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Resilience Working Group Report for Integrated Grid Planning

Hawaiian Electric Company, Maui Electric Company, and Hawai‘i Electric Light Company

April 29, 2020

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Table of Contents

Table of Figures

1. Executive Summary

1.1 Resilience Working Group Objectives and Process

The Hawaiian Electric Companies (the Utilities) have embarked on the development of a long-term Integrated Grid Planning (IGP) process, one of the first of its kind in the U.S. The IGP will evaluate a combination of generation resources, transmission options and distribution assets in an integrated manner to provide a solution that meets the Utilities' environmental, regulatory, reliability, and resilience objectives in an affordable manner.

As this is the first of its kind, the Utilities have organized several stakeholder working groups, including the Resilience Working Group (RWG), to allow the Utilities to consider stakeholder inputs to the process. The goal of the RWG is to:

- Identify and prioritize resilience threat scenarios and potential grid impacts
- Identify key customer and infrastructure sector capabilities and needs following a severe event and loss of power
- Identify gaps and priorities in grid and customer capabilities following a severe event and loss of power
- Provide recommendations and inputs for the IGP to address resilience needs
- Recommend additional grid and customer actions to close gaps in capabilities following severe events

The Utilities retained Siemens and Where Talk Works, Inc. to facilitate a series of six RWG meetings and assist the RWG in reaching consensus around the definition of resilience of the grid, its importance to its customers, the vulnerability of the grid to severe events, and utility and customer options for mitigating these vulnerabilities.

1.2 Assessment of Grid Resilience Needs in Hawaiʻi

A methodical process was applied to develop the RWG inputs through a series of presentations, group discussions, and breakout sessions over a six-month period. The process included the following steps:

- Agree on a definition of resilience
- Identify severe threats to Hawaiian Electric service areas
- Screen the threats to focus on those having the most severe impacts on the power grids and to consolidate threats that have similar or overlapping impacts
- Identify and prioritize key customers and infrastructure sectors with focus on system recovery and public safety and well-being
- Identify gaps and opportunities to improve grid resilience, some of which can be with the Utilities and the grid itself and some of which can be provided by customers, particularly critical infrastructure partners

- Provide inputs to the IGP process for those resilience options that involve power grid enhancements

The RWG adopted the Public Utility Commission (PUC) Staff's definition of resilience as "the ability of a system or its components to adapt to changing conditions and withstand and rapidly recover from disruptions." With regard to the electric power system in particular, this can be interpreted as the ability to anticipate, absorb, adapt to, and rapidly recover from a catastrophic event.

Resilience objectives that were discussed by the RWG consistent with the PUC's definition include:

- Reduce the likelihood of power outages during a severe event
- Reduce the severity and duration of any outages that do occur during and after a severe event
- Reduce restoration and recovery times following a severe event
- Return critical infrastructure customers' power rapidly to enable mutual support and recovery during an emergency
- Return all customers within appropriate times
- Limit environmental impacts of a severe event

The RWG determined by consensus that five types of severe events were determined to be of utmost importance to consider for achieving a resilient grid. They are:

- Hurricanes
- Earthquakes and tsunamis
- Volcanos (Hawai‘i Island)
- Wildfires
- Physical and cyber-attacks

Siemens constructed twenty-three scenarios to represent different potential impacts on grid infrastructure for these five events on O‘ahu, Hawai‘i Island and Maui County (Maui, Moloka‘i, and Lāna‘i). These scenarios identify facilities that could be impacted and possible lengths of time that the facilities would be out of service. The five event types and applicability to the islands are summarized in Exhibit 1. Each event type has a moderate and severe case, which would translate to 24 possible cases to study. However, the volcano scenario has only one severe case, so the total number of possible scenarios constructed for consideration in the IGP is 23. The Utilities are not expected to study all cases presented, but rather a select number of cases to assess the benefits and costs of mitigation strategies.

Exhibit 1: Consolidated Threat Scenarios for IGP

Threat	Includes	Oahu	Hawai'i	Maui County
Hurricane	Flood, Wind	X	X	X
Tsunami	Earthquake	X	X	X
Wild Fire		X		X
Physical Attack	Cyber Attack	X	X	X
Volcano			X	

Each of the scenarios has a brief narrative that provides some key assumptions for the case, as described more fully in the body of the report. In the description of these scenarios, there are instances where certain critical infrastructures could be out of service for weeks or even months. The RWG recommends the Utilities consider the impacts of these events in the IGP though they do not necessarily need to run all 23 scenarios in the IGP. The scenario descriptions include maps of areas most vulnerable to damage on each of the affected islands to assist the Utilities in identifying the potential impacts of these events on grid infrastructure.

In addition to the development of the risk of these events on grid infrastructure, the RWG provided a summary of the relative priorities of customer groupings based on how critical it is to return these types of organizations to electric service during an extended outage. These are summarized in Exhibit 2.

Exhibit 2: RWG Recommended Customer Classifications by Tier

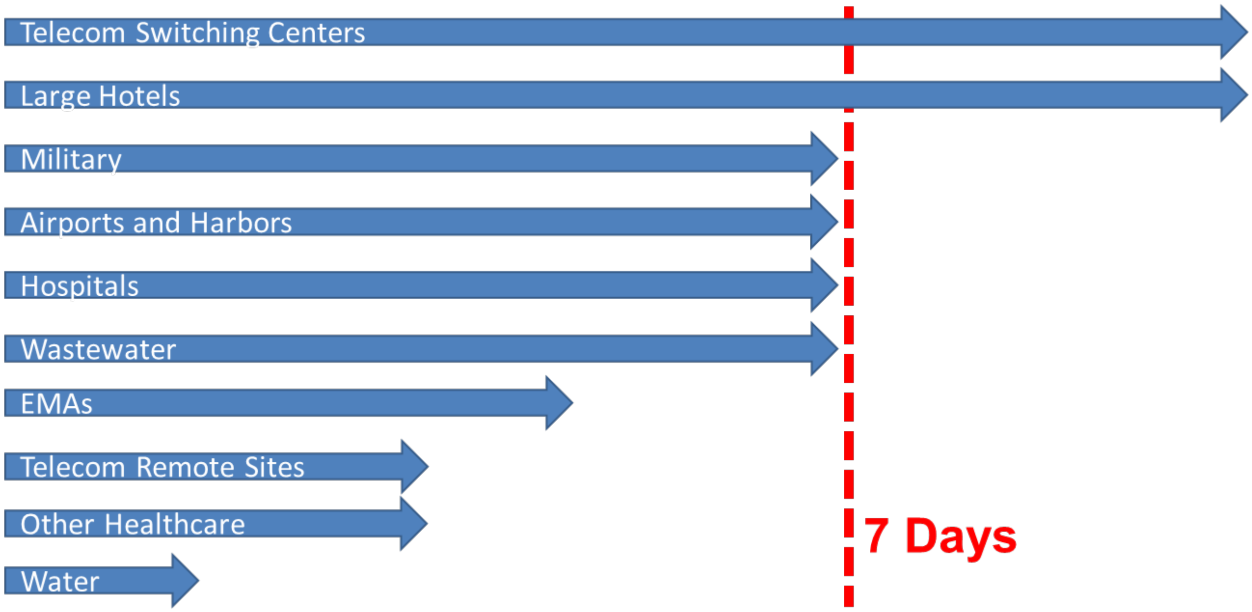
Tier 1	Tier 2	Tier 3
• Military • Telecommunications • Hospitals and critical healthcare • Water and wastewater • Emergency management and first responders	• Transportation • Hospitality • Banking and finance	• Remaining customers

This identification of customer groups represents the stakeholders' views of the prioritization of customers with the greatest need to be returned to service quickly. An action item for the RWG and the Utilities should be to reconcile these customer priorities with the Utilities' and, at a strategic level, emergency managements' restoration plans to ensure that they are in alignment. The RWG and the Utilities should remain flexible to adjusting customer groupings and Tiers over time to ensure that prioritized customers and sectors are cross-validated with other sources such as FEMA's Community Lifelines construct and DHS's Critical Infrastructure Sectors[1].

[1] One member offered the following recommendation for future work and reporting by the RWG: RWG selected these particular sectors (in Tiers 1 & 2 above) during breakout discussions with a scope of providing inputs to the IGP – focused on resilience of the power grid. The RWG has not identified the whole "Energy" sector in its Tiers and priorities. Electricity is commonly a subcomponent of Energy (https://www.cisa.gov/energy-sector; https://www.fema.gov/lifelines). The work of the RWG was focused on making the grid more resilient and the interdependencies with other critical sectors. However, the RWG should have considered including other elements of the Energy sector including, for example, liquid fuels, gas, and other energy subcomponents. This is relevant to the RWG because it led to "Energy" not being specifically called out in the RWG Tiers nor identified in the "Sector Interdependencies", "Customer Sector Needs vs Capability", or in the discussion of key customers / capabilities by

The RWG also provided general information on the ability of customer classes to withstand severe events, as shown in Exhibit 3.

Exhibit 3: Summary of Backup Power and Fuel Capabilities by Customer Class



When comparing the potential vulnerability of critical infrastructure in remote locations for weeks to months, to the current backup power capability of the stakeholders, there are gaps between customers' ability to withstand an outage and the potential downtime associated with the severe events contemplated by the RWG.

By listening to the discussions through the stakeholder process and by conducting interviews with experts within the Utilities, Siemens was able to draft an initial list of some of the options available to mitigate these gaps. The recommendations were refined after review and discussion with the RWG. This is not meant to be a comprehensive list but rather a starting point for further evaluation. In addition to IGP process recommendations presented later, the Utilities should consider the following potential mitigation actions to improve grid resilience:

- Utilities continue to explore and develop advanced resilience data as demonstrated by the technologies of Jupiter Intelligence
- Utilities partner with key customers and the government to develop microgrids for power that can be isolated from the grid when needed (severe events)
- Utilities reinforce fuel resupply options by increasing distributed storage and delivery capability for severe event emergencies

sector. In general, it would be preferential to align the definition of the sectors to the extent possible with the DHS/FEMA designated functions so that there is a common language being used by all.

- Utilities plan for additional crews during emergencies and provide more robust and regular training for emergency situations
- Utilities expand critical resources, supplies, backup equipment, and materials to restore damaged circuits, substations or generators, including distribution more quickly following severe events
- Utilities plan for emergency access to additional helicopters on the islands to support repairs in remote, difficult to access sites
- Utilities plan for enhanced vegetation management, particularly in critical grid areas susceptible to damage from wind and falling or flying debris
- Utilities continue hardening or reinforcing critical transmission circuits, including upgrading wind criteria and flood mitigation, upgrading structures, and using enhanced construction methods and materials
- Utilities continue efforts at enhancing physical and cyber security of assets, resources, and systems.
- Utilities continue planning for expanding underground cables (water resistant) and locating equipment outside flood prone areas
- Utilities consider alternative paths for transmission circuits to increase diversity of location and enhance performance during severe events
- Utilities establish one or more priority circuits with enhanced restoration capabilities and greater hardening
- Utilities continue to require that new RFPs for renewables bids include grid-forming inverters, meaning they can provide a blackstart capability
- Utilities consider adopting advanced technologies in a more distributed resource approach, including grid-forming renewable energy sources, battery storage, and joint projects with key customers to provide microgrid capabilities for emergency and backup operations
- Utilities develop wildfire mitigation strategies for worst case wildfire event at Maalaea
- Utilities develop and test capabilities of expanded use of drones for emergency response and regular maintenance inspections
- Utilities evaluate options for distribution automation, digital meters and associated communications networks which can be valuable in assessing system conditions, the extent of outages, and how to best prioritize recovery efforts to get key customers reenergized more quickly
- Utilities consider actions to reduce tsunami risk impacting generation in inundation zones on O‘ahu

Additionally, the RWG identified mitigation and resiliency recommendations for key customers and critical infrastructure sectors:

- Infrastructure owners and operators work together in close partnerships to coordinate disaster planning and recovery. Recovery and risk mitigation are shared responsibilities between the power companies, key customers and the government.
- Key customers develop and implement load management/load curtailment capabilities to limit power usage to mission critical loads during emergencies with loss of offsite utility power

- Key customers maintain ample onsite fuel supplies for generators during extended power outages and transportation disruptions and have in place plans and fuel supply arrangements resupply fuel for outages exceeding operational expectations; coordinate resupply plans so that multiple facilities, sectors, and geographic areas are not relying on the same fuel resources at the same time; provide backup power sources that can supply essential loads during prolonged outages and emergencies; test and exercise backup power resources
- Under their Continuity of Operations Planning (COOP), key customers should consider relocating essential functions to alternative facilities at sites/locations with more robust infrastructure support
- Key customers consider developing plans and arrangements for deployment of temporary emergency power generators that can be relocated to critical sites during prolonged outages
- Key customers consider partnering with Utilities and the government to develop local microgrids for power that can be isolated from the grid when needed (during severe events); consider alternative technologies, such as renewables and storage, and other blackstart resources,
- Key customers in the transportation sector ensure availability of adequate road clearing equipment to speed recovery of key roads, ports and airports
- Key customers reinforce harbors and port facilities against catastrophic flooding and storm damage to ensure they can maintain maritime operations during extended power outages
- Customers maintain training and exercise programs that address performing emergency and contingency operations with loss of utility power

1.3 Resilience Considerations for Integrated Grid Planning and Other Activities

The RWG was intentionally not prescriptive in defining inputs to the IGP. Much of the IGP is very technical, but the RWG focused on developing general guidance rather than detailed planning requirements for the IGP process. Both Siemens and the Utilities provided a high-level description of the planning process, so the RWG offered recommendations for consideration in both the IGP and for activities outside of the IGP.

Objectives

Siemens provided the RWG a high-level perspective to utility planning that suggested that utilities begin with a list of objectives that customers are looking for in a plan. The list includes grid qualities such as least cost, reliable, resilient, sustainable, and flexible. Each objective would typically have a corresponding metric which could be measured so that the Utilities has a basis to assess tradeoffs between each objective.

- The least cost objective typically uses the Net Present Value (NPV) of costs over a planning horizon as a metric
- Reliability is often measured by a loss of load probability
- Sustainability is often measured in terms of percentage of renewable resources in the portfolio or carbon tons emitted

Resilience is relatively new as an objective in utility resource planning. Currently, no formal grid resilience definitions, metrics, or analysis methods have been universally accepted. The RWG didn't have a specific metric in mind, but the group did express the view that costs should not be the only measure of resilience to consider. Hence Siemens facilitated an RWG discussion of possibilities that the Utilities might consider.

The RWG reached general agreement that all relevant costs need to be captured, which includes the costs that utilities might incur to mitigate (and recover from) severe outages, as well as the cost of the outage to customers and stakeholders. It might also include costs that customers incur to mitigate the impact of severe outages, especially if those measures might be more cost effective than those incurred by the utility.

Regarding the measure of resilience, the RWG provided no guidance other than there should be metrics to measure the resilience of electricity distribution systems that are not strictly cost based to measure its performance. In this way, the Utilities will have an analytical framework to quantify resilience metrics and a process to utilize them to measure tradeoffs between cost and resilience, just as it can measure the cost associated with greater levels of sustainability or cost and flexibility.

Inputs to the Process

Once again, the RWG did not have a view towards what technical inputs the Utilities should consider in tracking resilience. However, the RWG expressed a lot of interest in the presentation made by Jupiter Intelligence in developing forecasts of future weather patterns, such as sea level rise, the frequency of future events such as hurricanes based on science, trends and weather patterns.

The RWG agreed that one needs forecasts and probability distributions of the frequency, duration, and severity of wind and flood damage associated with these events, considering the vulnerability of the grid to these events in terms of recovery times by location and other performance indicators. Customers need to understand their ability to withstand these events without future options being implemented.

Strategies That Might be Considered

Siemens also described to the RWG some strategies that could be considered in the context of an IGP. Strategies are high level activities that might shape the portfolio of actions the Utilities could take. The following are illustrations of the types of strategies the Utilities might consider in their IGP that appeared reasonable to the stakeholder group:

- One strategy that might be considered is different levels of power generation decentralization. By considering locating generation resources closer to load centers and key customers (decentralization), one can evaluate tradeoffs between more and less centralized generation strategies. If the Utilities were to construct portfolios of options that are more decentralized, one can assess how much moving more of its generation closer to load pockets improves resilience and at what cost.
- A second type of strategy would be to evaluate what actions (portfolios) the Utilities can undertake on their own versus a strategy that considers the most cost-effective solutions with potential customer and other service provider actions along with utility actions. This could come about through partnerships that are mutually beneficial to the Utilities and customers in terms of achieving resilience, environmental, sustainability and other mutual objectives.
- A third strategy might entail setting specific targets for recovery times and other performance measures for different classes of customers. By evaluating more stringent targets one can determine the cost effectiveness of each alternative.

The RWG did not express a view towards which of these strategies to consider but felt that these were reasonable ones that the Utility might choose to evaluate. It is also possible for the Utilities to consider combinations of strategies.

