist for Risk and Vulnerability Assessment. https://coast.noaa.gov/digitalcoast/training/checklist-risk-vulnerability.html

Singh, S.R., Eghdami, M.R. and Singh, S. (2014). "The concept of social vulnerability: A review from disasters perspectives." *International Journal of Interdisciplinary and Multidisciplinary Studies* 1 (6):71-82.

Spielman, S.E., Tuccillo, J., Folch, D.C., Schweikert, A., Davies, R., Wood, N. and Tate, E. (2020). "Evaluating social vulnerability indicators: criteria and their application to the Social Vulnerability Index." *Natural Hazards* 100 (1):417-436.

Tapsell, S. M., Penning-Rowsell, E. C., Tunstall, S. M., & Wilson, T. L. (2002). "Vulnerability to flooding: health and social dimensions." *Philosophical Transactions of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences*, 360(1796), 1511-1525.

Tuccillo, J.V. (2020). "Individual-Oriented Assessment of Social Vulnerability to Environmental Hazards." Dissertation, University of Colorado at Boulder.

Walker, G. (2009). Environmental justice and normative thinking. *Antipode*, 41(1), 203-205.

Wisner, B. (2013). Assessment of capability and vulnerability. *In Mapping Vulnerability* (pp. 202-212). Routledge.

Wood, E., Sanders, M. and Frazier, T. (2021). "The practical use of social vulnerability indicators in disaster management." *International Journal of Disaster Risk Reduction* 63:102464.

Zimmerer, K.S., and Bassett, T.J. (2003). Political Ecology: an Integrative Approach to Geography and environment-development studies: Guilford Press.

Appendix 1: List of Data Relevant to Climate Change Social Vulnerability in Hawai‘i

Data Title	Data Format	Issuing/Hosting Organization	Website link
		Composite Indexes	
O‘ahu Social Vulnerability Index	Interactive map	CCSR	https://cchnl.maps.arcgis.com/home/webmap/viewer.html?webmap=2964a940b4844eff90c167b1a9dba391
ALICE Map	Hard Map	Aloha United Way	https://www.aliceplatform.com/
EJSCREEN	GIS	EPA	https://ejscreen.epa.gov/mapper/
Coastal Resilience Evaluation and Siting Tool (CREST)	GIS	NOAA	https://resilientcoasts.org/#Download
CDC Social Vulnerability Index	Interactive Map	CDC	https://svi.cdc.gov/map.html
FEMA National Risk Index	Interactive map, GIS	FEMA	https://hazards.fema.gov/nri/map
		Critical Infrastructure and Land Use	
Wastewater Treatment Plants	GIS	Statewide GIS Program	https://geoportal.hawaii.gov/datasets/wastewater-treatment-plants/explore?location=20.672197%2C-157.362250%2C8.43
Onsite sewage disposal systems	GIS	Statewide GIS Program	https://geoportal.hawaii.gov/search?collection=Dataset&groupIds=77ed1fe17b2f4628b47b4c6b026cb093
Sewer- Submersible Pump	GIS	Honolulu Open Data Portal	https://honolulu-cchnl.opendata.arcgis.com/datasets/sewer-submersible-pump/explore?location=21.470350%2C-157.910750%2C11.36&showTable=true
Sewer- Manholes	GIS	Honolulu Open Data Portal	https://honolulu-cchnl.opendata.arcgis.com/datasets/sewer-manhole/explore?location=21.470100%2C-157.954050%2C11.35
Sewer- Mains	GIS	Honolulu Open Data Portal	https://honolulu-cchnl.opendata.arcgis.com/datasets/sewer-mains/explore?location=21.315437%2C-158.094275%2C15.00
Hospitals	GIS	Hawai‘i Office of Planning	https://geoportal.hawaii.gov/datasets/hospitals-1/explore?location=20.639400%2C-157.361100%2C8.61&showTable=true
Police Stations	GIS	Statewide GIS Program	https://geoportal.hawaii.gov/datasets/police-stations-statewide/explore?location=20.633087%2C-157.272450%2C8.45

