High-Performance and Energy Resilient Communities: Disaster prevention through community engagement

A F de Roode, I Martinac and G Kayo
Division of Building Services and Energy Systems, School of Architecture and the Built Environment, KTH Royal Institute of Technology, Brinellvägen 23, 100 44 Stockholm, Sweden
E-mail: deroode@hawaii.edu

Abstract. As a part of an integrated approach to formulating a plan and comprehensive program for facing natural disasters, human settlements need to first understand the strengths, weaknesses, opportunities and threats (SWOT) within their own localized communities with respect to such disasters. A starting point is to engage local communities in order to assess their baseline understanding of community capacity and capabilities, and to identify and synergize already established disaster prevention and response programs, systems and initiatives. Maui Island, located in the State of Hawaii within the United States of America, was used as a case study to highlight specific opportunities and constraints that selected communities located on Maui Island face in their decision making for energy resilience. Relevant stakeholder groups and their respective roles in disaster mitigation and response are described. Methods for how best to engage local communities around such topics are described, including community surveys, stakeholder workshops, community working groups, and community forums. Methods for how to assess community capacity and capabilities around disaster resilience are also described, including identifying key stakeholders representing a cross section of the local community and studying community response to past disaster events in order to identify successes, best practices, failures and lessons learned. More specifically, this paper provides a deeper understanding of the opportunities and constraints associated with energy infrastructure on Maui Island when seeking to optimize for energy resilience in the face of natural disasters such as hurricanes, tsunamis, flooding and earthquakes. This baseline inventory of energy resilience for selected Maui communities is assessed at the community level. Further research will then apply an adapted methodology to an analysis at the building cluster or district level. This framework can serve to inform similar communities seeking to enhance their energy resilience through bottom-up community engagement.

1. Introduction (Energy Resilience for Island and Remote Communities)
As human communities become larger, more organized and established, considerations such as energy, shelter, transportation, communication, waste management and manufacturing capabilities become increasingly critical to the survival and evolution of what we understand to be modern human societies. These can be considered critical “lifelines” required for human societies to thrive. The infrastructure developed to support these lifelines has been cobbled together over centuries of human ingenuity and often takes the form of difficult and expensive to maintain centralized infrastructure systems. When natural and human caused disasters occur, the weaknesses of such systems are frequently laid bare. These weaknesses often include: a lack of system redundancy resulting in disruptions to critical community services for varying and often undetermined durations of time; a lack
of system resiliency in being able to absorb the shock of disaster events of varying magnitudes and to recover from such shocks in a timely and affordable manner; and a lack of system adaptive capacity characterized by a lack of and gaps in planning for and responding to disaster induced shocks to critical infrastructure systems and long recovery time, coupled with difficulty in reorganizing to adapt to new system conditions.

This paper presents a case study of the island of Maui, Hawaii located in the remote Hawaiian archipelago to illustrate opportunities and constraints of managing for energy resilience in island and remote communities. Given its remote location and its associated dependence on imported resources to support basic critical community services (or “lifelines”), Maui is a prime example of a community facing significant constraints to energy resilience. In particular, when faced with natural disasters such as hurricanes, tsunamis, earthquakes and flooding, the island of Maui, when compared to less remote geographical areas such as most of the U.S. Mainland, faces disproportionate risks of its critical supply chains being cut off and of emergency assistance from outside communities being constrained and limited due to the difficulty and cost of accessing the island. As such, communities such as Maui have an increased sense of need and urgency to be better prepared, more self-sufficient and more resilient than their less remote counterparts. This is particularly true when it comes to its energy systems and infrastructure, which rely heavily on imported fuels such as diesel oil, propane and natural gas to meet community energy demand.

Resilience can be defined as “the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks” (Walker et al., 2004). Adaptability can be defined as “the capacity of actors in a system to influence resilience. In a social–ecological system (SES), this amounts to the capacity of humans to manage resilience” (Walker et al., 2004). According to Pelling, “adaptation is defined as: the process through which an actor is able to reflect upon and exact changes in those practices and underlying institutions that generate root and proximate causes of risks, frame capacity to cope and further rounds of adaptation to climate change” (Pelling, 2011). In other words, adaptive management can be described as a systematic process integrating lessons learned from outcomes of implemented strategies to improve management policies and practices (Pahl-Wostl, 2008).