RWG Recommendations for Integrated Grid Planning Process

The RWG recommends that:

- The following threat scenarios be considered by the Utilities to guide the IGP process and other resilience initiatives, and also by key customers and critical infrastructure partners in developing resilience preparations:
    - Hurricane/flood/wind
    - Tsunami/earthquake

  - Wildfire
  - Physical and cyberattack
  - Volcano

- Utilities consider the key customer and infrastructure priorities identified by the RWG when planning system expansion or improvements
- Utilities develop IGP objectives that include optimizing resilience and cost of resilience; and merge resilience with other planning goals such as reliability, renewable energy expansion, sustainability, carbon emissions reduction, environmental stewardship, rate stability, etc.
- Utilities should consider the following elements of resilience:
  - Reduce probability of power outages during severe and catastrophic events
  - Reduce outage severity and duration during and following a severe or catastrophic event
  - Reduce restoration and recovery times following severe and catastrophic events;
  - Optimize cost (including capital and operating costs, and probability weighted outage and recovery costs, etc.)
  - Return critical and priority customers power within specified times
  - Return power to other customers within specified times
  - Limit environmental impacts
- That the Utilities consider all possible lowest cost solutions, whether they are best accomplished solely through utility actions or through a combination of utility customer and other service provider actions; hence RWG recommends that some consideration of non-utility stakeholder actions be captured in the analysis of options
- That all relevant costs should be captured, which includes the costs that Utilities might incur to mitigate (and recover from) severe and catastrophic outages, as well as the cost of the outage to customers and other stakeholders; it might also include costs that customers or other service providers incur in response to and recover from the consequences of a prolonged severe outage, especially if those measures might be more cost effective than those incurred by the utility
- That Utilities develop measures of resilience for Integrated Grid Planning in collaboration with stakeholders to allow evaluation of resilience performance of various options or combination of options under assumed scenarios and conditions
- That resilience should not only be measured as a cost but should be a separate goal with its own measurable outcomes. This step requires the definition of each individual resilience goal and quantification of the degree of resilience achieved in a single and/or combination of metrics
- That Utilities consider options for more decentralized or distributed energy resources closer to load areas and options for expanding customer-based programs and other non-wires solutions for improving reliability and resilience
- That Utilities assess options for enhancing resilience through the mix and location of generation resources, including expanding renewable resources with grid-forming capabilities
- That Utilities consider configuring portions of the grid in several mini grids that could operate as independent islands which could be self-supplying over an extended period of time during severe emergencies and outages.
- That Utilities consider planning for best locations to expand and diversify blackstart resources and delivery paths to support grid restoration and timely recovery of key customers and critical infrastructure sectors

- That Utilities consider targeted transmission/sub-transmission additions to enhance redundancy and diversity of delivery paths and reduce risk from severe events

1.4 Organization and Uses of Report

The report is intended to be a starting point for the IGP, but it has value well beyond the analysis that the Utilities plan to consider in its upcoming study. For one, it brings the Utilities' interests and the customers interests together and creates a dialogue that can result in partnerships that might not otherwise exist. It also provides the Utilities with information that it could not find otherwise on the true vulnerabilities of the islands. Finally, it creates a vehicle for information sharing going forward to ensure that the Utilities are focused on customer interests. Stakeholder views will continue to evolve as technological advances occur. None of this report should be considered as final, since we are in a rapidly evolving energy future.

The RWG expressed a willingness to continue to contribute to the IGP as it evolves, over the next 18 months and into the future. The partnership between the Utilities and the stakeholders is critical to the achievement of joint resilience objectives for the future of Hawaiʻi.

Following Section 2 reviewing the RWG process, the remaining sections of the report describe the process used by the RWG to:

- Identify priority resilience threats impacting the grid and customers (Section 3)
- Identify priority customer and infrastructure sectors and their capabilities and needs (Section 4)
- Identify grid vulnerabilities and capabilities to withstand severe events (Section 5)
- Provide inputs for consideration in the IGP (Section 6)

Section 7 summarizes the RWG's recommendations from across all areas of the report.

2. Introduction

2.1 Resilience Working Group

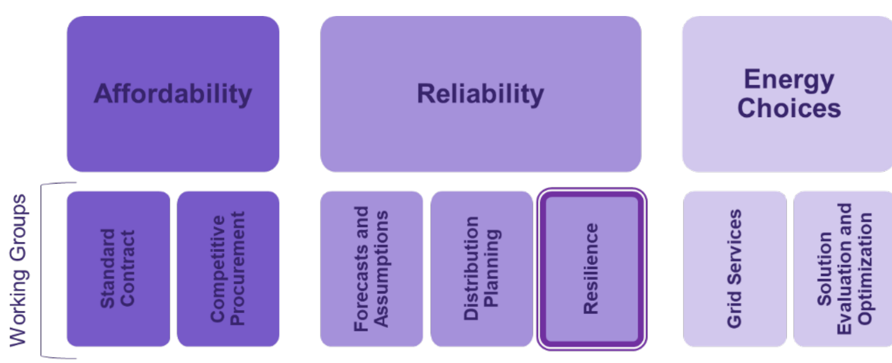
2.1.1 Goals and Objectives

The Hawaiian Electric Companies (the Utilities), comprised of Hawaiian Electric Company, Maui Electric Company, and Hawai‘i Electric Light Company, are undertaking a comprehensive Integrated Grid Planning (IGP) process, which brings together resource, transmission and distribution planning, seeking best solutions to provide affordable, reliable, resilient, and clean energy to Hawai‘i while minimizing risks. Noting the State’s isolated island location, vulnerability to natural hazards, and history of disasters, resilience of electricity supply and delivery is a key consideration in the IGP. This report details the activities and recommendations of the 2019 Resilience Working Group (RWG).

An integrated grid planning process is new to Hawai‘i and to the industry. Few such processes have been performed and only a portion of those few have directly considered resilience in the planning process. For this reason, the Utilities decided to form several stakeholder groups to provide input to the process, including the RWG.

Stakeholder engagement is core to the IGP process. A broad stakeholder engagement process was launched in 2019 to identify customer and stakeholder inputs and to solicit feedback throughout the IGP process. Stakeholder activities early in the IGP process will support the identification of customer needs and how these translate into policy goals, objectives, forecasts and assumptions feeding into the IGP analysis. Several advisory working groups under the broader stakeholder process were formed to focus on key components of IGP. Exhibit 4 presents the organization of the IGP stakeholder process, including the RWG.

Exhibit 4: IGP Stakeholder Engagement Organization



Source: HECO

The goal of the RWG is to support the development of resilience planning inputs for Hawaii’s power system including resource, transmission and distribution assets, in relation to potential societal and economic impacts of potential severe events. More specifically, the goals are to:

- Identify and prioritize resilience threat scenarios and potential grid impacts
- Identify key customer and infrastructure sector capabilities and needs following a severe event and loss of power
- Identify gaps and priorities in grid and customer capabilities following a severe event and loss of power
- Provide recommendations and inputs for the IGP to address resilience needs
- Recommend additional grid and customer actions to close gaps in capabilities following severe events

The RWG realized during the process that achieving resilience meant key customers and infrastructure sectors would be able to continue providing essential services during and following a severe event, even if power outages occur. This requires a strong partnership and cooperation between the Utilities and their key customers to support essential operations and disaster response. The Utilities are focused on rapid restoration and recovery of the power supply while customers can ensure their own emergency business continuity through backup power resources, fuel storage and resupply capabilities, and other measures to mitigate the consequences of possible power outages following severe events.

2.1.2 Member Organizations and Participants

The RWG members included a broad range of state and national agencies, commercial and industrial customers, and not for profit interest groups. It was important that the members were able to bring to the discussion expertise from their sectors, including:

- Defense
- Telecommunications
- Transportation (Energy as a subset)
- Water and wastewater
- Hospitals and health care
- Emergency management and first responders
- Hospitality industry

The RWG member organizations and individual representatives are listed in Exhibit 5. The Utilities retained Siemens Energy Business Advisory (Siemens EBA) to advise and facilitate the RWG through the stakeholder engagement process. Siemens EBA provided technical facilitators with expertise in integrated grid planning and resilience. The Utilities also retained Where Talk Works, Inc., a Hawaiʻi-based company that provides collaborative meeting facilitation services.

Exhibit 5: Resilience Working Group External Member Organizations and Representatives

Name	Organization
Dan Kouchi	Chamber of Commerce
Hirokazu Toiya	City & County of Honolulu Emergency Management
Jennifer Walter	City & County of Honolulu Emergency Management
Crystal van Beelen	City & County of Honolulu Emergency Management
Rocky Mould	City & County of Honolulu Office of Climate Change, Sustainability and Resiliency
Chris Cunningham	City & County of Honolulu Office of Climate Change, Sustainability and Resiliency
Christian "Kaliko" Kabasawa	City & County of Honolulu Office of Climate Change, Sustainability and Resiliency
Dean Nishina	Consumer Advocate's Office
Marcey Chang	Consumer Advocate's Office
Talmadge Magno	County of Hawaii Civil Defense
Keith Okamoto	County of Hawaii Dept. of Water Supply
Jeffrey Pearson	County of Maui Department of Water Supply
Herman Andaya	County of Maui Emergency Management Agency
Alex de Roode	County of Maui Energy Commissioner
Eric Nakagawa	County of Maui Environmental Management
Andy Schwartz	Energy Freedom Coalition of America (EFCA)
Tristan Glenwright	Energy Freedom Coalition of America (EFCA)
Owen Sanford	Energy Freedom Coalition of America (EFCA)
William Rolston	Energy Island
Jeanne Johnston	Federal Emergency Management Agency
Janet Yocum	Federal Emergency Management Agency
Robert Harris	Hawaii PV Coalition
Judy Kern, Chief	Hawaii Department of Health
Thomas Travis	Hawaii Emergency Management Agency
David Lopez	Hawaii Emergency Management Agency
Chris Crabtree	Hawaii Healthcare Emergency Management
Daniel Kelly	Hawaii Healthcare Emergency Management
Paul Agena	Hawaii National Guard
Aaron Lau	Hawaii National Guard
Wade Ishii	Hawaii National Guard
Stan Garcia	Hawaii National Guard
Tony Moiso	Hawaii Society of Healthcare Engineers
William Giese	Hawaii Solar Energy Association (HSEA)
Carilyn Shon	Hawaii State Energy Office
Chris Yunker	Hawaii State Energy Office
Mark Want	Hawaii State Energy Office

Francis Alueta	Hawaiian Telcom
Dan Masutomi	Hawaiian Telcom
Kevin Ihu	Honolulu Board of Water Supply
Lori Kahikina	Honolulu Dept. of Environmental Services
Henry Curtis	Life of the Land
Raymond Tanabe	National Oceanic and Atmospheric Administration
John Bravender	National Oceanic and Atmospheric Administration
Leigh Anne Eaton	National Oceanic and Atmospheric Administration
Jonathan Choi	Par Hawaii
Wren Wescoatt	Progression HI Offshore Wind
Noelani Kalipi	Progression HI Offshore Wind
Dave Parsons	Public Utilities Commission
Jay-Paul D Lenker	Public Utilities Commission
Gina Yi	Public Utilities Commission
Samantha Ruiz	Public Utilities Commission
Clarice Schafer	Public Utilities Commission
Mike Wallerstein	Public Utilities Commission
Jason Prince	Public Utilities Commission
Erik Kvam	REACH
Eric Au	Sheraton Hotels
Jade Butay	State of Hawaiʻi Department of Transportation
Ed Sniffen	State of Hawaiʻi Department of Transportation
Ross Higashi	State of Hawaiʻi Department of Transportation
Gary Yokoyama	State of Hawaiʻi Department of Transportation
Peter Pillone	State of Hawaiʻi Department of Transportation
Joseph Beagley	State of Hawaiʻi Department of Transportation
Murray Clay	Ulupono Initiative
Keith Yamanaka	United States Army
Casey Ann Hiraiwa	United States Army
Glen Yanagi	United States Coast Guard
Jennifer DeCesaro	United States Department of Energy
Sonny Rasay	United States Marine Corps
Shaun Sakai	United States Marine Corps
Robert Malaca	United States Marine Corps
Joe Baysa	United States Marine Corps
Dan Lougen	United States Navy
Shereen Wachi	United States Navy
Peter Yuen	United States Navy
Gary Ting	United States Navy
Corey Shaffer	Verizon Wireless

2.1.3 Meetings and Exercises

The RWG held six meetings starting in July and concluding in December of 2019. A summary of the meetings and agendas is presented in Exhibit 6. The initial meetings focused on defining and raising awareness of resilience and threats to the electric grid. The next few sessions identified and prioritized threats to the islands and defined key customer needs and priorities under severe event scenarios. Looking at these factors, as well as the infrastructure and state of the electric grid today, the RWG formed inputs and considerations to address resilience in the IGP.

Exhibit 6: RWG 2019 Meeting Summary and Process Overview

Meeting	Date	Topics of Focus
1	July 22, 2019	• Introduce RWG • Define resilience and raise awareness • Solicit initial inputs
2	August 29, 2019	• Review needs and existing capabilities of critical infrastructure • Identify customer segments under severe hurricane scenario • Preliminary consensus on resilience process
3	September 17, 2019	• Define severe event priorities • Identify and map potential impacts of all hazards • Identify, assess, and discuss mitigation options
4	October 28, 2019	• Map threats, vulnerabilities, key customer needs and capabilities as related to the grid • Review planning criteria and scenarios
5	November 22, 2019	• Review outline of the final working group report
6	December 16, 2019	• Review final report and recommendations • Open comment period (through Jan 10, 2019) • Consensus and acceptance by RWG • Consider minority views

Source: RWG

2.1.4 Report Development and Review

Throughout the six-month process, the RWG sought consensus and inclusiveness in preparing its recommended inputs to the Utilities' IGP process and overall resilience planning efforts. The group met frequently in breakout groups to discuss threat scenarios, customer capabilities and needs during a severe event, and inputs to the IGP. Minority views were considered and incorporated when appropriate. Meeting notes were recorded for the general sessions and breakouts to ensure comments were captured and considered in the final report. Additionally, frequent use was made of a meeting collaboration and polling app (Sift.Ly) to assess consensus and collect individual written comments.

A draft of the RWG report was prepared by Siemens facilitators and distributed prior to the December 16, 2019 meeting. The draft report was discussed during the final meeting and the RWG provided feedback on key issues and recommendations. The report remained open for written comment by the RWG through January 10, 2020. All comments were given due consideration while striving to achieve strong consensus across the RWG.

2.2 Resilience Framework

2.2.1 Definition of Grid Resilience

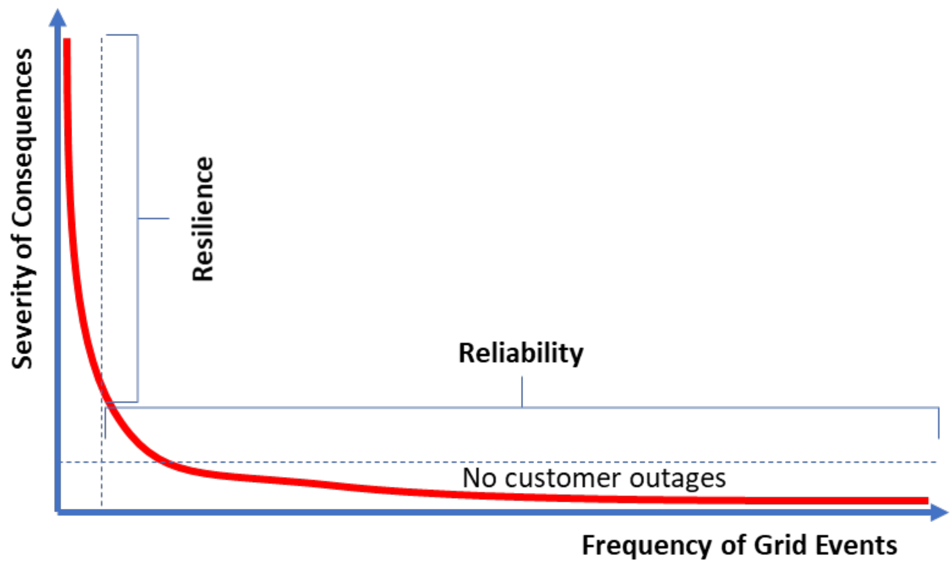
The RWG aligned on the definition of resilience as defined by the Hawaiian Public Utilities Commission (PUC) staff: "Resilience is the ability of a system or its components to adapt to changing conditions and withstand and rapidly recover from disruptions." As it relates to the electric grid and the IGP process, resiliency considers the ability to anticipate, absorb, adapt to, and rapidly recover from a potentially catastrophic event while sustaining mission critical functions.

The RWG's framework is consistent with the U.S. Federal Emergency Management Agency's (FEMA) National Preparedness Goal. The National Preparedness Goal describes the five mission areas as follows:

- Prevention: Prevent, avoid, or stop an imminent, threatened, or actual act of terrorism.
- Protection: Protect our citizens, residents, visitors, and assets against the greatest threats and hazards in a manner that allows our interests, aspirations, and way of life to thrive.
- Mitigation: Reduce the loss of life and property by lessening the impact of future disasters.
- Response: Respond quickly to save lives; protect property and the environment; and meet basic human needs in the aftermath of an incident.
- Recovery: Recover through a focus on the timely restoration, strengthening, and revitalization of infrastructure, housing, and a sustainable economy, as well as the health, social, cultural, historic, and environmental fabric of communities affected by an incident.