Fire Stations	GIS	Statewide GIS Program	https://geoportal.hawaii.gov/datasets/fire-stations-statewide/explore?location=20.619150%2C-157.222800%2C8.47	
Roads	GIS	Statewide GIS Program	https://geoportal.hawaii.gov/search?collection=Dataset&groupIds=278c3b15f1d1430c9fb88d1603f09abd	
Carbon Assessment of Hawaii Land Cover Map	GIS	USGS	https://geoportal.hawaii.gov/datasets/agricultural-land-use-2020-update/explore?location=20.566794%2C-157.274800%2C8.40	
Agricultural Land Use	GIS	Statewide GIS Program	https://geoportal.hawaii.gov/datasets/public-schools/explore?location=20.623840%2C-157.481550%2C8.26	
Public schools	GIS	Statewide GIS Program	https://geoportal.hawaii.gov/datasets/public-schools/explore?location=20.623840%2C-157.481550%2C8.26	
Private schools	GIS	Statewide GIS Program	https://geoportal.hawaii.gov/datasets/private-schools/explore	
Pre-schools	GIS	Statewide GIS Program	https://geoportal.hawaii.gov/datasets/preschools/explore?location=20.632300%2C-157.298450%2C8.42	
Health Professional Shortage Area Story Map Series	Online map	Statewide GIS Program	https://histategis.maps.arcgis.com/apps/MapSeries/index.html?appid=d376433ec05043308fe9a40d264a9097	Yes
		Demographics		
High school graduate or higher, percent	Table - Excel	US Census Bureau (2019, 5-year)	https://www.census.gov/quickfacts/fact/table/easthonolulucdphawaii,HI,US/PST045221	
2015 Census Hawaiian Homelands	GIS	State GIS Portal	https://dhhl.hawaii.gov/po/maps/	
Hispanic or latino, and not hispanic or latino by race	Excel	US Census Bureau (Decennial Census P.L. 94-171 Redistricting Data)	https://data.census.gov/cedsci/table?g=0400000US15%241000000&y=2020	
Persons under 5 years, percent	Excel	US Census Bureau (2019, 1,year)	https://www.census.gov/quickfacts/fact/table/easthonolulucdphawaii,HI,US/PST045220	
Persons 65 years and older, percent	Excel	US Census Bureau (2019, 1,year)	https://www.census.gov/quickfacts/fact/table/easthonolulucdphawaii,HI,US/PST045220	
Limited english speaking households	Excel	US Census Bureau (2019, 5-year)	https://www.census.gov/quickfacts/fact/table/easthonolulucdphawaii,HI,US/PST045220	

Sex by occupation for the civilian employed population 16 years and over	Excel	US Census Bureau (2019, 5-year)	https://data.census.gov/cedsci/table?q=female&g=0500000US15003%241500000&y=2019&tid=ACSDT5Y2019.C24010
Living arrangements, including living alone, by sex and relationship	Excel	US Census Bureau (2019, 5-year)	https://data.census.gov/cedsci/table?q=female&g=0500000US15003%241500000&y=2019&tid=ACSDT5Y2019.C24011
		Economic	
Persons in poverty, percent	Table - Excel	US Census Bureau (2019, 5-year)	https://www.census.gov/quickfacts/fact/table/easthonolulucdphawaii,HI,US/PST045221
Allocation of industry for the civilian population 16 years and older (by sex)	Table - Excel	US Census Bureau (2019, 5-year)	https://data.census.gov/cedsci/table?t=Industry&g=0400000US15%241500000&tid=DECENNIALSF32000.P049
Opportunity Zones in the State of Hawai'i	GIS	State GIS Portal	https://geoportal.hawaii.gov/datasets/HiStateGIS::opportunity-zones/about
		Exposure	
Urban tree database	GIS	USDA	https://www.fs.usda.gov/rds/archive/catalog/RDS-2016-0005
SLR Annual High Wave Flooding - 0.5, 1.1, 2.0, and 3.2 Ft. Scenario	GIS	State GIS Portal, Pacios, HI SLR Viewer	https://geoportal.hawaii.gov/search?collection=Dataset&groupIds=a247b90d2fd14f60a64c0c75db5d5731
SLR Potentially Flooded Highways - 0.5, 1.1, 2.0, and 3.2 Ft. Scenario	GIS	State GIS Portal, Pacios, HI SLR Viewer	https://geoportal.hawaii.gov/search?collection=Dataset&groupIds=a247b90d2fd14f60a64c0c75db5d5731
SLR Potential Economic Loss - 0.5, 1.1, 2.0, and 3.2 Ft. Scenario	GIS	State GIS Portal, Pacios, HI SLR Viewer	https://geoportal.hawaii.gov/search?collection=Dataset&groupIds=a247b90d2fd14f60a64c0c75db5d5731
SLR Passive Flooding - 0.5, 1.1, 2.0, and 3.2 Ft. Scenario	GIS	State GIS Portal, Pacios, HI SLR Viewer	https://geoportal.hawaii.gov/search?collection=Dataset&groupIds=a247b90d2fd14f60a64c0c75db5d5731
SLR Exposure Area - 0.5, 1.1, 2.0, and 3.2 Ft. Scenario	GIS	State GIS Portal, Pacios, HI SLR Viewer	https://geoportal.hawaii.gov/search?collection=Dataset&groupIds=a247b90d2fd14f60a64c0c75db5d5731