In order to assess the level of risk a community faces, one must assess the nature of the hazards it faces, how vulnerable a community is to the potentially damaging effects of those hazards, and its coping capacity relative to the effects of those hazards (Ribeiro and Bailey, 2017). This relationship can be expressed through the following formula: Risk = Hazards × Vulnerability ÷ Coping Capacity. The risk to community resilience is impacted by each factor in this equation. In this relationship, hazards represent threats faced by a community (e.g., tsunamis); vulnerability represents how exposed or susceptible a community is to the potential impacts of a hazard (e.g., power plant’s vulnerability to flooding resulting from the impacts of tsunamis); and coping capacity represents the degree to which a community is able to respond to the potential impacts of a hazard (e.g., ability to shelter individuals displaced by a hazard and to maintain an effective communication network during and after a hazard event) (Ribeiro and Bailey, 2017).

Resilience theory establishes that a given system is able to remain functional and evolve by pursuing strategies that exhibit high levels of adaptability in the face of external stressors (Gunderson and Holling, 2002; Allen et al., 2014; Clément and Rivera, 2017; Bundhoo et al., 2018). The energy resilience of a community and its associated energy infrastructure are dependent on three primary factors: robustness, resourcefulness and the ability to recover (OECD/IEA, 2015). Energy infrastructure can be considered robust based on its ability to withstand external forces (e.g., ability of a power plant to withstand seismic events) (OECD/IEA, 2015). Failure of such systems during extreme external events (e.g., hurricanes, tsunamis, etc.) would indicate a lack of robustness. An energy system would be considered resourceful based on its ability to leverage available resources in order to withstand potential impacts of an event thereby efficiently maintaining service and reliability of its operations (OECD/IEA, 2015; Bundhoo et al., 2018). Being able to organize resources effectively to ensure reliability of electricity supply to critical loads is a demonstration of
resourcefulness. The ability to restore operations of an energy system back to acceptable performance levels in the aftermath of an extreme disruptive event indicates the recovery potential of this system (OECD/IEA, 2015; Bundhoo et al., 2018). It is therefore rational for a community to allocate resources to enhance energy resiliency as a strategy to mitigate risks and reduce vulnerabilities to its energy systems (Zevenbergen et al., 2011).

While restorative resilience, driven mainly by government and service professionals, focuses primarily on infrastructural and technological solutions to disaster response and prevention, adaptive resilience-seeking solutions involve effective public engagement and active learning with the goal of achieving more flexibility, adaptability and sustainability in approaching disaster response and prevention (Zevenbergen et al., 2011; Odemerho, 2015). This adaptive approach can help to mitigate risks and vulnerabilities associated with the dynamic and unpredictable nature of climate change and associated natural disasters. Such an adaptive approach is enhanced by effective engagement of community stakeholders, incorporating lessons learned from past disaster events and community response to such events, actively monitoring disaster mitigation, response and recovery efforts, and using the observations of such monitoring as a source of feedback to inform future actions and strategies for optimizing system resilience (Odemerho, 2015). Community Disaster Resilience (CDR) can be defined as the “capability of a community to anticipate and reduce risks and vulnerabilities and increase adaptive capacity and the potential for transformative learning in the face of disasters and other major changes” (Cox, 2008, 2011; Cox and Hamlen, 2015). Disaster resilience represents an evolution in emergency management away from focusing on deficits or vulnerabilities of communities in relation to risk assessment and management and towards focusing on enhancing community coping capacity and adaptation. A number of emerging community resilience frameworks aim to provide communities with methodologies to participate in resilience assessment and planning in situations when technical expertise is lacking and/or a participatory, community-based approach is deemed more appropriate. Such frameworks provide a systematic mechanism for local stakeholders in rural and remote communities to define and assess disaster resilience (Cox and Hamlen, 2015). This, in turn, provides a platform for local resilience planning, as well as enhancing local capacity to engage with authorities and regulators around disaster and resilience planning. This approach to participatory planning and local stakeholder engagement can be informed and guided by principles and best practices from participatory action research, which aims to optimize the contribution of research to social change and transformation (Kemmis & McTaggart, 2000; Cox and Hamlen, 2015). By emphasizing a participatory and hands-on approach, participatory action research acknowledges the research process as a learning opportunity to be as beneficial as the findings and conclusions of the research itself (Reason & Bradbury, 2008; Cox and Hamlen, 2015).