The RWG discussed the distinction between reliability and resilience. The facilitators presented the graphic in Exhibit 7 to address the concepts. Reliability provides a level of assurance that the lights will stay on through most normal events on the system (a power circuit or generator trips offline) or there are limited customer outages. At the bend of the curve one can see that reliability issues can sometimes lead to customer outages or in rare instances even an island wide outage. Reliability is achieved through achieving construction standards and accepted planning and operating practices; it addresses expected conditions during the life of the facilities in the system.

Exhibit 7: Grid Reliability vs. Resilience



Resilience addresses the performance of the system under more severe conditions such as the natural disasters discussed in this report that exceed the design expectations of the grid. As shown in Exhibit 7 on rare occasions a severe natural event such as a hurricane, flooding, high winds or wildfire could cause widespread grid outages and even permanent damage requiring weeks or even months to repair. The severity (consequences) axis in Exhibit 8 includes the magnitude and duration of power outages, and potential downstream impacts. The focus of the RWG in developing this report was to suggest recommendations to the IGP process that would reduce the frequency and consequences of system outages caused by severe events, in other words shift the steep part of the risk curve toward the left and downward. This can be achieved by improving the capability of the grid to withstand more severe events, and by being able to reduce the impact of the event and restore power more quickly once an event occurs.

The RWG also discussed the meaning of the term "disruption" in the PUC staff definition and agreed it would include any outage or loss of firm load. The report is focused on severe events that result in prolonged large-scale disruptions.

2.2.2 Framework for Assessing Grid Resilience Needs

It is important to note that grid resilience was the focus of the RWG work, which is somewhat different than other resilience initiatives that focus on the entire spectrum of resilience issues. The goal of this effort was to develop stakeholder inputs to guide the IGP process to address resilience risks involving extensive and potentially long-term electrical outages.

The framework for this assessment went through the following methodical steps in a series of presentations, group discussions, and breakout sessions:

- Agree on a definition of resilience

- Identify severe threats to Hawaiian Electric service areas
- Screen the threats to focus on those having the most severe impacts on the power grids and to consolidate threats that have similar or overlapping impacts
- Identify and prioritize key customers and infrastructure sectors with focus on system recovery and public safety and well-being
- Identify gaps and opportunities to improve grid resilience, some of which can be with the Utilities and the grid itself and some of which can be provided by customers, particularly critical infrastructure partners
- Provide inputs to the IGP process for those resilience options that involve power grid expansion or enhancement

Subject to future assessments the RWG believes the resilience objectives at the core of the IGP process should be:

- Reduce outage risk during severe events
- Increase ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially catastrophic event
- Reduce restoration and recovery time following a severe event
- Optimize cost (including capital and operating costs, and probability weighted outage and recovery costs, etc.)
- Return critical and priority (Tier 1 and 2) customers' power within specified time
- Return power to other customers within specified time
- Limit environmental impacts

The RWG is cognizant that all of these objectives may not be explicitly addressed within the current IGP process; rather, some objectives will support the Utilities' broader resiliency planning efforts and may be addressed through other means such as; grid modernization, resilience and asset strategies, operating procedures, and future IGP planning cycles.

For customers, resilience objectives aim to maintain critical functions, limit fatalities and human suffering, limit infrastructure and property damage, and limit the overall cost and economic impacts of an outage.

3. Prioritizing Threats to Grid Resilience

A grid resilience needs assessment begins first with identifying and prioritizing severe threats and understanding their impacts on the grid and customers. The RWG spent several meetings working on severe event scenarios and conducting tabletop exercises in breakout sessions to discuss the event impacts within their various sectors. The RWG recommends that the threat scenarios proposed here be used by the Utilities to guide the IGP process and other resilience initiatives, and by key customers and critical infrastructure partners in developing resilience preparations.

3.1 Historical Perspective on Severe Events Affecting Hawaiian Infrastructure

Hawai‘i is a paradise and an attractive tourist destination. At the same time, being an island state and subject to natural events and climate change, Hawai‘i has experienced its share of severe events. Exhibit 8 from Hawaii’s 2018 Hazard Mitigation Plan identifies just a few events of note and demonstrates that severe events have happened in the past and are likely to continue in the future. Some hazards are expected to increase in both frequency and severity in the future due to climate change impacts, as will be discussed later.

Exhibit 8: Overview of Hazards and Projected Future Change in Hawai‘i

Hazard	Projected Change			Confidence in Changing Future Conditions [a]
	Location	Extent/ Intensity	Frequency/ Duration	
Climate Change and Sea Level Rise	↑	↑	↑	Highly Likely
Chronic Coastal Flood	↑	↑	↑	Highly Likely
Dam Failure	— [b]	— [b]	↑ [b]	Likely
Drought	↑	↑	↑	Highly Likely
Earthquake	—	—	—	Uncertain
Event-Based Flood	↑	↑	↑	Highly Likely
Hazardous Materials	—	—	—	No Change
Health Risks	—	—	—	No Change
High Wind Storms	—	—	↓ [c]	Likely
Hurricane	↑	↑	↑	Highly Likely
Landslide and Rockfall	—	—	↑	Highly Likely
Tsunami	↑	↑	—	Highly Likely
Volcanic (lava flow and vog)	— [d]	— [d]	— [d]	Uncertain
Wildfire	↑	↑	↑	Highly Likely

Note: Arrow direction indicates a projected increase or decrease; straight line indicates uncertain and/or no change expected at this time.

Source: Hawai'i 2018 Hazard Mitigation Plan

3.2 Prioritization of Threats to the Power Grid

The RWG considered and prioritized a range of severe events including natural, technological, and attack events. The RWG started with an initial list of threats that they felt would be the most important to address regarding impacts on the electric system.

Exhibit 9 is a summary of threats listed in the FEMA Threat and Hazzard Identification Report CPG 201. The RWG considered the threats under Column C (Considered by RWG) as possibly being important to the grid and supply of electricity to customers in Hawaiʻi. Column P (Prioritized by RWG) indicates the RWG made the scenario a priority for IGP consideration. Scenarios not recommended as input to the IGP were screened out because (1) they do not apply to Hawaiʻi, (2) they do not affect the power grid and cause system-wide power outages, (3) the impacts were redundant with other threats, or (4) they were considered outside the scope of the resilience planning. the utility outage box is not checked, but obviously is an overarching focus of the entire RWG efforts and the IGP process.

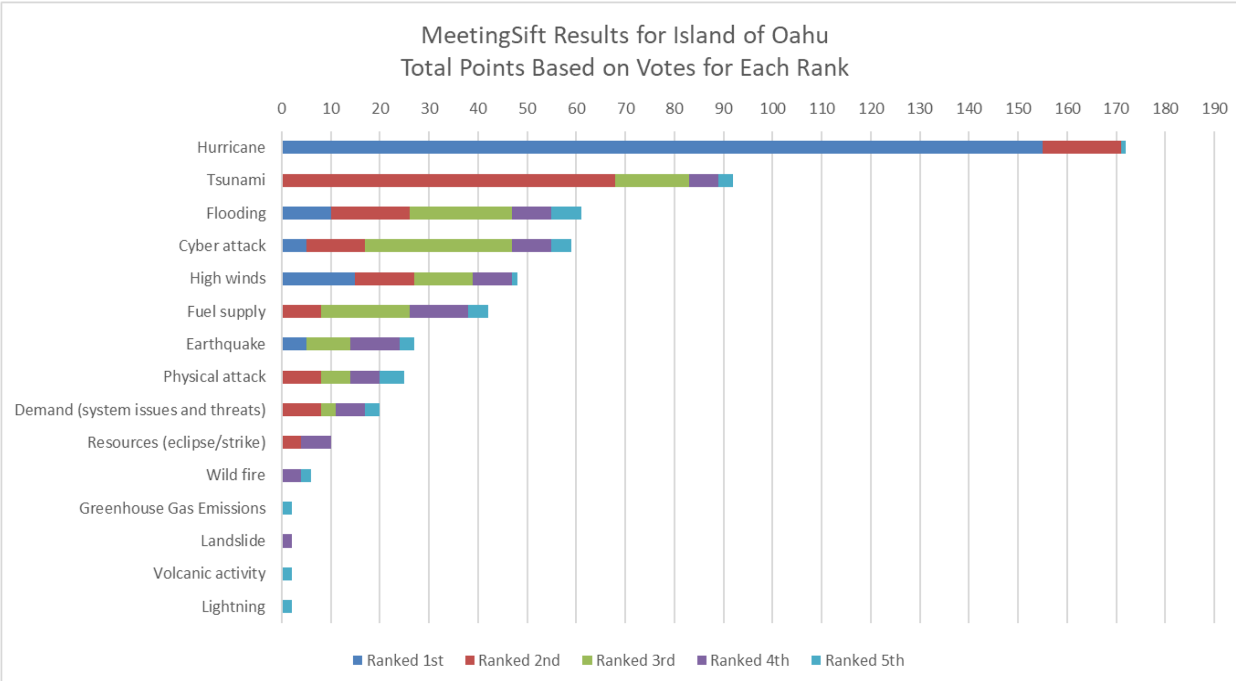
Exhibit 9: Severe Events Considered and Prioritized by the RWG

Natural	C	P	Technological	C	P	Attack	C	P
Avalanche			Dam failure			Physical (shooter)	X	X
Drought			HazMat			Physical (explosive)	X	X
Earthquake	X	X	Industrial Acc			Cyber	X	X
Epidemic			Levee failure			Chemical		
Flood	X	X	Mine Accident			Improvised nuke		
Hurricane	X	X	Pipeline			Terrorist nuke		
High wind	X	X	Radiological			Radiological		
Space weather			Train Derail					
Tornado			Transportation					
Tsunami	X	X	Urban fire					
Volcano	X	X	Utility outage					
Wildfire	X	X	Fuel supply	X				
Landslides	X		Demand/resources	X				
Greenhouse gas	X					**C - Considered**		
Lightning	X					**P – Prioritized**		

Source: FEMA Threat and Hazzard Identification Report CPG 201 and the RWG

Through a series of breakout sessions over several meetings, the RWG discussed how each of the threat scenarios would impact the electric system of each island and difficulties associated with recovery and the associated social and economic consequences for each island. The scenarios were then prioritized by electronic vote of the members. A sample vote is shown in Exhibit 10 for O‘ahu. Similar votes were taken for the other islands serviced by the Utilities. (Note the electronic votes were weighted at five points for first choice, 4 points for second choice, etc.)

Exhibit 10: Prioritization of Critical Threats – O'ahu



Source: RWG

Exhibit 11 shows how the threats were prioritized by island during breakout discussions and electronic votes to assess consensus. The graphic confirms that the top five priority events for each island are included in the final recommended set of scenarios for input to the IGP.

Exhibit 11: Ranking of Critical Threats – Top Five by Island

	O'ahu	Hawai'i	Maui	Lāna'i	Moloka'i
Hurricane	X	X	X	X	X
Tsunami	X	X	X	X	X
Flooding	X	X	X	X	X
Cyber attack	X				
High winds	X		X	X	X
Fuel supply				X	X
Earthquake		X			
Physical attack					
Demand (system issues and threats)					
Resources (eclipse/strike)					
Wild fire			X		
Greenhouse Gas Emissions					
Landslide					
Volcanic activity		X			
Lightning					

Source: RWG

Hurricane, tsunami, flooding, and high winds were common themes across all islands, according to the RWG. The scenarios highlighted in pink are included in the recommendations for consideration in the IGP. In later discussions, fuel supply was deemed to be an extremely important issue, but it was common to all severe events and outages – if the power is out for an extended period, resupply of fuel for backup power is a common concern for all critical sectors. Therefore, backup power and fuel supply should be considered across all scenarios and is not a scenario by itself.

Exhibit 12 presents the results of additional work to consolidate the list of threat scenarios. The goal of the RWG was to recommend a reasonable number of scenarios that could be used by the Utilities in the planning process to test the grid's ability to withstand severe conditions and recover in a timely manner. Hurricanes, floods and wind were consolidated into one threat scenario; earthquake and tsunami were combined; and physical and cyberattack were combined. These three combined threat scenarios were considered by the RWG to be important to all five islands. To allow further consolidation down to 12 scenarios for study, the RWG agreed to combine Maui, Moloka‘i, and Lāna‘i into one group of scenarios covering Maui County. Wildfires were deemed most important regarding grid impacts on O‘ahu and Maui. Volcano threats are most relevant on Hawai‘i Island.

Exhibit 12: Final Consolidated List of Recommended Threat Scenarios for IGP

Threat	Includes	Oahu	Hawai'i	Maui County
Hurricane	Flood, Wind	X	X	X
Tsunami	Earthquake	X	X	X
Wild Fire		X		X
Physical Attack	Cyber Attack	X	X	X
Volcano			X	

Source: RWG

This consolidation allows a reasonable number of resilience threat scenarios to be submitted into the integrated grid planning process, while capturing the most severe potential impacts and avoiding overlapping or redundant impacts to the grid. Below these threats are described in more detail using two levels of severity for each event except volcano, for a total of 23 possible scenarios covering O‘ahu, Hawai‘i, and Maui Counties.

3.3 Threat Cases for Grid Resilience Planning

Siemens developed and the RWG commented on reference cases for each threat scenario by county. Except for volcanos, Siemens developed two cases for each threat scenario, a moderate case and a severe case. Only a severe case is suggested for a volcano on Hawai‘i as a moderate volcano is likely to have limited direct impacts on the grid and a single severe case is enough.

Moderate cases are ones deemed to be less severe but more likely (approximately 50% or greater likelihood to occur in the IGP study period, through 2040, based on historical experience). The severe cases are intended to be more severe and realistically plausible but low probability of occurring during the IGP study period (e.g., less than 20% chance of occurring over the twenty-year period). However, the severity of impacts in the severe cases are important for consideration in testing the system under stressful conditions and evaluating recovery capabilities. The two cases for each threat are intended to provide a range of assumptions regarding grid impacts to see how well proposed solution options stand up under different conditions. Solutions that perform well on both resilience metrics and cost under all or most threat scenarios, both moderate and severe, should be deemed to be the most favorable options.

The RWG reviewed and supported assumptions regarding the impacts to the grid from each threat scenario. A summary of the severe event cases considered the threats to infrastructure and electric supply. The scenarios are developed to provide the Utilities a perspective on how components of the grid could be affected by different types of events. With this guidance, the Utilities can construct scenarios that reflect outages to key grid infrastructure.

It is important to note that the RWG discussed alternative views about providing moderate and severe scenarios. Some thought only the most severe cases (e.g. Category 4 hurricane) should be considered in the IGP process. One reason supporting this view is that the Hawai‘i legislature has stated a Category 3 hurricane is the target basis for resilience and studying a Category 2 hurricane might be viewed as lowering the bar. However, others on the RWG preferred to keep both the moderate (e.g. Category 2 hurricane) and the severe (Category 4) cases for consideration in the IGP process due to the ability to provide a more comprehensive look at the frequency and costs associated with two types of events. In either case, note that these events should not be considered as targets but rather as scenarios that could be evaluated to determine the best overall investment solution. Utilities are encouraged to consider the impacts of both moderate and severe cases in the IGP process, but if only one is selected, it should be the severe case.

This discussion of the severity of the threat scenarios raises an important point of principle. The threat scenarios and case examples are not intended to set targets or standards of performance under severe conditions (i.e. the RWG is not saying the grid must withstand a Category 2 or Category 4 hurricane). The threat scenarios are intended to provide a set of stressed conditions to evaluate the performance of the grid under a variety of conditions and to determine which strategies or investment portfolios perform the best for the least cost. Once the tradeoffs between resilience benefits and costs can be demonstrated through analysis, appropriate goals and plans can be determined. This concept is described further in Section 6 of the report.