SLR Coastal Erosion-0.5, 1.1, 2.0, and 3.2 Ft. Scenario	GIS	State GIS Portal, Pacios, HI SLR Viewer	https://geoportal.hawaii.gov/search?collection=Dataset&groupIds=a247b90d2fd14f60a64c0c75db5d5731
Rainwater Runoff Potential (2D)	GIS	Statewide GIS Program	https://geoportal.hawaii.gov/datasets/HiStateGIS::rainwater-runoff-potential-2d/about
DFIRM Special Flood Hazard Area Line Features	GIS	Statewide GIS Pogram, FEMA	https://geoportal.hawaii.gov/datasets/HiStateGIS::dfirm-special-flood-hazard-area-line-features/about
Hawai'i Heat Index Map	GIS	ArcGIS (CCSR)	https://www.arcgis.com/apps/View/index.html?appid=ff1b73d836074cf6b2aca420fffbd930
1 Pct Coastal Flood Zone with 3.2 ft Sea Level Rise - Statewide	GIS	Statewide GIS Pogram, Sobis Inc. under State of Hawai'i Department of Land and Natural Resources	https://geoportal.hawaii.gov/datasets/HiStateGIS::1-pct-coastal-flood-zone-with-3-2-ft-sea-level-rise-statewide/about
NWS Hawai'i Archived Hydronet Data	Comma delineated text file	National Weather Service	https://www.weather.gov/hfo/hydronet-data
Rainfall Atlas of Hawai'i, historical annual mean	GIS, Excel, JPEG	University of Hawai'i - Department of Geography	http://rainfall.geography.hawaii.edu/downloads.html
Air temperature - historical annual mean	GIS, JPEG	University of Hawai'i - Department of Geography	http://climate.geography.hawaii.edu/downloads.html
Surface temperature - historical annual mean	GIS, JPEG	University of Hawai'i - Department of Geography	http://climate.geography.hawaii.edu/downloads.html
Wind speed, historical annual mean	GIS, JPEG	University of Hawai'i - Department of Geography	http://climate.geography.hawaii.edu/downloads.html
Ocean Acidification-Coral Reef Moorings	Excel, PNG	NOAA - Pacioos	http://www.pacioos.hawaii.edu/voyager/

Air Temperature-Forecast	Excel, PNG	NOAA - Pacioos	https://pae-paha.pacioos.hawaii.edu/erddap/griddap/wrf_hi.graph
Landslides susceptibility maps	Excel, PNG	USGS	https://www.usgs.gov/programs/landslide-hazards/science/preliminary-landslide-susceptibility-maps-and-data-hawaii?qt-science_center_objects=0
Hurricane storm surge innundation current and 1m SLR	GIS	NOAA - Pacioos (Hawai'i Sea Grant and Dr. Kwok Fai Cheung (UH/SOEST))	http://www.pacioos.hawaii.edu/shoreline/slr-honolulu/
Combined Inundation	GIS	Hawai'i Sea Grant, Dr. Kwok Fai Cheung (UH/SOEST), and Dr. Charles "Chip" Fletcher (UH/SOEST)	http://www.pacioos.hawaii.edu/shoreline/slr-honolulu/
Combined Inundation	GIS	Hawai'i Sea Grant, Dr. Kwok Fai Cheung (UH/SOEST), and Dr. Charles "Chip" Fletcher (UH/SOEST)	http://www.pacioos.hawaii.edu/shoreline/slr-honolulu/
Heat index O'ahu - morning, day, evening	GIS	Honolulu Open Data Portal	https://honolulu-cchnl.opendata.arcgis.com/search?tags=environmental
Fire Detection Data	GIS	USDA Forest Service	https://fsapps.nwcg.gov/afm/gisdata.php
Sea surface temperature	GeoTIFF, cvs, png, others	PacIOOS	https://pae-paha.pacioos.hawaii.edu/erddap/griddap/roms_hiig.graph?temp%5B(2021-12-28T00:00:00Z)%5D%5B(0.25)%5D%5B(17.01843):(23.98239)%5D%5B(-163.8307):(-152.5193)%5D&.draw=surface&.vars=longitude%7Clatitude%7Ctemp&.colorBar=%7C%7C%7C%7C%7C&.bgColor=0xffcccff
U.S, Drought Monitor	GIS, Excel, GIFF	National Drought Mitigation Center (NDMC), the U.S. Department of Agriculture (USDA) and the National Oceanic and Atmospheric Administration (NOAA)	https://droughtmonitor.unl.edu/DmData/GISData.aspx
Tsunami Evacuation Zone	GIS	NOAA Pacioos (City & County of	http://www.pacioos.hawaii.edu/shoreline/slr-honolulu/