This bottom-up approach will allow community adaptation to disaster impacts to be more flexible and successful in incorporating established and emerging best practices and lessons learned. This approach can then be used to inform the creation of more holistic top-down policies and programs informed by community involvement, that are more practical, meaningful and relevant to community needs when implemented within affected communities. Disaster Risk Reduction (DRR) practitioners should recognize and embrace the fact that, as stated by Gaillard, “enhancing capacities, reducing vulnerability and building resilience requires increased participation of local communities” (Gaillard 2010; Burnside-Lawry and Carvalho, 2015).

As mentioned, participatory stakeholder engagement and bottom-up planning tools and methodologies can be used to facilitate community goals, such as transitioning to more resilient energy systems. This paper describes how such bottom-up tools and methodologies were used as a foundation for pursuing increased energy resilience for Maui Island. More specifically, stakeholder workshops, community working groups, strengths, weaknesses, opportunities and threats (SWOT) analysis, community surveys, and community forums are presented as tools and methodologies used in Maui’s energy resilience case study.
2. Methodology and Research Approach

2.1. Launch Phase: Stakeholder Engagement and Initial Community Outreach

The research context for this paper is set within a larger multi-year study focused on developing disaster risk reduction (DRR) and community disaster resilience (CDR) strategies and frameworks that can be applied to the island of Maui to address local energy resilience. The intent is to generate research that can translate into meaningful real world applications within the local community to help address the increasing level of need and urgency around resilience and sustainable energy systems within the State of Hawaii. The research team includes representatives from the Royal Institute of Technology (KTH) of Sweden; the University of Hawaii; and the Pacific Disaster Center. Representatives from these entities form the core of the High-Performance and Energy Resilient Communities (HiPER Comm) research team. The research team brings a transdisciplinary perspective to this research project from the fields of buildings and energy systems at both building and neighborhood scales, as well as from the fields of natural resources management, disaster planning and hazard mitigation. The name HiPER Comm was chosen to emphasize a “high-performance” community that is defined by the research group as a community that is highly functional, effective, coordinated, efficient and focused in its efforts to continuously and aggressively improve energy resilience within its community boundaries by developing and implementing strategies informed by best practices and lessons learned from transdisciplinary international research and local participatory engagement. This concept of “high-performance” is inspired from the built environment field in relation to building performance. Within the built environment context, a high-performance building can be defined as “a building that integrates and optimizes all major high-performance building attributes, including energy efficiency, durability, life-cycle performance, and occupant productivity” (U.S. Energy Policy Act of 2005). As supporting the transformation of the built environment towards high-performance buildings is a strategy for improving community energy resilience, the term “high-performance” was selected by the research team as an appropriate term to describe this research project and its associated energy resilience focused community-based initiative.

Paralleling the HiPER Comm Research Team, a Maui Island HiPER Comm Working Group (HCWG) was launched with the intent of galvanizing key community stakeholders around comprehensive and integrated energy resilience efforts for Maui Island. The HCWG is made up of representatives from the private sector, government sector, public sector and non-profit sector. These include representatives from local government, from the hotel and resort industry, from the energy industry (including the local electric utility Maui Electric Company – MECO, independent power producers or IPPs such as Sempra Energy, and energy services companies or ESCOs such as Johnson Controls), and from economic development and educational organizations. These stakeholders were identified using a “snowball” strategy whereby the research team reached out to stakeholders known as being active contributors to local energy and resilience efforts, and then asking this first tier of identified stakeholders for recommendations of additional stakeholders to invite to be a part of this community effort for energy resilience. This “snowball” approach of participant recruitment continues to be implemented throughout the research and community working group process, thereby allowing for continued growth of community involvement and ownership of this effort, as well as being an adaptive process that can assist the research team in identifying future stakeholders to meet emerging needs of the community and of the research effort. For the launch of the Maui HCWG, the HiPER Comm research team convened the invited stakeholders for a half day launch meeting. The first half of this meeting was dedicated to establishing a common set of terminology and a conceptual framework that the HCWG would be working within. The material presented to the HCWG included terminology and concepts related to hazard mitigation, energy resilience, energy efficiency and district energy systems. This allowed the research team to set the stage for how the HCWG could optimize its input into the research and community based efforts. The research team described the research objectives of the doctoral research project and explained the parallel structure of the HCWG. The research team emphasized that it was there to serve as a resource and facilitator to the HCWG.
The second half of the meeting was dedicated to hosting a moderated working session during which the HCWG members were invited to brainstorm and provide input on three topical areas identified by the research team. Attendees were directed to take 45 minutes to discuss their assigned focal area and to self-select which of the three focal area groups they would join based on personal preference. Each group was asked to identify one note taker and one person who would be responsible for reporting out to the larger group after the 45 minute breakout session. Groups were instructed to give each group member an opportunity to provide opening remarks on the focal area topic. They were then instructed to discuss the theme further as a group focusing on identifying needs, priorities, challenges and opportunities. Participants were instructed to discuss their topic within a multi-scalar context (i.e. building level, building-cluster level, neighborhood level, and island-wide scales). Each of the groups was assigned a member of the HiPER Comm research team to serve as a technical resource and facilitator for the group discussion. The three focal area topics to select from were as follows:

1. **Focal Area Topic 1**: Focusing on hazard mitigation, resilience and energy infrastructure, assess current risks and hazard mitigation efforts for Maui’s energy infrastructure. Best practices and lessons learned from past events and comparisons with Hurricane Maria’s impacts on Puerto Rico can be used to help inform this discussion.

2. **Focal Area Topic 2**: Focusing on hazard mitigation, resilience and energy infrastructure, identify current opportunities, synergies and alignment with existing community-based plans and programs.

3. **Focal Area Topic 3**: Focusing on hazard mitigation, resilience and energy infrastructure, identify and describe how we could best integrate the priorities of all sectors of society (i.e. private sector, public sector and civil society).

The primary feedback and recommendations resulting from the group breakout sessions and larger group discussions are summarized in the results and discussion section of this paper along with strengths, weaknesses, opportunities and threats (SWOT) being identified for the main discussion themes.

### 2.2. Strengths, Weaknesses, Opportunities and Strengths (SWOT) Analysis

The SWOT analysis methodology is often used by private sector companies and non-governmental organizations for assessing and organizing its resources into four core areas: strengths, weaknesses, opportunities and threats (Samejima, Shimizu, Akiyoshi, & Komoda, 2006). Strengths and weaknesses are categorized as internal controllable factors that either support or hinder an organization’s ability to achieve its mission. Within the SWOT methodology, opportunities and threats are considered external uncontrollable factors that either support or hinder an organization’s ability to achieve its mission (Dyson, 2004). SWOT analysis provides a way for decision makers and planners to describe and analyze the qualitative nature of a process or system, as well as to identify strategies that can enhance it by capitalizing and building on existing strengths, reducing the impact of existing weaknesses, taking advantage of opportunities, and strategically avoiding identified threats (Karppi et al., 2001; Fertel et al., 2013; Goffetti et al., 2018). Although SWOT analysis is often used for strategic planning processes of small and medium-sized enterprises (Houben et al., 1999), it is becoming increasingly recognized as a viable planning methodology for qualitatively assessing socio-economic sectors (such as the energy sector) (Terrados et al., 2007; Markovska et al., 2009; Goffetti et al., 2018).

In this study, SWOT analysis was used to establish a preliminary baseline for determining the internal and external factors that may hinder or foster energy resilience on Maui Island. The SWOT analysis was conducted on feedback gathered from community stakeholders who convened for a working group meeting session focused on exploring energy resilience for Maui Island. Additional input will continue to be collected by the research team from engaged stakeholders in order to further refine this analysis.
2.3. Taking the Call to Action: Community Stakeholders Engage and Take Ownership

In addition to performing a SWOT analysis on feedback gathered during the working group meeting, complementary and synergistic activities were pursued by the HiPER Comm research team in collaboration with members of the HCWG. These included organizing an educational tour (or site visit) of the primary electric power plant on Maui Island, developing and conducting a survey during a local community event to gage community awareness and understanding of Maui’s state of energy resilience, and hosting a community forum with a panel of experts in order to inform and engage the Maui community-at-large about energy resilience.

As a part of the initial stakeholder outreach and working group launch process, participating stakeholders were encouraged to engage and to take ownership of the HCWG process in the following ways:

• suggest experiential activities that could provide HCWG members with a real-world understanding of the strengths, weaknesses, opportunities and threats to energy resilience on Maui Island, including exposing them to applied examples of best practices and lessons learned;
• recommend relevant subject matter experts that could be invited to share their expertise on best practices and lessons learned for improving energy resilience;
• identify knowledge and data gaps, as well as key issues for further research and discussion; and
• recommend additional stakeholders that should be invited to join the HCWG.