3.3.1 Hurricane/Wind/Flood Scenarios

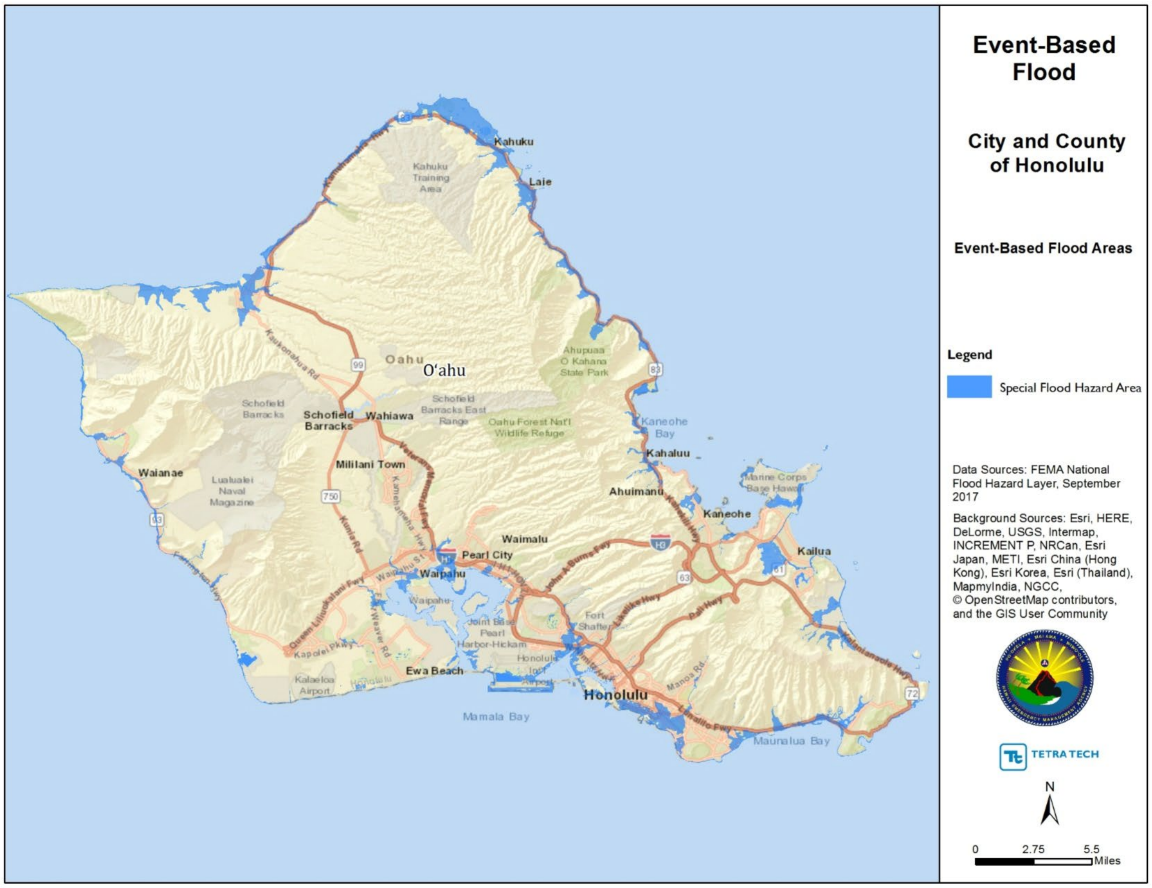
Exhibit 13 shows the proposed moderate and severe hurricane conditions proposed for all three counties (six cases total). The threat impacts are based on representative historical events in Hawai‘i. These scenarios combine hurricane, flooding, and high wind conditions.

Exhibit 13: Hurricane, Flood, Wind Moderate and Severe Cases

Hurricane: Depending on path of hurricane, all islands and locations can be subject to damaging wind, rain and coastal and inland flooding.		
	Moderate	Severe
Scenario Description	Category 2 hurricane with wind speeds of 96 to110 mph, 6 to 10-foot surge	Category 4 hurricane with wind speeds of 130 to 156 mph, 13 to 20-foot surge
Scenario Impacts	• 10-foot storm surge • Coastal infrastructure damage • Damage to distribution lines and poles due to wind, falling trees/branches, and flying debris • 5-8% of transmission circuits have sustained outage and restored in 3-7 days • 20-30% of distribution circuits out and restored in 1-4 weeks • Roads cleared 3-7 days • Fuel resupply chain is available after 3-4 days	• 20-foot storm surge • Coastal infrastructure destroyed • Damage to transmission lines, poles and towers due to wind, falling trees/branches, and flying debris • 25-30% of transmission lines have sustained outages and restored over four months • 50-75% of distribution lines out of service and restored over six months • Road washouts and clearing may require weeks or longer, especially secondary roadways • Fuel resupply chain available after four weeks

Exhibit 14 shows a flood map for O‘ahu. Under the hurricane and flood cases, the most severe flooding would be expected along the southern and northern coasts of O‘ahu with more limited coastal impacts on Maui. Key customers and backup generators are expected to flood in these coastal areas as well as utility distribution substations and lines in affected areas. Flooding impacts to electrical infrastructure are expected to be minimal on Hawai‘i Island.

Exhibit 14: Coastal Flooding Impact Areas in O‘ahu



Source: FEMA, State of Hawai‘i 2018 Emergency Management Plan

During the RWG discussions, it was suggested that rain bombs should also be on the list of scenarios studied. Rain bombs in Hawai‘i can be severe. For example, on April 28, 2018, approximately 50 inches of rain was recorded at Waipa on Kaua‘i in a 24-hour period, the greatest amount in U.S. recorded history. After some discussion, the majority of the RWG agreed that while rain bombs can result in severe flooding and heavy damage to local infrastructure and human suffering, that these storms typically do not impact the power grid more severely than a hurricane event that incorporates high winds and flooding. The group consensus was to acknowledge the importance of rain bombs in general when discussing resilience, but to focus on the two hurricane cases for the purpose of stress-testing the grid for resilience planning.

The primary impacts from the hurricane scenarios are expected to affect transmission and distribution circuits. Transmission circuits are much fewer in number compared to the distribution system, but transmission lines can traverse remote, difficult terrain with limited access, such as on the western slope of O‘ahu. Some repairs may only be possible with the assistance of helicopters.

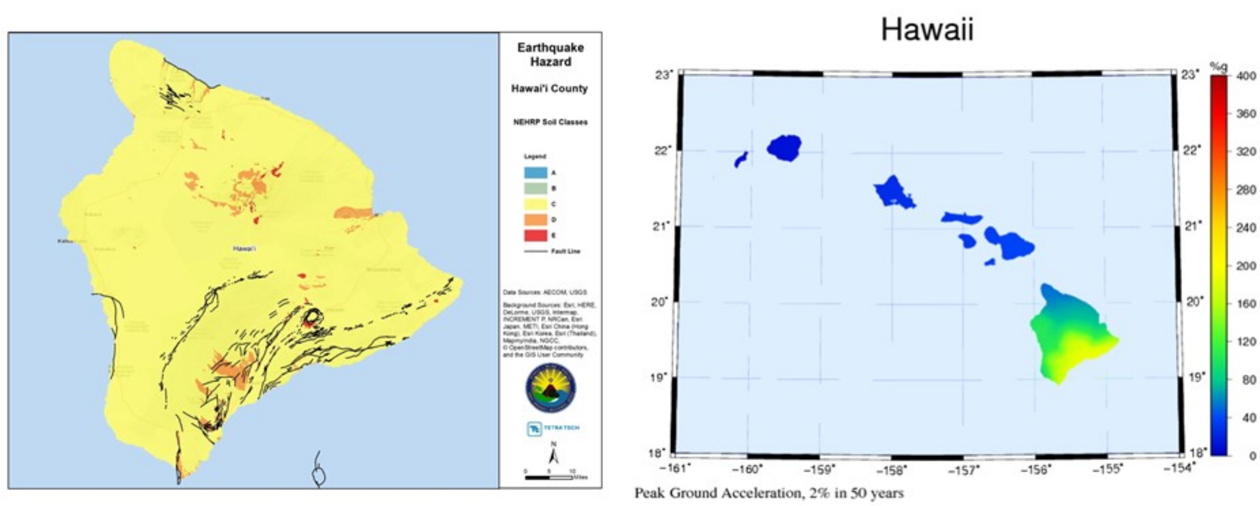
Distribution feeders would also be affected by hurricanes and would be much greater in number to repair. Even though distribution feeders are likely in more accessible areas, the sheer number of poles, transformers, and conductors to be repaired or replaced could make recovery last weeks to months under these hurricane conditions.

3.3.2 Earthquake/Tsunami Cases

Earthquakes are relatively common in Hawai‘i, particularly on the Island of Hawai‘i. Exhibit 15 depicts earthquake impacts for Hawai‘i. The island of Hawai‘i has the highest risk due to fault lines on the east portion of island near Hilo including areas with critical infrastructure. On May 4, 2018 a magnitude 6.9 earthquake struck the island with the epicenter on the south side of Kilauea. Minimal impact to the grid was experienced with this earthquake.

Seismic damage is a risk on the remaining islands, but much lower impacts would be expected. In addition to the grid, earthquakes can affect harbors and fuel supply, and possibly create hazmat conditions that could delay recovery of electricity if fuel supplies are not available for weeks or more.

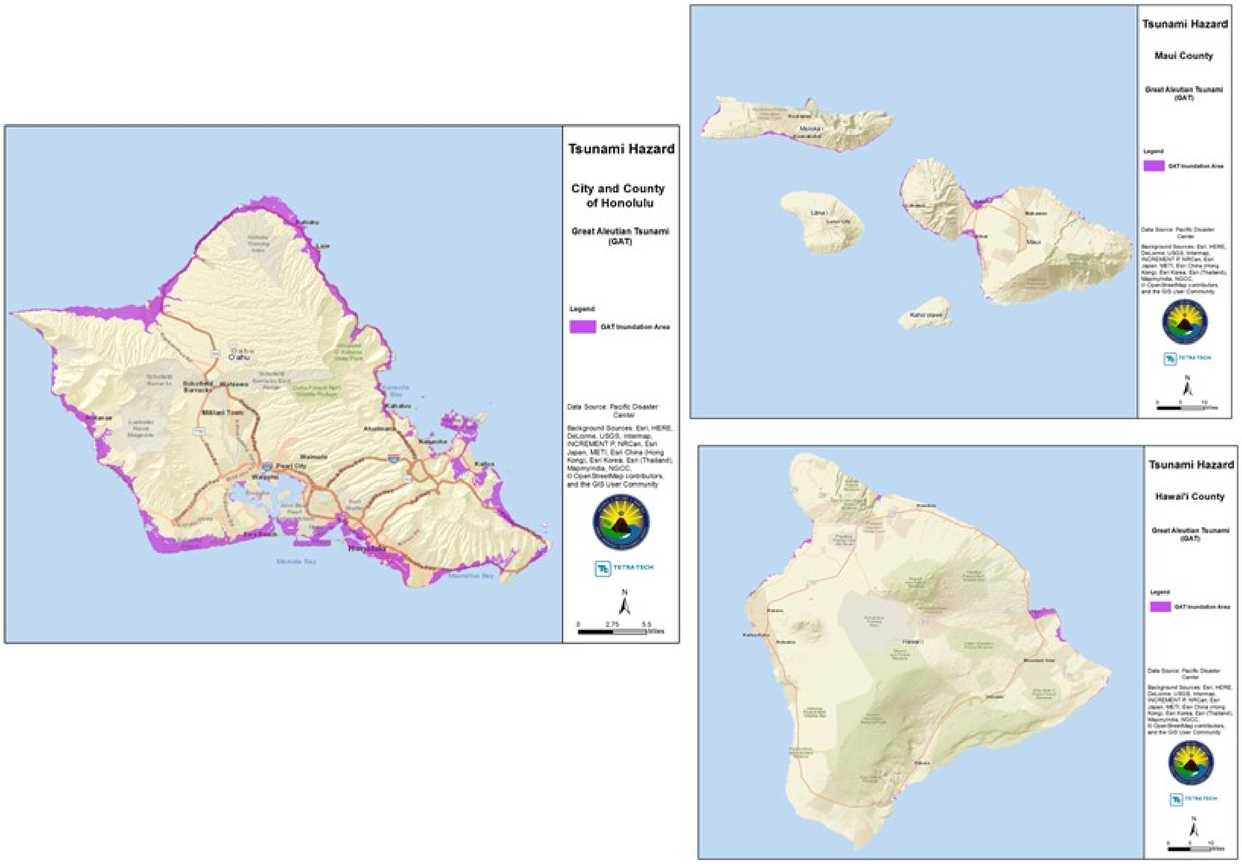
Exhibit 15: Earthquake Impacts Hawai‘i



Source: State of Hawai‘i 2018 Emergency Management Plan

As shown in Exhibit 16, tsunami impact areas and infrastructure risks are the greatest on O‘ahu. In a severe event, significant damage to utility and customer infrastructure would be expected along coastal areas. Some coastal infrastructure damage, albeit more moderate, would also be expected in Maui. From an electric grid infrastructure perspective, critical facilities on Hawai‘i Island are not in the tsunami or flood impact areas.

Exhibit 16: Tsunami Impact Areas focused in O‘ahu and Maui



Source: State of Hawai‘i 2018 Emergency Management Plan

The second set of threat scenarios recommended for consideration in the IGP, shown in Exhibit 17, is a combination of earthquake and tsunami impacts. The moderate case proposed by the RWG is a 7.0 magnitude earthquake on Hawai‘i Island. A magnitude 6.9 earthquake struck in May 2018 and resulted in minimal impact to the grid. Much of this can be attributed to lessons learned being addressed from a 2006 earthquake that resulted in island-wide power outages in Hawai‘i, O‘ahu, and Maui Counties. These outages were predominantly the result of unintended operations of protection and control systems on generators and did not result in permanent damage to equipment due to the seismic activity. As a result, power systems were restored in a relatively short period of time. Although it is unlikely a 7.0 magnitude earthquake will impact electricity infrastructure on Hawai‘i Island, the RWG considers it important to keep earthquake in the list of severe events for consideration.

The severe case recommended by the RWG is a massive seismic event that results in grid and other infrastructure damage well inland on O‘ahu and Maui, due to major tsunami conditions.

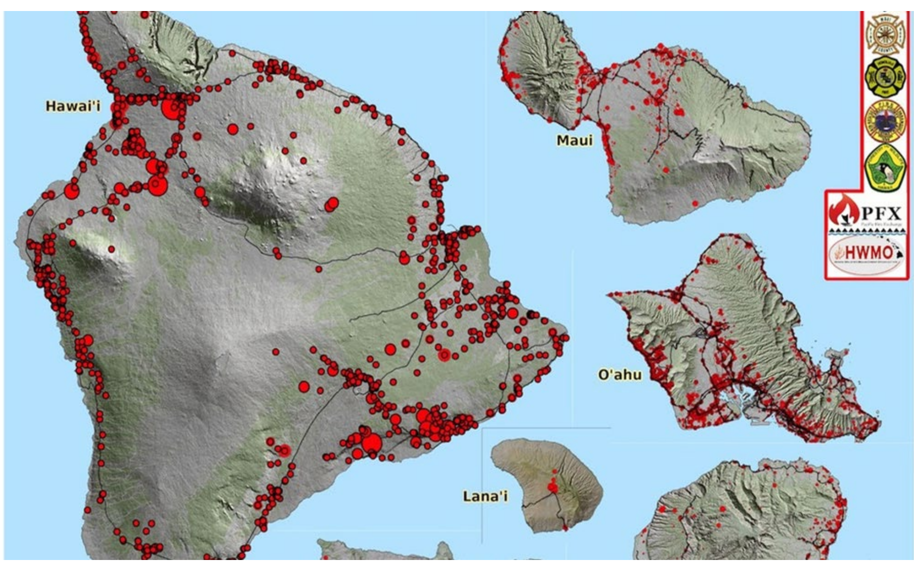
Exhibit 17: Earthquake/Tsunami Moderate and Severe Cases

Earthquake/Tsunami: Hawai‘i has the highest earthquake risk with major fault lines on the eastern portion of the island. Tsunami risk is the highest in O‘ahu.		
	Moderate	Severe
Scenario Description	7.0 earthquake on Hawai‘i island	8.5 earthquake near East Aleutian islands
Scenario Threats	• Infrastructure damage on eastern and southern portions of the island including Hilo where critical infrastructure resides • Transmission and distribution lines and poles damaged • Restoration times one day to two weeks	• 50+ foot runup moving as far inland as 0.75 mile affecting all islands • Coastal distribution substations and feeders restored over one week to six months

3.3.3 Wildfire Scenarios

Wildfires continue to present greater threats to infrastructure and the power grid. As shown in Exhibit 18, the risks to the grid from wildfires are most prevalent in Maui and O‘ahu – Moloka‘i also experiences wildfire risks, although there is less grid infrastructure on that island. On O‘ahu, the threat has the greatest potential impacts on the transmission circuits on the western slope where transmission lines traverse rough terrain and vegetation. Wildfires can damage power lines and poles, as well as substations and other facilities in fire prone areas. On Maui, the greatest risks are to the main power plant at Maalaea.

Exhibit 18: Wildfire Impact Areas



Source: HWMO, a 501(c)(3) Organization based in Waimea on Hawaii Island

The frequency and impacts of wildfires have increased recently. This may be attributable in some parts of the islands to the decline of the sugarcane industry. Sugarcane enterprises historically managed wildfire risks on the islands, including responding to fires. However, today these areas present vast amounts of vegetation that can burn longer and with less ability and resources to control them.

Maui presents unique wildfire risks. Risk is highest along the saddle road due in part to existence of an invasive grass species prone to drying out. The main power plant on the island at Maalaea is in this high-risk area for wildfire. A worst-case consequence is the potential loss of the plant and/or the associated switchyard for months or longer and the resulting power shortages during that period.

As shown in Exhibit 19, the RWG proposes a moderate scenario to include wildfires on the western slope of Oʻahu causing permanent damage to poles, conductors and other equipment. The impacts are worsened by the difficult access to many portions of these facilities.