		Honolulu and State of Hawai‘i)	
Extreme Tsunami Evacuation Zone	GIS	NOAA - Pacioos	http://www.pacioos.hawaii.edu/shoreline/slr-honolulu/
Tsunami Wave Heights	GIS	NOAA - Pacioos	http://www.pacioos.hawaii.edu/shoreline/slr-honolulu/
Tsunami Run-Up Inundation	GIS	NOAA - Pacioos (Hawai‘i Sea Grant and Dr. Kwok Fai Cheung (UH/SOEST))	http://www.pacioos.hawaii.edu/shoreline/slr-honolulu/
Hawaii Climate Data Portal (release date 2022)	GIS	University of Hawai‘i – Department of Geopgraphy	https://www.hawaii.edu/climate-data-portal/
		Public Health	
Developmental Disabilities Domiciliary Homes	GIS	Statewide GIS Program, DOH	https://geoportal.hawaii.gov/datasets/HiStateGIS::developmental-disabilities-domiciliary-homes/about
Adult Day Care Centers	GIS	Statewide GIS Program, DOH	https://geoportal.hawaii.gov/datasets/HiStateGIS::adult-day-health-centers-1/about
Hospice Facilities	GIS	Statewide GIS Program, DOH	https://geoportal.hawaii.gov/datasets/HiStateGIS::hospice-facilities-1/about
Special Treatment Facilities	GIS	Statewide GIS Program, DOH	https://geoportal.hawaii.gov/datasets/HiStateGIS::special-treatment-facilities/about
Therapeutic Living Facilities	GIS	Statewide GIS Program, DOH	https://geoportal.hawaii.gov/datasets/HiStateGIS::therapeutic-living-program-facilities/about
Assisted Living Facilities	GIS	Statewide GIS Program, DOH	https://geoportal.hawaii.gov/datasets/HiStateGIS::assisted-living-facilities/about
Skilled Nursing Facilities	GIS	Statewide GIS Program, DOH	https://geoportal.hawaii.gov/datasets/HiStateGIS::skilled-nursing-facilities/about
Adult Residential Care Homes	GIS	Statewide GIS Program, DOH	https://geoportal.hawaii.gov/datasets/HiStateGIS::adult-residential-care-homes/about
Intermediate Care Facilities for Individuals with Intellectual Disabilities	GIS	Statewide GIS Program, DOH	https://geoportal.hawaii.gov/datasets/HiStateGIS::intermediate-care-facilities-for-individuals-with-intellectual-disabilities/about
Community Care Foster Family Homes	GIS	Statewide GIS Program, DOH	https://geoportal.hawaii.gov/datasets/HiStateGIS::community-care-foster-family-homes/about
Households with a disability, under age 65 years, percent	Table - Excel	US Census Bureau (2019, 5-year)	https://www.census.gov/quickfacts/fact/table/easthonolulucdphawaii,HI,US/PST045221
Health insurance coverage by age	Table - Excel	US Census Bureau (2019, 5-year)	https://data.census.gov/cedsci/table?t=Health%20Insurance&g=0500000US15003%241500000&y=2019&tid=ACSDT5Y2019.B27010
		Shelter and Housing	