The above call to action resulted in the following activities and events that served as a way to galvanize and focus the Maui community around the topic of energy resilience:

• as a part of an organized site visit, the local electric utility company (i.e. Maui Electric Company, aka MECO) provided the HCWG with detailed information on the operation of their largest power plant (Maalaea Power Plant), including sharing information about their disaster planning and power restoration practices;
• a survey questionnaire focusing on community perceptions of local energy resilience was developed in coordination with the HiPER Comm research team and the HCWG, (in partnership with local stakeholder Maui Economic Development Board, aka MEDB), and administered during the course of a multi-day community event; results were analyzed and shared with the HCWG; and
• a community forum on the topic of Maui energy resilience was organized by MECO and the HiPER Comm research team as a way to invite the general public to learn more about Maui energy resilience and to take part in a community conversation regarding this topic.

The following sections provide details of the results and a discussion of each of the aforementioned activities.

3. Results and Discussion

3.1. HiPER Comm Working Group Launch Meeting

The primary themes that emerged from the group breakout discussion sessions from the HCWG launch meeting were as follows:

Additional resources in the form of financial support, and technical knowledge and expertise, need to be identified, secured and then responsibly and effectively managed and coordinated in order to help organize, educate and inform community stakeholders about best practices and lessons learned in disaster mitigation and energy resilience strategies. These strategies need to be informed by and contextualized to local needs and local understanding. The acquired knowledge and information must then be widely disseminated in a coordinated manner throughout the community. Although there are existing efforts to address disaster response and recovery within the community by actors from across the public sector, private sector and academic institutions, these efforts are often not jointly coordinated and most of them do not focus on hazard mitigation and adaptive resilience strategies but
rather on disaster preparedness and recovery. This results in a more reactive, resistive and restorative approach to resilience based on infrastructural and technological solutions, as opposed to adaptive resilience based on optimized approaches to planning and organizing systems. This lack of community understanding, awareness and participation in adaptive resilience is categorized as a weakness in Maui’s energy resilience efforts until it is sufficiently enhanced by an infusion of financial and human resources. In order to avoid a duplication of efforts, making sure to engage relevant community groups and stakeholders in these efforts is critical to ensuring the success of resilience planning efforts and successful implementation of adaptive resilience strategies. A number of critical stakeholders were identified as not being involved in the early stages of the HiPER Comm effort. This was identified as a weakness that could be addressed with increased engagement and participation of critical community stakeholders, such as first responders, hospitals and port authorities. Making sure to identify synergies with other resilience and energy related community initiatives was also deemed critical. By leveraging existing public and private sector financial resources, as well as pursuing new funding opportunities, these energy resilience efforts would be adequately supported to yield greater traction and success.

Another recurring theme was that a comprehensive baseline vulnerability assessment of Maui’s energy resilience is currently lacking. There are existing studies and analyses stemming from the efforts of entities such as the Pacific Disaster Center (PDC), the County of Maui Emergency Management Agency (MEMA), the University of Hawaii, and the State of Hawaii Office of Planning that each have elements that could feed into a comprehensive baseline vulnerability assessment of Maui’s energy resilience. However, these information resources need to be brought together and enhanced by the input of local stakeholder knowledge, (including more granular energy systems information on critical infrastructure such as hospitals, ports, and electric power plants that are owned and managed by local stakeholders), in order to provide a more useful and implementable vulnerability assessment and hazard mitigation plan for adaptive energy resilience for Maui Island. The lack of such an assessment and associated plan was identified as a weakness in Maui’s energy resilience efforts. Additionally, many existing community plans lack vulnerability data and associated considerations, thereby increasing community vulnerability and creating gaps in critical understanding of how to optimize efforts such as land use planning and zoning.