The severe scenario is proposed to occur in Maui and affect the Maalaea power plant and switchyard, thus damaging the main supply of power to Maui Island.

Exhibit 19: Wildfire Moderate and Severe Cases

Wildfire: Depending on path of hurricane, all islands and locations can be subject to damaging wind, rain and coastal and inland flooding.		
	Moderate	Severe
Scenario Description	Massive wildfire on western slopes of Oʻahu	Severe wildfire in northeastern Maui
Scenario Threats	• Damage all northern transmission corridor circuits • 25% of poles and towers sustain permanent damage • One line restored after 8 weeks; remaining lines restored over four months	• Destroys Maalaea power plant switchyard and power lines emanating from station • Reconstruction and repairs completed in six months

3.3.4 Physical and Cyber Security Scenarios

The RWG recommends that cyber and physical security scenarios also be considered in the IGP process. Physical attacks can result in long-term outages to key electrical equipment, especially hard to replace bulk power transformers. A worst-case condition, outlined in the two scenarios in

Exhibit 20, includes permanent loss of high voltage transformers due to high caliber rifles or explosives. It would be optimistic to replace one of these transformers in 12-18 months, as they would be built overseas and shipped in and transported through very complex procedures and equipment.

Manmade attacks on the grid are not limited to substations and transformers. Historically in the United States, most attacks occur on transmission lines, which can be more remote but still accessible in some areas. Attacks have included shooting at insulators, taking down poles or towers, or shorting out conductors by dropping objects over conductors. These impacts generally though can be readily repaired, and power restored. In some cases, no customers lose power if a transmission line is damaged.

Although the impacts of physical attacks on the grid can be more obvious and longer lasting, cyberattacks are also considered by the RWG to be a significant threat condition. A cyberattack is much less likely to result in permanent damage to grid equipment and therefore allow recovery in a reasonable time. In December 2016, a Russian cyberattack on the Ukraine power grid resulted in loss of power across most of the country. However, Ukraine operators we able to gain manual control of the grid and restore customers within hours. The effect of a cyberattack in scenarios recommended above is to delay restoration and recovery by disrupting situation awareness and damage assessment and requiring manual operations where control computers are removed from service.

In the cases below, one substation is attacked in the moderate case and two of the most critical substations are attacked in the severe case. Half of the high voltage transformers at these affected substation(s) are destroyed in each case (if there are two transformers, one is destroyed; if four, then two are destroyed.)

Exhibit 20: Physical/Cyber Security Moderate and Severe Cases

Physical/Cyber Attack: The relative risk for a physical or cyber attack is fairly constant across all islands.		
	Moderate	Severe
Scenario Description	Moderate physical attack	Severe physical attack
Scenario Threats	• Most critical substation sustains physical damage from high powered rifles and several explosive devices • Half of transformers at substation can be repaired within two weeks • Half of transformers at substation are permanently damaged and require 12-18 months for permanent replacement • Lines and switchgear can be repaired in two to six weeks	• Two most critical substations sustain physical damage from high powered rifles and several explosive devices • Half of transformers at those two stations can be repaired within two weeks • Half of transformers at the two stations are permanently damaged and require 12-18 months for permanent replacement • Lines and switchgear repaired in two to six weeks • Cyberattack disables control center situational awareness and primary voice communications for 24 hours

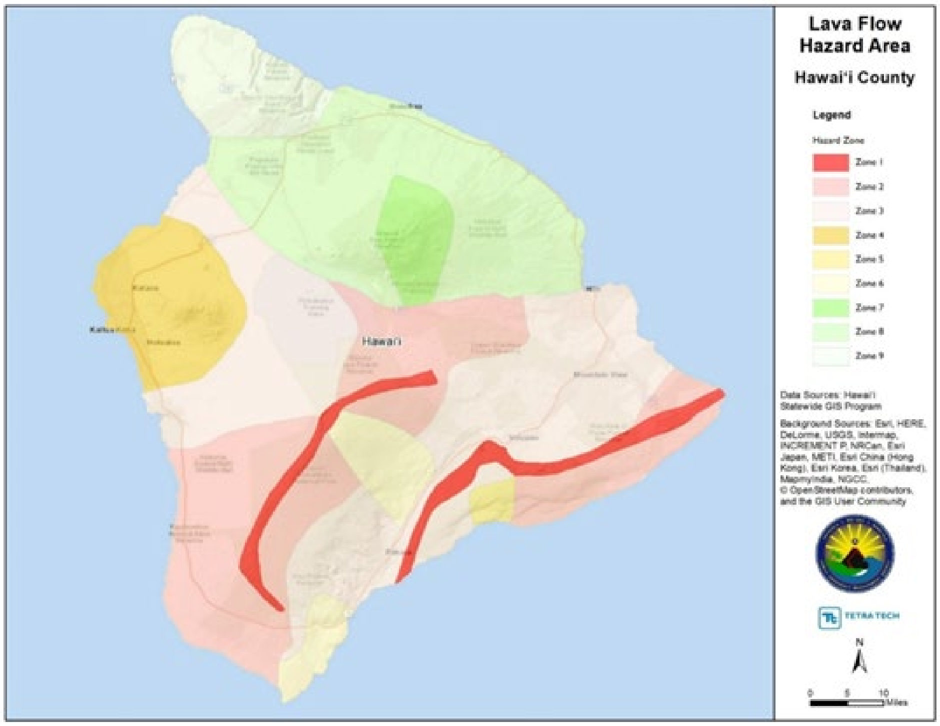
Source: RWG

There was a suggestion that cyber and physical security would not be an issue of concern on Hawai‘i Island. However, the majority of the RWG preferred to recommend the physical and cyber security cases in all three counties.

3.3.5 Volcano Scenarios

The final threat scenario recommended by the RWG is a massive volcano eruption on Hawai‘i Island affecting power generators and limiting access to the area to rebuild for months or possibly years. Historically, the Puna Geothermal Venture has supplied as much as 27% of power to the island. The site is currently inoperable due to the impacts of the 2018 Kilauea lava event affecting operations. Although volcanic activity seems unlikely to affect other electrical infrastructure on the island, the RWG recommends volcanoes remain a grid resilience threat case to be considered. The Kilauea volcano began erupting in 1983 and continued off and on over several decades. Although not currently erupting at the time of this report, Kilauea remains seismically active and can present additional risks in the future. Mauna Loa also remains potentially active.

Exhibit 21: Volcano Impact Areas, Hawai‘i



Source: State of Hawai‘i 2018 Emergency Management Plan

Exhibit 22: Volcano Severe Case

Volcano: Hawai‘i island has the highest risk of a volcano event. Moderate events would not be expected to have a significant impact to the grid and electric supply.	
Scenario Description	Severe eruption on Kilauea
Scenario Threats	• Experiences massive eruption including record lava flows and toxic gases through the south and central portions of the island • Severe activity continues for one month • Transmission outages include north-south corridor in east and east-west corridor splitting the loop • Worker access limited for indefinite period due to conditions • All geothermal and other resources in the area remain out of service indefinitely

3.4 Future Impacts of Climate Change on Infrastructure – Reference to Jupiter Intelligence Report

The Utilities are working with Jupiter Intelligence to assess future climate trends affecting the islands of Hawai‘i.

Hazards in Hawai‘i that lead to flood peril include: (1) riverine and pluvial (direct rain-on-ground) flooding due to heavy rainfall; the flooding is expected to be affected by rising sea levels especially in coastal plains. An emerging view is that rainfall intensity will increase on the wet, windward zones of the islands, and a slight decrease in rainfall event frequency on the dry, leeward zones of the islands during the winter; (2) coastal flooding resulting from tropical cyclone and synoptic winter-storm events, which will be affected by rising sea levels and lead to increased impacts. A scientific consensus about intensification of storms that cause coastal flooding has not yet been established; (3) coastal flooding resulting from high tides, which is sometimes called a King Tide or sunny day flood. The frequency of these events will increase with rising sea levels. Though currently the sea level rise around Hawaii is modest, the rate of sea level rise is expected to increase later this century.

Three primary wind systems affect the Hawaiian Islands. The Trade Winds define nearly 70% of the low-level wind type and variability throughout the year. While Trade Wind strength, which is defined as the wind speed, varies throughout the year, the winds are marked by a persistent direction from the northeast. The most notable exception to the dominant Trade-Wind regime is the occurrence of Kona Lows, which result in a shift in wind direction from the northeast to the south or southwest. Tropical cyclones impact the islands less frequently as they typically pass to the south of the islands, which can result in strong winds from the east.

An analysis of climate projections indicate that even though projected changes to key atmospheric circulations over the eastern North Pacific may occur, they do not translate into significant changes in the Trade Wind systems that affect Hawai‘i. A poleward shift in the primary midlatitude storm track over the eastern North Pacific is a quite robust result from many climate studies. There is some indication that this shift may result in fewer Kona Low type events, but the confidence is low. Furthermore, most extreme wind events over Hawai‘i occur due to Kona Lows and winter storms so a more important factor may be projected changes in the character of the future wind distributions rather than the frequency of events. Finally, tropical cyclones rarely impact the islands directly, but when they have occurred impacts have been severe. There is a low-confidence projection that the large-scale environment of the central North Pacific may become more favorable for tropical cyclone occurrence, which could impact the frequency of hurricane events in the region of the islands.

4. Capabilities of Key Customers and Infrastructures

The second stage of understanding resilience needs related to the power grid is assessing the capabilities of key customers and infrastructure sectors to withstand severe events. These events include extended power outages while continuing to provide essential services under emergency conditions and, in some cases, assisting in restoring power. The RWG determined the most critical capability for most key customers and infrastructure sectors was having backup power capabilities and the ability to acquire fuel resupply if outages are extended beyond a few days into weeks.

4.1 Prioritizing Customers and Infrastructure Sectors

The RWG worked in breakout exercises by sector to develop inputs on customer priorities, needs and capabilities. They identified and prioritized key customers, their roles in recovery and emergency operations, gaps in capabilities and potential solutions to mitigate risks. It is important that critical infrastructure owners and operators work together in a close partnership to plan and coordinate disaster recovery. Recovery and risk mitigation are shared responsibilities between the power companies and key customers.

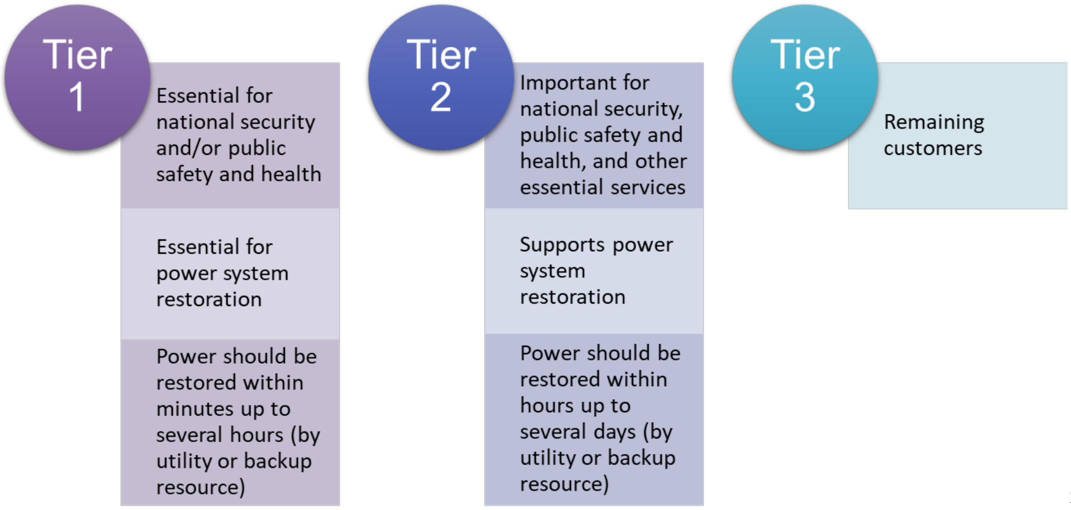
The RWG identified the following objectives for key customers/sectors during a severe emergency:

- Maintain critical functions and services
- Limit fatalities and human suffering
- Limit infrastructure damage
- Limit property damage
- Limit cost and economic impacts
- Limit environmental impacts

It was clear during the severe event scenarios discussed during breakout sessions that loss of electricity in critical customer and infrastructure sectors, whether utility-supplied power or customer-owned backup power, could have severe impacts. These impacts include severe disruption to mission critical services, impacts to life and health of the public, damage to infrastructure and property, environmental impacts, and immense cost and economic implications.

The RWG developed a framework for prioritizing customers and infrastructure sectors from a perspective of importance to supporting (1) national security and/or public safety and health and 2) essential for power system recovery. Exhibit 23 presents the prioritization criteria and customer classifications.

Exhibit 23: Criteria for Identifying Customers and Sectors



[2]

Through a series of breakout discussions, the stakeholders identified which sectors should be in each tier, as shown in Exhibit 24. As a future action item, the Utilities and the RWG need to collaborate to ensure that their priority list is consistent with the Utilities' and emergency managements' restoration plans. Specifically, it was also noted by one member during final review of the report that the energy sector should have been considered. The RWG report does capture important aspects the non-electricity energy sector by

[2] Comment received regarding need to include energy as a separate segment in future RWG work and reports for consistency with state, federal and local emergency planning programs:

Criteria used by the RWG to identify critical customers/sectors should be open for further cross validation with additional subject matter experts and sources. This cross validation would strengthen and more comprehensively and holistically consider all critical facilities'/sectors' energy capabilities and needs following a severe event and extended loss of power. The RWG did not have adequate time, situational awareness of means and data/information to identify critical power (and lifeline) interdependencies and dependencies. It was pointed out in meetings that details may not be known by individual RWG members, facility owners/operators, and emergency response planners.

Because the focus of RWG's work was on electric grid planning inputs, the use and designation of Tier classifications and customers for electric power purposes may vary from the tiering and prioritization of these sectors/customers under existing emergency management, homeland security, and hazard mitigation/resiliency frameworks. There should be a transparent, objective, and justifiable rationale for using any utility regulatory-based tier criteria as a basis for assessments/decisions that are directed at supporting overall resiliency objectives within emergency management's hazard evaluation/mitigation and response planning. The Utilities should consider existing and developing energy resiliency planning priorities in developing planning inputs.

RWG selected these particular eight sectors (in Tiers 1 & 2 above) during breakout discussions with a scope of providing inputs to the IGP – focused on resilience of the power grid. The RWG has not identified the whole "Energy" sector in its Tiers and priorities. Electricity is commonly a subcomponent of Energy (https://www.cisa.gov/energy-sector; https://www.fema.gov/lifelines). The work of the RWG was focused on making the grid more resilient and the interdependencies with other critical sectors. However, the RWG should have considered including other elements of the Energy sector including, for example, liquid fuels, gas, and other energy subcomponents. This is relevant to the RWG because it led to "Energy" not being specifically called out in the RWG Tiers nor identified in the "Sector Interdependencies", "Customer Sector Needs vs Capability", or in the discussion of key customers / capabilities by sector. In general, it would be preferential to align the definition of the sectors to the extent possible with the DHS/FEMA designated functions so that there is a common language being used by all.

focusing so much attention on the storage and transportation of fuel during an emergency, particularly for backup power generation. However, future work should consider adding energy as another critical sector.

Exhibit 24: RWG Recommended Customer Classifications by Tier

Tier 1	Tier 2	Tier 3
• Military • Telecommunications • Hospitals and critical healthcare • Water and wastewater • Emergency management and first responders	• Transportation • Hospitality • Banking and finance	• Remaining customers

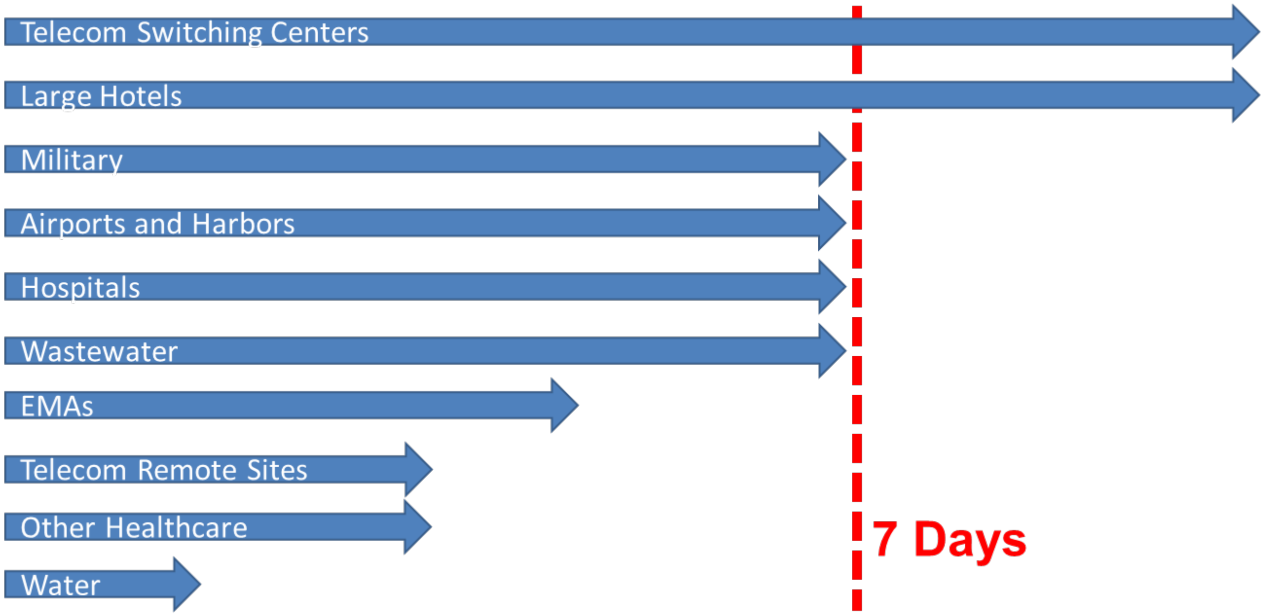
Source: RWG (Transportation included 'Energy' sector)

Tier 1 addressed not just priority but also urgency, in terms of time to restore power. These are life sustaining services. Harbors and airports can come back in a few days and would likely be closed the initial few days while situation assessment is ongoing. It should be noted that this prioritization is broad brush and that within each sector there is a wide range of capabilities and needs. For example, during a disaster there may need to be an emphasis on restoring harbors, ports, and airports to bring in urgent supplies. Not all military facilities rise to the same level of criticality to national defense.