Tenure	Table - Excel	US Census Bureau (2019, 5-year)	https://data.census.gov/cedsci/table?g=0400000US15%241500000&y=2019&tid=ACSDT5Y2019.B25003
Aggregate Income Deficit (Dollars) in The Past 12 Months for Families by Family Type	Table - Excel	US Census Bureau (2019, 5-year)	https://data.census.gov/cedsci/table?g=0400000US15%241500000&y=2019&tid=ACSDT5Y2019.B17011
Median Number of Rooms by Tenure	Table - Excel	US Census Bureau (2019, 5-year)	https://data.census.gov/cedsci/table?g=0400000US15%241500000&y=2019&tid=ACSDT5Y2019.B25021
Year structure built	Table - Excel	US Census Bureau (2019, 5-year)	https://data.census.gov/cedsci/table?g=0400000US15%241500000&y=2019&tid=ACSDT5Y2019.B25034
Potential Emergency Shelters	GIS	Hawai'i Office of Planning	https://opendata.hawaii.gov/dataset/potential-emergency-shelters
Transportation and Communication			
Households with a computer	Table - Excel	US Census Bureau	https://www.census.gov/quickfacts/fact/table/easthonolulucdphawaii,HI,US/PST045221
Households with broadband internet subscription, percent	Table - Excel	US Census Bureau	https://www.census.gov/quickfacts/fact/table/easthonolulucdphawaii,HI,US/PST045221
Broadband Connectivity Summary App - Storymap	Online map	Statewide GIS Program	https://histategis.maps.arcgis.com/apps/webappviewer/index.html?id=c9adeb847069483b9df5ac32769a2353
4G LTE Coverage	GIS	Federal Communications Commission (FCC)	https://fcc.maps.arcgis.com/apps/webappviewer/index.html?id=6c1b2e73d9d749cdb7bc88a0d1bdd25b
Aggregate number of vehicles available by tenure	Table - Excel	US Census Bureau (2019, 5-year)	https://data.census.gov/cedsci/table?q=vehicle&g=0400000US15%241500000&tid=ACSDT5Y2019.B25046

Appendix 2: List of Organizations Invited to Join the Hui Meetings by Type

County Government
Board of Water Supply
City and County of Honolulu Office of Climate Change Sustainability and Resiliency
Hawai'i County Council
Hawai'i County Planning Dept
Hawai‘i County Economic Opportunity Council
Hawai‘i County
Long range planning, Kaua‘i County
Maui County
City and County of Honolulu - Department of Facility Maintennance
US Environmental Protection Agency
Department of Housing and Urban Development - Honolulu Field Office
NOAA Office of Coastal Management
State Government
Department of Commerce and Consumer Affairs
Department of Planning and Permitting
Department of Human Services - Homelessness Initianive
Department of Human Services - The Adult Protective and Community Services Branch (APCSB)
Department of Hawaiian Homelands
Department of Health
Department of Transportation
Department of Transportation Services
Hawai‘i Energy Office
Hawai‘i Emergency Management Agency (HI-EMA)
Hawai‘i Department of Agriculture
Hawai‘i Green Infrastructure Authority
Office of Planning and Sustainable Development
Office of Hawaiian Affairs
O‘ahu Metropolitan Planning Organization (state and county)
Hawaii State Council on Developmental Disabilities
Hawaii Public Housing Authority
Hawaii Legislature
Maui Metropolitan Planning Organization (state and county)

Academia
University of Hawai‘i at Mānoa – University of Hawai‘i Economic Research Organization
University of Hawai‘i at Mānoa - Department of Public Health
University of Hawai‘i at Mānoa - Department of Economic
University of Hawai‘i at Mānoa - Department of Social Work
University of Hawai‘i at Mānoa - Health Science Policy Initiative
Non-profit Organizations
‘A‘ali‘i Allliance
Aloha United Way
AlohaCare
American Red Cross of Hawaii
Child and Family Services
Conservation International
Faith Action Hawai‘i
Hanalei Watershed Hui
Ho’ōla Nā Pua (New Life for Our Children)
Liliuokalani Trust
Honolulu Community Action Program
Kaua‘i Plannig and Action Alliance
Kua‘āina Ulu 'Auamo (KUA)
Kupu Hawai‘i
Maui Economic Opportunity (MEO)
Moloka‘i Community Service Council
Pacific Gateway Center
Sierra Club
Ulupono Initiative
We are Oceania
Women Organizing for Change in Agriculture and Natural Resource Management
Hawai‘i Data Collaborative
Kupuna Food Security Coalition
AARP Hawai‘i
Private Sector
Hawaiian Electric
Independent Consultant
Disaster Resilience LLC
Honolulu Authority for Rapid Transportation
Kaua‘i Island Utility Cooperative