4.2 Key Customer Capabilities and Needs

The RWG worked through a series of breakout sessions to evaluate the capabilities of key customers and sectors to operate during power outages. The first exercise in August looked at initial impacts, impacts after seven days and then impacts after four weeks without offsite power. Once again, these tests were not intended as expectations, but stress tests to find the range of capabilities in the key customer sectors. As shown in Exhibit 25 below, most sectors reported having backup power at key sites and generally a seven-day supply of fuel. Telecommunications main switching centers reported more than seven days of backup fuel supply. Many water facilities were deemed to not have backup power supply onsite (some portable facilities are available) and in many cases have a one-day fuel supply.

Exhibit 25: Summary of Backup Power and Fuel Capabilities



Source: RWG

The summaries above are not uniform across each sector but represent a broad estimate for the sector. Facilities vary in importance and remoteness, therefore there is a wide dispersion of capabilities across various sectors.

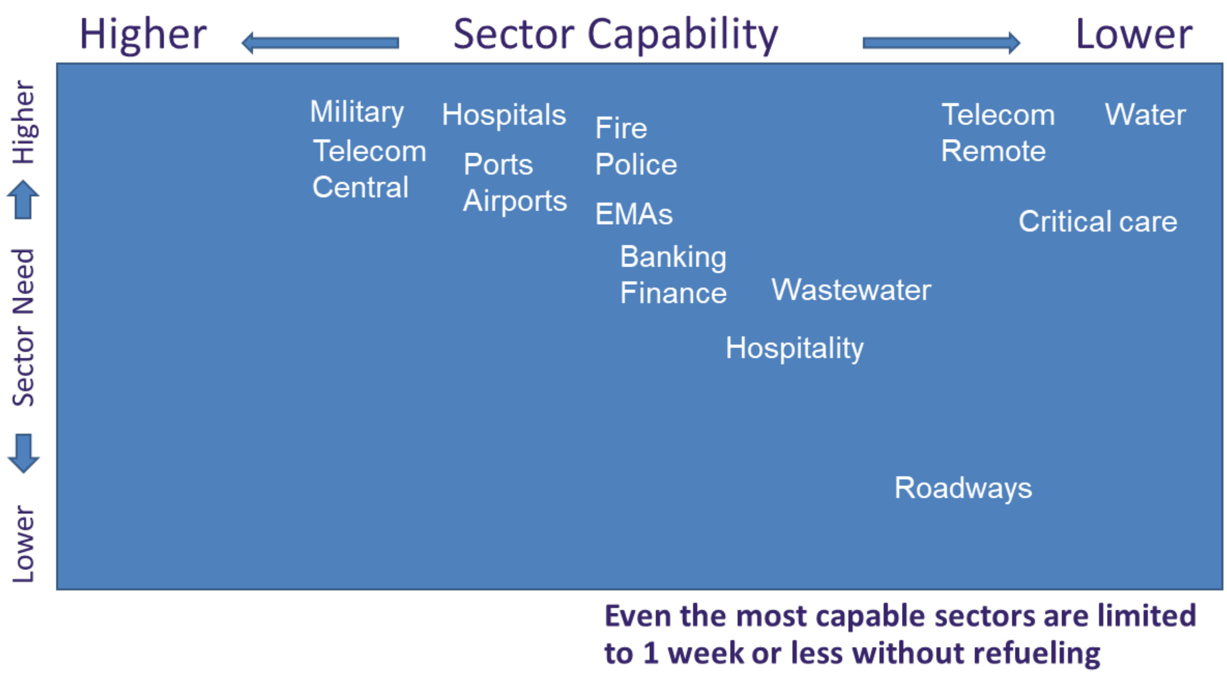
Resilience goes to issues beyond the utility grid that are not under the control of Utilities. For example, fuel supply and distribution, water availability, and communication issues were identified as significant issues across all segments.

Normal planning contingencies for power outages lasting days or a week is insufficient for major events that result in outages that could last weeks or even months in some areas. In these situations, road access to transport fuel and the shipping, ports, loading/unloading facilities and fuel storage become very critical on all islands.

Exhibit 26 below shows the relative capabilities of each sector compared to the need or importance of that sector to defense, health and welfare or system recovery. Most sectors are aligned as would be expected, most urgent need sectors have the highest capabilities to maintain backup power for longer periods when offsite power is unavailable. Three exceptions were noted where there is a high level of urgency for backup power and continuous operation, yet there are comparatively limited capabilities. These areas are:

- Telecommunications remote sites (e.g. cell towers and other distributed facilities)
- Water facilities and remote pumping stations
- Critical care facilities other than major hospitals

Exhibit 26: Customer Sector Need v. Capability to Self-Supply



Source: RWG

Once again, this graphic is a simplification showing a high-level, aggregated perspective discussed during breakout sessions. There are variations by facility within each sector. For example, not all military facilities have backup power. Generally, the mission critical facilities within each sector do have backup power capabilities.

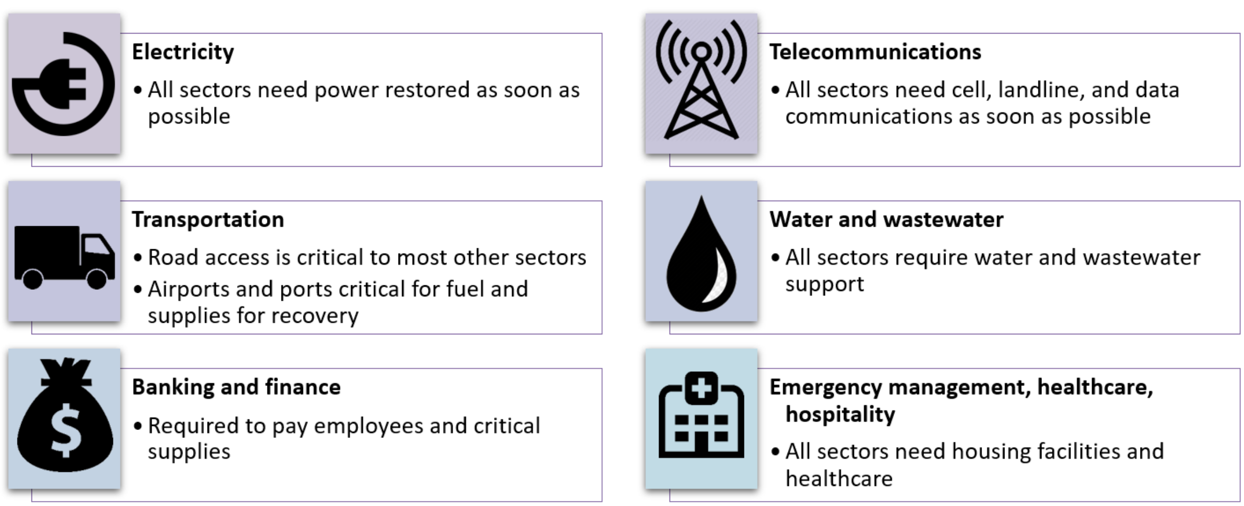
It should be noted that even the most capable sectors are shifted somewhat to the right and there is a blank area on the left of this diagram. That area could be called 'the backup fuel' gap. All sectors could be moved to the left (greater resilience capability) with longer-term backup fuel plans and resources.

A key result of the exercises that included simulation of extended power outages was that all sectors are heavily dependent on replacement fuel if there is an extended power outage on one or more of the islands. Access to fuel replenishment depends on clearing of roadways, access to and distribution of fuel storage and supplies, and in the longer term, the ability of ports and ships to bring in more bulk fuel. Worst case scenarios with extended power outages are those that also include severe disruption of the fuel supply chain resulting, for example, from damage to harbors, ports, storage tanks, loading/offloading equipment, and distribution capabilities (pipelines, tanker trucks, barges).

Key customers and infrastructure sectors, such as hospitals, first responders, emergency management, and food supplies, are not only important to the health and safety of the public during emergencies, they are also part of FEMA's Community Lifelines construct. A lifeline enables the continuous operation of critical government and business functions and is essential to human health and safety or economic security. The 7 identified Lifelines are the most fundamental services in the community that, when stabilized, enable all other aspects of society to function. The response prioritizes the rapid stabilization of Community Lifelines after a disaster. The integrated network of assets, services, and capabilities that provide lifeline services are used day-to-day to support the recurring needs of the community and enable all other aspects of society to function. When disrupted, decisive intervention (e.g., rapid re-establishment or employment of contingency response solutions) is required to stabilize the incident.

These sector interdependencies became clear as the RWG worked through several severe event scenarios and identified capabilities and needs of each sector to ensure essential services could survive during and after severe events.

Exhibit 27: Sector Interdependencies



4.3 Opportunities for Critical Customers to Improve Resilience from Loss of Power Events

It is important to realize that grid resilience is not limited to grid solutions and what the Utilities invest for resilience enhancements. The goal of resilience, as previously mentioned includes the health and safety of the public, national security, minimizing the environmental and economic impacts of disasters, and other objectives. These objectives are a shared responsibility of the critical infrastructure sectors, including electricity but not the sole responsibility of the power companies.

There are several steps key customers and sectors can take to mitigate the risks of extended power outages due to disasters:

- Infrastructure owners and operators work together in close partnerships to coordinate disaster planning and recovery. Recovery and risk mitigation are shared responsibilities between the power companies, key customers and the government
- Key customers develop and implement load management/load curtailment capabilities to limit power usage to mission critical loads during emergencies with loss of offsite utility power
- Key customers maintain ample onsite fuel supplies for generators during extended power outages and transportation disruptions and have in place plans and fuel supply arrangements resupply fuel for outages exceeding operational expectations; coordinate resupply plans so that multiple facilities, sectors, and geographic areas are not relying on the same fuel resources at the same time; provide backup power sources that can supply essential loads during prolonged outages and emergencies; test and exercise backup power resources
- Under their Continuity of Operations Planning (COOP), key customers should consider relocating essential functions to alternative facilities at sites/locations with more robust infrastructure support
- Key customers consider developing plans and arrangements for deployment of temporary emergency power generators that can be relocated to critical sites during prolonged outages
- Key customers consider partnering with Utilities and the government to develop local microgrids for power that can be isolated from the grid when needed (during severe events); consider alternative technologies, such as renewables and storage, and other blackstart resources
- Key customers in the transportation sector ensure availability of adequate road clearing equipment to speed recovery of key roads, ports and airports
- Key customers reinforce harbors and port facilities against catastrophic flooding and storm damage to ensure they can maintain maritime operations during extended power outages
- Customers maintain training and exercise programs that address performing emergency and contingency operations with loss of utility power

Key customers and critical infrastructure owners and operators should consider partnerships with the Utilities, other energy companies, and the government in developing local resilience solutions that can provide resilient power for essential service providers and enhance the overall resilience of the grid for all customers in mutually beneficial projects. Key customers and critical infrastructure owners and operators should also consider alternative technologies, such as microgrids, renewables and storage, and other blackstart resources, potentially working in partnership with the utilities. Recently, utilities began requiring in their RFPs that renewables bids have grid-forming inverters, meaning they can provide a blackstart capability which is something that renewable energy projects normally cannot do.

5. Opportunities to Improve Grid Resilience

This section examines the configuration and capabilities of the power grid on each island and how key customers and infrastructure sectors map to each grid. This allows the RWG to identify opportunities for solutions that may improve grid resilience in important ways that allow the critical sectors to provide essential services during emergencies.

5.1 Characteristics of Power Grid on Each Island

Oʻahu is characterized by a concentration of generation on the leeward side of the island in the southwest corner (Exhibit 28). Two primary transmission corridors deliver bulk power to the major load centers along the southern coast. This area is also where many of the critical customer facilities are located. It should be noted, however, that not all key customer sites are in the major load center area in the south. Some are remote and require alternative solutions between the Utilities and the customers to ensure these critical sites can perform mission critical functions during extended power outages.

The northern transmission corridor is comprised of four circuits that traverse steep and rugged terrain. This key backbone of the system can be susceptible to high wind events due to vegetation and flying debris. Being on the leeward side of the island, this corridor can also be susceptible to severe impacts from wildfire. Being remote, this corridor could also be susceptible to physical sabotage. The southern transmission corridor has two circuits, with some under underground cable sections. This corridor is easier to access during system restoration, but some portions could experience flood risks.

There are blackstart units available in the area surrounding Honolulu Harbor, providing an option to restore power from the load end of the system. Typically, during a blackstart situation, however, the priority of the Utilities would be to reenergize backbone circuits and then add load as the system was reconnected. During severe, extended events such as those contemplated in the recommended scenarios, alternative strategies may be needed to reconnect essential customers as a priority before being able to restore the backbone of the system.

Exhibit 28: Oʻahu Grid Characteristics and Key Customers

[MAP REMOVED FOR SENSITIVITY]

The configuration of the Oʻahu power system has most of the generation on the southwest side of the island, transmission lines delivering bulk power to the major load centers, and then distribution facilities delivering power the final step. One potential resilience challenge in some sections of the transmission network is that individual lines are physically close in proximity, in places sharing the same easement. Electrically the circuits are networked and can provide uninterrupted power flow during N-1 and N-1-1 events. However, impacts of some of the severe events contemplated in this report may result in multiple circuits lost in the same easement. This impact could be further exacerbated by some locations having difficult access for repairs. A summary of O'ahu grid resilience characteristics is presented in Exhibit 29.

Exhibit 29: Summary of O'ahu Grid Resilience Characteristics

Characteristics

- More linear system
- Load concentration in Honolulu
- Generation concentration in one location

Major Vulnerabilities

- Transmission disruption
  - Towers and poles damaged
  - Difficult access in some areas
  - Limited spares
- Generation flooding
- Fuel disruption

Resilience and flexibility could be enhanced on O'ahu for the severe events presented by considering some alternative strategies:

- Expanding blackstart capabilities at or near substations serving key customers and infrastructure facilities.
- Expanding generation at an alternative site such as Schofield Barracks and reinforcing circuits from there into the load centers, rather than relying on in-city blackstart or restoring the transmission circuits from the west.
- Establishing one or more circuits with enhanced restoration capabilities and greater hardening to serve as primary paths for system recovery.
- Adopting advanced technologies in a more distributed resource approach, including grid-forming renewable energy sources, alternative blackstart resources, battery storage, and joint projects with key customers to provide microgrid capabilities for emergency operations and disaster recovery.
- Configuring the grid in several mini grids that could operate as independent islands that could be self-supplying over an extended period during severe or prolonged utility power outages.
- Developing alternative facilities and transportation to import replacement fuel.

- Expanding critical resources, supplies, backup equipment, and materials to more quickly restore damaged circuits, substations, generators, and distribution facilities following severe events.

The Hawai‘i Island grid is characterized by a ring configuration (a loop around the island), which is beneficial from a resilience perspective because there can be alternative paths and resources available if one part of the system becomes damaged. Generation is located on the system in three areas on the east and northwest coasts and in the south. Puna Geothermal Ventures, a clean energy resource in the eastern portion of the island, makes up 27% of the generating capacity for the island and is currently non-operational due to the impacts of the 2018 Kilauea lava event. A depiction of the grid and key customers is presented in Exhibit 30.

Exhibit 30: Hawai‘i Island Grid Characteristics and Key Customers

[MAP REMOVED FOR SENSITIVITY]

Load centers and key customers in Hawai‘i are much less concentrated than on O‘ahu and are also distributed around the island similar to the generation resources, mostly around Hilo and the west and northwest coastal areas. This configuration has some advantages from a resilience perspective that generation is already more distributed and closer to the loads than on O‘ahu. Grid facilities also are generally outside inundation zones, on Hawai‘i Island, which is an important feature.

Exhibit 31: Summary of Hawai‘i Island Resilience Characteristics

Characteristics

- Ring system with cross ties
- Load center and key loads
  - Hilo
  - Kona
- Generation distributed around ring

Major Vulnerabilities

- Vegetation impacting power lines and access
- Fuel disruption
- Earthquakes
- Volcanic activity
- Spares, supplies and road access

Resilience and flexibility could be enhanced on Hawai‘i Island for the severe events presented by considering some alternative strategies:

- Expanding blackstart capabilities at or near substations serving key customers and infrastructure facilities in the Hilo area and along the west and northwest coast.
- Adopting advanced technologies in a more distributed resource approach, including grid-forming renewable energy sources, battery storage, and joint projects with key customers to provide microgrid capabilities for emergency operations and disaster recovery.
- Configuring the grid into two or three mini grids that could be self-supplying during severe emergencies over extended periods.
- Developing alternative facilities and transportation to import and distribute replacement fuel, as disruption to the port at Hilo could result in major delays in energy system recovery.
- Expanding critical resources, supplies, backup equipment, and materials to restore damaged circuits, substations or generators, including distribution more quickly following severe events.

Exhibit 32: Maui Grid Characteristics and Key Customers

[MAP REMOVED FOR SENSITIVITY]

Maui has resilience characteristics similar to O‘ahu (Exhibit 33). First, the generation is concentrated in one area, mainly Maalaea power plant near the southern saddle coast. Several load centers are served from that point, the city of Kahului to the north and the residential and tourist loads along the western and southern shore areas. Once again, though much fewer in number, the key customer sites are somewhat concentrated in the load centers but also many are remote.

The south-central area near Maalaea has increasingly become a severe wildfire danger area. With the main plant for the island there, severe wildfire damage to the plant, switchyard or transmission could lead to extended outages across the island with limited options to provide alternative sources. In addition to the wildfire risk at Maalaea, generation facilities and the control room located in an inundation area and present a major resilience risk.

Exhibit 33: Summary of Maui Resilience Characteristics

Characteristics

- Load center at Kahului
- Resort and residential load along west coast
- Generation at Maalaea

Major Vulnerabilities

- Fuel disruption
- One major generating plant
- Wildfire hazards
- Coastal flooding
- Spares, supplies and road access

Resilience and flexibility could be enhanced on Maui for the severe events presented by considering some alternative strategies:

- Expanding blackstart capabilities at or near substations serving key customers and infrastructure facilities in the Kahului area and along the west coast.
- Adopting advanced technologies in a more distributed resource approach, including grid-forming renewable energy sources, battery storage, and joint projects with key customers to provide microgrid capabilities for emergency operations and disaster recovery.
- Configuring the grid into two or three mini grids that could be self-supplying during severe emergencies.
- Developing alternative facilities and transportation to import and distribute replacement fuel, as disruption to the port at Kahului could result in major delays in energy system recovery.
- Expanding critical resources, supplies, backup equipment, and materials to restore damaged circuits, substations or generators, including distribution more quickly following severe events.
- Consider extraordinary wildfire mitigation strategies to minimize risk of damage at Maalaea.

Exhibit 34: Moloka‘i Grid Characteristics and Key Customers

[MAP REMOVED FOR SENSITIVITY]

Exhibit 35: Lāna‘i Grid Characteristics and Key Customers

[MAP REMOVED FOR SENSITIVITY]

Exhibit 34 and Exhibit 35 show grid characteristics and key customers in Moloka‘i and Lāna‘i. Both have similar characteristics regarding resilience. They have much less development and load and fewer key customer sites. The system is predominantly radial supplied by a central generator site, and there is a single site for bringing in fuel and supplies. Therefore, each system has limited flexibility in the event of severe grid damage from one of the scenarios contemplated in this resilience assessment. Resilience characteristics of the islands are summarized in Exhibit 36.

Exhibit 36: Summary of Moloka‘i and Lāna‘i Resilience Characteristics

Characteristics	Major Vulnerabilities
• Directly connected to radial distribution feeds to customers • Limited refueling capability during emergency	• One generating plant • Wildfire hazards • Coastal flooding • Spares, supplies and road access

Please Add: “Fuel Disruption” (Resupply and Distribution) to and within Maui County (Lanai & Molokai) is and has been a major vulnerability for years.

Resilience and flexibility could be enhanced on Moloka‘i and Lāna‘i for the severe events presented by considering some alternative strategies:

- Expanding blackstart capabilities at alternative locations.
- Adopting advanced technologies in a more distributed resource approach, including grid-forming renewable energy sources, battery storage, and joint projects with key customers to provide microgrid capabilities for emergency operations and disaster recovery.

- Developing alternative facilities and transportation to import and distribute replacement fuel, as disruption to ports could result in major delays in energy system recovery.
- Expanding critical resources, supplies, backup equipment, and materials to restore damaged circuits, substations or generators, including distribution more quickly following severe events.

5.2 Additional Options for Improving Grid Resilience

There are numerous options for enhancing grid resilience to the threats identified in this report. The priority is to close gaps identified in the ability to withstand severe events or recover from them in a timely manner. This objective applies to grid facilities as well as key customer capabilities.

An integrated plan should consider options across generation resources, transmission and distribution. The previous summary of options for each island provides good examples of how a combination of resource, transmission and distribution options may provide more flexible and effective risk mitigation while also providing better investment value, as will be discussed in the next section.

It is also worth noting that some grid resilience solutions may not be about the grid at all or may not be developed through an IGP process. An example is enhancement of the resilience or redundancy of fuel supply and distribution facilities and airports to ensure fuel and critical supplies can be delivered to end users. From an operational perspective, fuel supply is a very significant concern as barge schedules become disrupted with hurricanes/surf/wind conditions, and any significant damage to pipelines, barges, or ground transportation will impact all Community Lifelines. This, when coupled with the shutdown of certain renewable resources during stormy conditions (wind, solar), will strain energy system recovery even more. It doesn’t take many missed barges to get into a fuel shortage situation and this has happened in the past. One solution is to define a minimum fuel supply based on missing barges and a changed fuel mix during emergency conditions.

Other resilience options for the Utilities to consider outside of the grid planning process include:

- Utilities continue to explore and develop advanced resilience data as demonstrated by the technologies of Jupiter Intelligence
- Utilities partner with key customers and the government to develop microgrids for power that can be isolated from the grid when needed (severe events)
- Utilities reinforce fuel resupply options by increasing distributed storage and delivery capability for severe event emergencies
- Utilities plan for additional crews during emergencies and provide more robust and regular training for emergency situations
- Utilities expand critical resources, supplies, backup equipment, and materials to restore damaged circuits, substations or generators, including distribution more quickly following severe events
- Utilities plan for emergency access to additional helicopters on the islands to support repairs in remote, difficult to access sites
- Utilities plan for enhanced vegetation management, particularly in critical grid areas susceptible to damage from wind and falling or flying debris

- Utilities continue hardening or reinforcing critical transmission circuits, including upgrading wind criteria and flood mitigation, upgrading structures, and using enhanced construction methods and materials
- Utilities continue efforts at enhancing physical and cyber security of assets, resources, and systems.
- Utilities continue planning for expanding underground cables (water resistant) and locating equipment outside flood prone areas
- Utilities consider alternative paths for transmission circuits to increase diversity of location and enhance performance during severe events
- Utilities establish one or more priority circuits with enhanced restoration capabilities and greater hardening
- Utilities continue to require that new RFPs for renewables bids include grid-forming inverters, meaning they can provide a blackstart capability
- Utilities consider adopting advanced technologies in a more distributed resource approach, including grid-forming renewable energy sources, battery storage, and joint projects with key customers to provide microgrid capabilities for emergency and backup operations
- Utilities develop wildfire mitigation strategies for worst case wildfire event at Maalaea
- Utilities develop and test capabilities of expanded use of drones for emergency response and regular maintenance inspections
- Utilities evaluate options for distribution automation, digital meters and associated communications networks which can be valuable in assessing system conditions, the extent of outages, and how to best prioritize recovery efforts to get key customers reenergized more quickly

Utilities consider actions to reduce tsunami risk impacting generation in inundation zones on O‘ahu

The RWG also considers these solution options to be available over the full period of the Integrated Plan – not everything has to be done at once. Many of the enhancements such as hardening select facilities can be done over time through regular maintenance or scheduled replacement. Thus, the existing system would be continuously improved and expanded, rather than replaced.

One option identified by the RWG was the increased use of underground cabling. Certainly, underground cable addresses the risk of many of the threats identified by the RWG. It is, however, much more expensive than overhead circuits and the IGP process should examine these tradeoffs. There has been use on O‘ahu of special water-resistant cables that can better address the flooding risk along the southern transmission corridor. One option could be to expand this program to upgrade and expand cables with water resistant technologies.

Drones and access to additional helicopters may need to be planned to address the severe scenarios considered in this report. Drones have gained rapid acceptance across the United States in providing damage assessments and condition inspections, helping to prioritize restoration and rebuilding facilities.

Distribution automation, digital meters and associated communications networks can be valuable in assessing system conditions, the extent of outages and how to best prioritize recovery efforts to get customers reenergized more quickly.

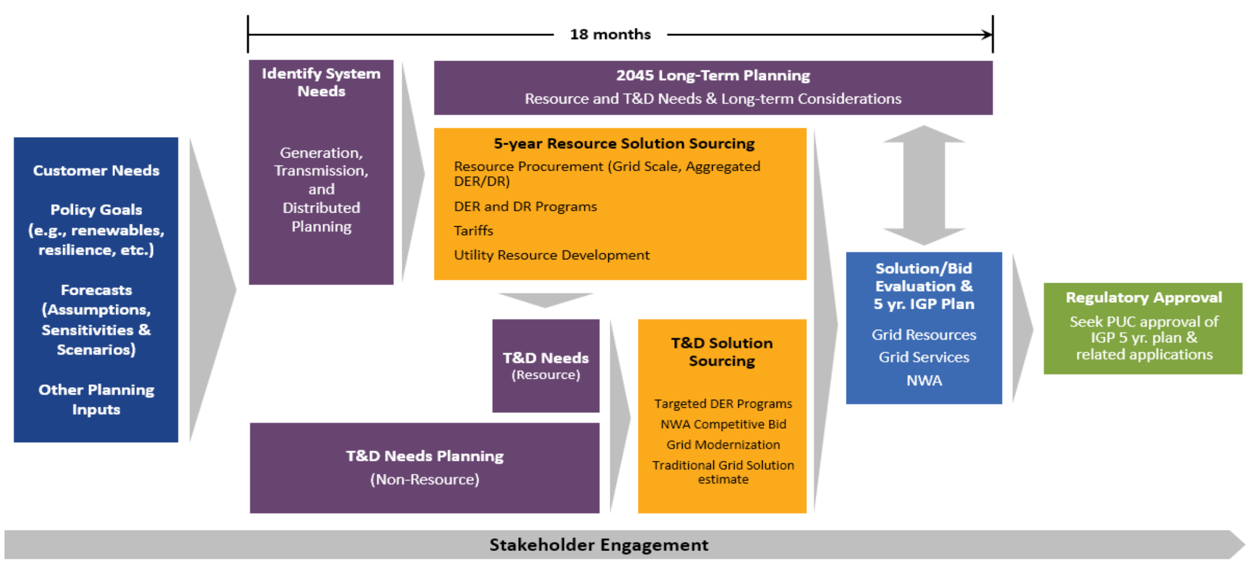
A robust vegetation management program should be considered as a top strategy for resilience risk management. Finally, fuel supply assurance under a range of severe conditions will have resilience benefits for the Utilities as well as key customers and infrastructure sectors.

6. Inputs to Integrated Grid Plan and Other Related Activities

6.1 Resilience Related Objectives

Building on the work performed and alignment on resilience priorities, a key outcome of the RWG is to provide recommendations and inputs for the IGP process to address resilience needs. The intent of the RWG is to provide guidance to the IGP process and related activities rather than to be prescriptive regarding inputs to a very technical process. There are several areas of development of an IGP that must consider resilience inputs, including defining resilience objectives and how resilience will be measured, defining alternative resilience strategies, consideration of a number of low probability, high impact scenarios, and measuring relevant costs of alternative strategies and various levels of resiliency. As shown in Exhibit 37, the RWG process to date aims to provide some perspectives on how resilience might influence inputs into the analysis.

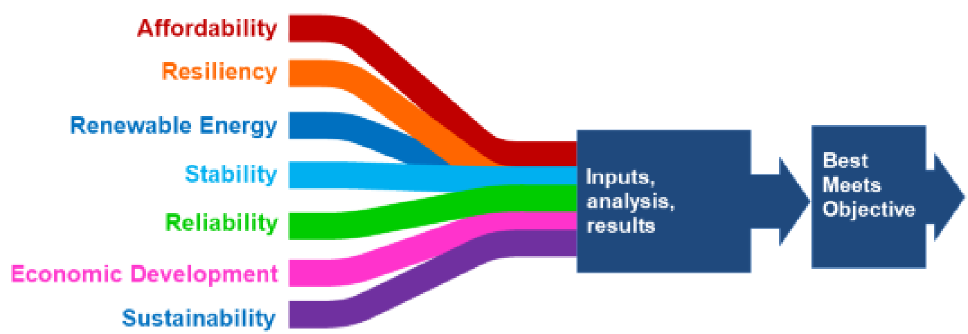
Exhibit 37: Overview of the IGP Process



Source: HECO

One of the first steps in any planning process is to define objectives and assign one or more metrics to each objective. Most stakeholders have multiple objectives. For example, some customers are interested in receiving power at the lowest possible cost. Other customers would pay more for reliability. Other customers might target resilience as a critical objective. Still others may value sustainability. Objectives are largely driven by customer needs. Since customers have different needs, the Utilities should evaluate multiple objectives and determine a portfolio of options that best meets all objectives at a reasonable cost. Exhibit 38 presents common utility objectives in a planning process.

Exhibit 38: Common System Objectives in Utility Planning



Source: HECO

Once selected, the Utilities can track how well each portfolio performs across all events or scenarios. A portfolio of options that performs well across all scenarios and all objectives/metrics is considered a the "viable" portfolio.

Siemens provided the RWG a high-level perspective to utility planning that suggested that utilities begin with a list of objectives that customers are looking for from a plan. The list includes things such as least cost, reliable, resilient, sustainable and flexible. Each objective typically should have a metric that can be measured so that the Utilities can assess tradeoffs between each objective.

- The least cost objective typically uses the NPV of costs over a planning horizon as a metric
- Reliability is often measured by a loss of load probability
- Sustainability is often measured in terms of renewable percentage of the portfolio or carbon tons.

Resilience is relatively new as an objective in planning. The RWG didn't propose a specific metric, but the group did express the view that costs should not be the only measure of resilience to consider. Hence Siemens facilitated a discussion of possibilities that the Utilities might consider as a resilience metric.

The RWG reached general agreement that all relevant costs need to be captured, which includes the costs that utilities might incur to mitigate severe outages, as well as the cost of the outage to customers and stakeholders. It might also include costs that customers incur to mitigate the impact of severe outages, especially if those measures might be more cost effective than those incurred by the utility.

The Least Cost Objective:

Nearly every planning effort looks to achieve a portfolio that is cost effective over a planning horizon as one objective. However, traditional planning by utilities tends to focus on actions under the control of the utility. The RWG recommends that the Utilities consider all possible lowest cost solutions, whether they can best be accomplished solely through utility actions or through a combination of utility, other energy sector market participants, and stakeholder actions. Hence RWG recommends that some consideration of market participant and stakeholder actions be captured in the analysis of options.

In addition, when the RWG recommends that several low-probability, high impact events are considered in the analysis phase, it becomes critical to consider the outage costs as an offset to the costs associated with building resilience into the grid. In other words, the incremental costs of actions to manage resilience may be cost justified relative to the cost to society if the outages occur without mitigation. For planning purposes, one needs to sum the costs applied in the grid to the cost of the outages (times the probability of the outage) to achieve the expected value of the net present value of costs over the planning horizon as the appropriate cost metric.

The Resilience Objective:

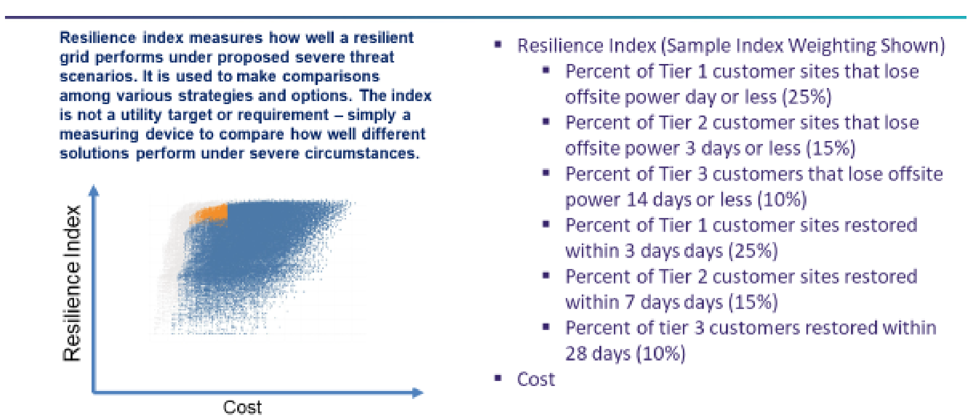
The second IGP recommendation of the RWG is that resilience should not only be measured as a cost but should be a separate goal with its own measurable outcomes. This step requires the definition of resilience goals and quantification of the degree of resilience achieved in a single or combination of metrics.

There is little experience to draw from in the construction of a resilience metric. Siemens provided an illustration of the concept. The example in Exhibit 39 shows an illustration of a resilience index that measures resilience performance across the three different customer tiers (Tier 1- Critical, Tier 2 – Priority and Tier 3 All). The index has two components. The first is the percentage of customers that do not lose power or lose power only for a relatively short time (times are specified by tier).

The concept is that enhanced resilience should result in critical customers having no interruption or interruptions for a shorter time. The second component of the resilience index is how long it takes to restore customers who do have extended outages caused by a severe event impacting the grid. Resilience enhancements would be expected to shorten recovery times.

If an index is constructed, it could allow for comparisons that allow one to determine the cost of higher levels of resilience, just as one can compare the cost of incremental levels of carbon reduction. The percentage numbers in parentheses indicate the relative weight of each component of the resilience metric (totaling 100%).

Exhibit 39: Example Resilience Metric



Source: Siemens

Policies, Assumptions and Other Inputs:

Policy goals are different than metrics. Policy goals for planning purposes can be considered in analysis as requirements to be met or constraints in modeling and analysis. So rather than simply tracking how quickly customers are returned to service after an event, the Utilities could establish goals that must be achieved through options. For example, the Utilities could specify that all critical customers should not have an outage of more than one day. This would require the Utilities and stakeholders to define a target for one or more of the most extreme events regardless of cost in order to assess the relative cost of resiliency.

Again, the RWG does not intend to define a policy goal, but some members of the RWG suggested that the Utilities should consider defining a realistic goal or goals during or at the end of the process, once the resilience benefits and costs are better understood from the planning analysis. The Utilities could then evaluate different policy goals and analyze the cost of each.

Key Inputs to the Analysis:

Data and inputs specific to assessing resilience will be needed to measure the relative costs and resilience characteristics of proposed portfolios and solutions in the IGP process. A forward view on the likelihood or relative risk of severe events specific to individual systems is needed and is likely to vary by island.

To properly determine the risks associated with different events such as hurricanes, tsunamis or volcanos one must have forecasts of both the frequency and the severity of future weather-related events. The Utilities already retained an organization that can provide forecasts of sea level rise, the probabilities of wind and flood damage and the severity of those events. These are critical to evaluating the need for mitigation measures and are critical for assessing the expected costs of outages with and without mitigation options.

Other inputs might include:

- Current restoration times for events by customer tier and location
- Costs to restore service under events (without mitigation options) by location
- Determining the cost of an outage to customers by class (e.g. the cost of load not served), and the state as a whole, will be another important input to the IGP process
- Current levels of backup power, fuel and water held by customer tier and location

Exhibit 40: Example Resilience Policy Goals, Forecasts and Other Inputs

Customer Needs

Policy Goals (Renewable, Resilience, etc.)	Forecasts (Assumptions and forecasts)	Other Planning Inputs
▪ Meeting renewable and carbon goals ▪ Tier 1 backup power available to maintain until restoration occurs under all scenarios ▪ Tier 2 power returned within hours/days until restoration occurs under all scenarios	▪ Future weather patterns (impacting surge etc ▪ Impacts of hurricanes, earthquakes, tsunamis, fires etc on levels of flooding, wind damage ▪ Recovery times for locations on each island	▪ Days supply of power for each Tier 1 and 2 customers ▪ Days supply of fuel and water for each Tier 1 and 2 customer ▪ Vulnerability assessment, including downtimes for all Tiers of customers for each scenario

Forecasting extreme events and the impacts to systems and recovery times will require structured inputs that when varied consistently measure the relative resilience of the system in the IGP process. This measure will be compared to the objectives and policy goals defined upfront in the IGP process.

6.2 Potential Solutions and Strategies

A solution is really a portfolio of options to achieve a set of target objectives. The RWG does not want to specify exactly how the alternatives might be developed but there are at least several strategies that might be considered, either as part of the IGP or separately as part of the Utility Bid process, or future utility stakeholder partnerships. Exhibit 41 shows some of the types of strategies that might be considered.

Exhibit 41: Potential Resilience Solutions

Potential Solutions to Consider in Planning Analysis		
Centralized/decentralized	Centralized resources	Decentralized resources
Transmission	High transmission expansion	Low/no transmission expansion
Solar	High solar energy	Low solar
Wind	High wind including offshore	Low wind
New technologies/non-wires	Yes	No
Underground	High underground expansion	Low/no underground expansion
Black start	High black start resources	Low new black start resources
System hardening	High	None
Fuel supply hardening	High	None
Recovery/construction supplies	High increase	No change

Some examples of potential strategic options include:

1. Varying the level of decentralization. Today most of the Hawaiian islands have a highly centralized system where generation is on one part of the island and long transmission lines carry the power to load centers (Hawai‘i island is the exception). At the other extreme would be a highly decentralized system where existing fossil generation is replaced by renewables and small-scale ramping technologies closer to load centers distributed throughout the islands. An in between strategy would be to focus the local generation at more remote parts of the islands. The RWG recommends that the Utilities consider two to three different levels of decentralization to determine how well each strategy performs on resilience and costs. In any event, consideration of blackstart technologies needs to be considered for each strategy.
2. Setting up different policy targets for recovery periods in the event of severe events. The RWG recommends that the Utilities consider defining alternative targets for recovery times for its customer tiers by region/location. More severe targets will cost more to comply with but may reduce outage costs. The Utilities will need to determine alternative portfolios that would meet the requirements of the policy targets.
3. Having separate strategies for the Utilities-only solutions and the Utilities-plus-stakeholder solutions. The RWG recommends that two separate strategies be considered to show whether focusing solely on the Utilities options is more expensive than one with stakeholder options.

Portfolio construction will consider a wide range of options. Different levels of renewables, storage, non-wire alternatives and grid hardening will be used in varying degrees in portfolios. By defining alternative strategies, the combinations of assets in each portfolio will be more clearly defined.

6.3 Alternative Scenarios

Each strategy will have several alternative portfolios to achieve the objectives of the strategy. Once the portfolios are developed, it is then necessary to test how well each portfolio performs against a wide range of scenarios.

In this context, the RWG understands that planning studies will always test portfolios against a range of future market and regulatory outcomes (by changing fuel market conditions or technology cost assumptions). In addition, for this study, the RWG developed a list of scenarios that should be evaluated.

Earlier in this report, up to 23 scenarios were described. These 23 scenarios consist of several different types of events, including those summarized in Exhibit 42.

Exhibit 42: Consolidated Threat Scenarios for IGP

Threat	Includes	Oahu	Hawai'i	Maui County
Hurricane	Flood, Wind	X	X	X
Tsunami	Earthquake	X	X	X
Wild Fire		X		X
Physical Attack	Cyber Attack	X	X	X
Volcano			X	

The RWG considered a wide range of events and developed a consensus that all these events should be considered. The Utilities could either evaluate these scenarios directly or simply consider the impacts of these events on the vulnerability of the grid and factor the implications of these scenarios in the IGP.

6.4 Harmonization of Resilience with Other Objectives

There are several working groups looking at other issues related to the IGP. Other working groups are looking into modeling issues, distribution issues, wire and non-wire alternatives and emerging technologies. There is a great deal of overlap between the development of the inputs to the Resilience committee and the findings from these working committees.

An integrated planning process can serve to bring the inputs from all these processes together. There is much to be studied. For example, until some of the emerging technologies (storage, hydrogen, etc.) become cost effective and proven for long duration, achieving resilience and sustainability goals may either not be achievable or only achievable at very high cost.

Ultimately the IGP will have to be continually updated as time goes on. In addition, stakeholder expectations may well change as technological advance occurs and as clarity around climate change and other issues evolve.

An IGP process will allow for the proper valuing of resources that have multiple uses such as storage and other non-wire alternatives. When viewed in individual use, some of these technologies might not be economic but when properly evaluated (using value stacking), some technologies may have greater value than traditional approaches consider.

6.5 Balanced Scorecard of Objectives

In the course of the IGP process, resilience should be considered in a fair and balanced manner along with all other objectives for the plan. Portfolios developed and analyzed can be compared on a common basis using a balanced scorecard. A balanced scorecard allows for the ranking of portfolios considering the relative importance of all objectives; objectives that often compete with one another.

An illustration of a balanced scorecard is shown in Exhibit 43. This example includes only three objectives but there could be many others. This example did not define or group portfolios under strategies, but rather just listed portfolios considered down the rows and listed some objectives across the columns. Where possible, one can calculate a value for each metric in every scenario run over the 20-year planning horizon. Then the results can be averaged across all scenarios so that each portfolio can be ranked accounting for every metric.

The RWG does not recommend one method for evaluating alternative strategies or portfolios. Rather we recommend that the Utilities in collaboration with stakeholders come up with a template for easily presenting the findings of the analysis in an understandable but thorough manner. A "viable" portfolio will be one that achieves high scores consistently across all metrics evaluated.

Exhibit 43: Sample Balanced Scorecard Including Resilience Metric

Criteria		Affordability			Resilience	Sustainability	
Portfolio		2020-2030 Cost NPV ($Mil)	2020-2040 Levelized Cost (2019 $/MWh)	Cost Rating Score	Resilience Composite Index	CO_2 Changes from (%)	Renewable Generation As % of Load (%)
Status Quo							
Portfolio 1							
Portfolio 2							
Portfolio 3							
Portfolio 4							
Portfolio 5							
Portfolio 6							
Portfolio 7							
Portfolio 8							
Portfolio 9							

6.6 Potential Actions outside of the IGP

There are a multitude of activities beyond the IGP that will benefit from the RWG. The Utilities have many activities on going including an emergency preparedness program, current bids for renewable power, and the traditional rate making processes. Education and training programs could be developed outside the IGP that could benefit stakeholders and utilities outside the IGP process. And there could be benefits on the operating side of the Utilities businesses, such as tree trimming and other programs. These actions were captured in Section 5 and are summarized in the recommendations listed at the end of the report.

6.7 How RWG Input Can Best Be Used

Ultimately, the RWG believes that its role is to guide but not prescribe inputs to the IGP process and other activities. The RWG is willing to continue to work with the Utilities after completion of this final report, in the belief that a continuing dialogue can be mutually beneficial. It is likely that the continuing dialogue will support utility stakeholder partnerships and will ensure that the Utilities understand customers' needs.

This process is new to the stakeholders and to the Utilities alike. It is unlikely that the RWG has thought of every issue that may come up as the Utilities embark on the IGP analysis phase of its work. By meeting periodically, the RWG can learn from the process and the Utilities can learn from the RWG.

7. Summary of Recommendations

7.1 Integrated Grid Planning Process Recommendations

The RWG recommends that:

- The following threat scenarios be considered by the Utilities to guide the IGP process and other resilience initiatives, and by key customers and critical infrastructure partners in developing resilience preparations:
  - Hurricane/flood/wind
  - Tsunami/earthquake
  - Wildfire
  - Physical and cyberattack
  - Volcano
- Utilities consider the key customer and infrastructure priorities identified by the RWG when planning system expansion or improvements
- Utilities develop IGP objectives that include optimizing resilience and cost of resilience; and merge resilience with other planning goals such as reliability, renewable energy expansion, sustainability, carbon emissions reduction, environmental stewardship, rate stability, etc.
- Utilities should consider the following elements of resilience:
  - Reduce probability of power outages during severe and catastrophic events
  - Reduce outage severity and duration during and following a severe or catastrophic event
  - Reduce restoration and recovery times following severe and catastrophic events
  - Optimize cost (including capital and operating costs, and probability weighted outage and recovery costs, etc.)
  - Return critical and priority customers power within specified times
  - Return power to other customers within specified times
  - Limit environmental impacts.
- Utilities consider all possible lowest cost solutions, whether they are best accomplished solely through utility actions or through a combination of utility customer and other service provider actions; hence RWG recommends that some consideration of non-utility stakeholder actions be captured in the analysis of options
- All relevant costs should be captured, which includes the costs that Utilities might incur to mitigate (and recover from) severe and catastrophic outages, as well as the cost of the outage to customers and other stakeholders; it might also include costs that customers or other service providers incur in response to and recover from the consequences of a prolonged severe outage, especially if those measures might be more cost effective than those incurred by the utility
- Utilities develop measures of resilience for Integrated Grid Planning in collaboration with stakeholders to allow evaluation of resilience performance of various options or combination of options under assumed scenarios and conditions

- Resilience should not only be measured as a cost but should be a separate goal with its own measurable outcomes. This step requires the definition of each individual resilience goal and quantification of the degree of resilience achieved in a single and/or combination of metrics .
- Utilities consider options for more decentralized or distributed energy resources closer to load areas and options for expanding customer-based programs and other non-wires solutions for improving reliability and resilience
- Utilities assess options for enhancing resilience through the mix and location of generation resources, including expanding renewable resources with grid-forming capabilities
- Utilities consider configuring portions of the grid in several mini grids that could operate as independent islands which could be self-supplying over an extended period of time during severe emergencies and outages.
- Utilities consider planning for best locations to expand and diversify blackstart resources and delivery paths to support grid restoration and timely recovery of key customers and critical infrastructure sectors
- Utilities consider targeted transmission/sub-transmission additions to enhance redundancy and diversity of delivery paths and reduce risk from severe events

7.2 Recommendations for Key Customers and Infrastructure Partners

The RWG recommends that:

- Infrastructure owners and operators work together in close partnerships to coordinate disaster planning and recovery. Recovery and risk mitigation are shared responsibilities between the power companies, key customers and the government
- Key customers develop and implement load management/load curtailment capabilities to limit power usage to mission critical loads during emergencies with loss of offsite utility power
- Key customers maintain ample onsite fuel supplies for generators during extended power outages and transportation disruptions and have in place plans and fuel supply arrangements resupply fuel for outages exceeding operational expectations; coordinate resupply plans so that multiple facilities, sectors, and geographic areas are not relying on the same fuel resources at the same time; provide backup power sources that can supply essential loads during prolonged outages and emergencies; test and exercise backup power resources
- Under their Continuity of Operations Planning (COOP), key customers should consider relocating essential functions to alternative facilities at sites/locations with more robust infrastructure support
- Key customers consider developing plans and arrangements for deployment of temporary emergency power generators that can be relocated to critical sites during prolonged outages
- Key customers consider partnering with Utilities and the government to develop local microgrids for power that can be isolated from the grid when needed (during severe events); consider alternative technologies, such as renewables and storage, and other blackstart resources
- Key customers in the transportation sector ensure availability of adequate road clearing equipment to speed recovery of key roads, ports and airports

- Key customers reinforce harbors and port facilities against catastrophic flooding and storm damage to ensure they can maintain maritime operations during extended power outages
- Customers maintain training and exercise programs that address performing emergency and contingency operations with loss of utility power

7.3 Recommendations for Utilities Outside the Integrated Grid Planning Process

The RWG recommends that:

- Utilities continue to explore and develop advanced resilience data as demonstrated by the technologies of Jupiter Intelligence
- Utilities partner with key customers and the government to develop microgrids for power that can be isolated from the grid when needed (severe events)
- Utilities reinforce fuel resupply options by increasing distributed storage and delivery capability for severe event emergencies
- Utilities plan for additional crews during emergencies and provide more robust and regular training for emergency situations
- Utilities expand critical resources, supplies, backup equipment, and materials to restore damaged circuits, substations or generators, including distribution more quickly following severe events
- Utilities plan for emergency access to additional helicopters on the islands to support repairs in remote, difficult to access sites
- Utilities plan for enhanced vegetation management, particularly in critical grid areas susceptible to damage from wind and falling or flying debris
- Utilities continue hardening or reinforcing critical transmission circuits, including upgrading wind criteria and flood mitigation, upgrading structures, and using enhanced construction methods and materials
- Utilities continue efforts at enhancing physical and cyber security of assets, resources, and systems.
- Utilities continue planning for expanding underground cables (water resistant) and locating equipment outside flood prone areas
- Utilities consider alternative paths for transmission circuits to increase diversity of location and enhance performance during severe events
- Utilities establish one or more priority circuits with enhanced restoration capabilities and greater hardening
- Utilities continue to require that new RFPs for renewables bids include grid-forming inverters, meaning they can provide a blackstart capability
- Utilities consider adopting advanced technologies in a more distributed resource approach, including grid-forming renewable energy sources, battery storage, and joint projects with key customers to provide microgrid capabilities for emergency and backup operations
- Utilities develop wildfire mitigation strategies for worst case wildfire event at Maalaea

- Utilities develop and test capabilities of expanded use of drones for emergency response and regular maintenance inspections
- Utilities evaluate options for distribution automation, digital meters and associated communications networks which can be valuable in assessing system conditions, the extent of outages, and how to best prioritize recovery efforts to get key customers reenergized more quickly
- Utilities consider actions to reduce tsunami risk impacting generation in inundation zones on Oʻahu