Maui’s remoteness was identified as a threat to its energy resilience. The geographical remoteness of Maui Island can and has led to disruptions in supply chains for critical equipment. Efforts to better coordinate the sharing of critical resources (e.g. backup generators, motors for water supply pumps, energy storage systems, etc.) among local actors during and following disaster events was suggested as an approach to mitigate the threat of supply chain disruptions. In addition, the HCGW identified a need to establish a baseline inventory of the current supply of emergency (backup) equipment located on Maui Island that is owned by various stakeholders throughout the island. This inventory should be updated routinely so that in a disaster event the community could better coordinate how to optimize the deployment of critical backup systems, such as backup generators. A further incentive for increasing the availability and number of backup energy systems on Maui would be to create opportunities for deploying shared energy backup systems that could generate revenue streams by meeting non-emergency needs when not being used for backup purposes. Such systems could be used for strategies such as peak load shaving to positively impact the financial bottom line of system owners, as well as reduce demand on the larger utility electrical grid.

Business uncertainty was also categorized as a weakness and a threat to Maui’s energy resilience. For example, not knowing if during and following a disaster event local, state or federal authorities would appropriate or commandeer private property such as facilities, land and equipment from private sector entities in order to meet higher priority public needs. Improved communication, cooperation and transparency around the circumstances and extent of such takings by the public sector would assist private sector entities in making better informed investment decision and contingency plans for meeting their own needs during a disaster event. Another identified weakness related to business uncertainty centered around the unknown financial impacts of regulatory actions impacting private sector entities. For example, business uncertainties exist around requiring stricter building codes for
critical infrastructure such as hospitals so that they can operate self-sufficiently for a period of time even when faced with a disruption of municipal and utility services. Assisting the private sector to be able to assess the cost-benefit of implementing such measures and supporting them in identifying and pursuing public sector funding to help offset such costs were identified as strategies to help mitigate these weaknesses. Although the State of Hawaii’s adopted goal of 100% clean energy by 2045 under the Hawaii Clean Energy Initiative (HCEI) and the Aloha+ Challenge was recognized as a strength helping to drive Hawaii’s energy transformation, there remained concerns regarding how various actors, (such as independent power producers), involved in increasing the amount of distributed energy resources (DER) being deployed are not regulated in the same way as public utilities thereby creating a gap in accountability and consistency in addressing energy resilience considerations. More consistent state regulation of the various actors involved in deploying DER was identified as a way to address this weakness. Additionally, adding both restorative and adaptive resiliency elements to the HCEI and Aloha+ Challenge would further strengthen these policy goals by providing a strong foundation for the deployment of more robust and sustainable clean energy systems.

The primary themes discussed during the HCWG launch meeting centered around infrastructure, regulatory considerations, financial and funding funding, multi-agency and community coordination, dissemination of information, data and knowledge gaps, supply chain constraints, and levels of stakeholder engagement, participation and involvement in resilience initiatives.

3.2. Stakeholder Site Visit

As an example of concrete action taken to further Maui-based energy resilience efforts, MECO offered to host the HCWG for a tour of their Maalaea generating station. The Maalaea generating station is a 212 MW power plant and is the largest source of electricity generation for the island of Maui, making up almost 49% of total generation capacity and almost 84% of total firm generation capacity.

Table 1: Renewable Energy and Firm Power Generating Capacity in Maui County (2017)

| Generation Source                    | MW of Generation Capacity | MW of Firm Generation Capacity | MW of Storage Capacity | % of Total Generation Capacity | % of Total Firm Generation Capacity |
|--------------------------------------|---------------------------|-------------------------------|------------------------|--------------------------------|------------------------------------|
| Makila Hydro                         | 0.5                       | 0.5                           | 0.12%                  | 0.20%                          |                                    |
| Kuia Solar                           | 2.9                       | n/a                           | 0.67%                  | n/a                            |                                    |
| Kaheawa Wind II                      | 21                        | n/a                           | 4.84%                  | n/a                            |                                    |
| Kaheawa Wind I                       | 30                        | n/a                           | 6.91%                  | n/a                            |                                    |
| **Maalaea Generating Station**       | **212.1**                 | **212.1**                     | **48.87%**             | **83.77%**                      |                                    |
| Wailea Substation BESS               | 1                         | 1                             | 1                      | 0.23%                          | 0.39%                             |
| Kahului Power Plant                 | 37.6                      | 37.6                          | 8.66%                  | 14.85%                         |                                    |
| South Maui Renewable Resources       | 2.9                       | n/a                           | 0.67%                  | n/a                            |                                    |
| Hana Substation                      | 2                         | 2                             | 0.46%                  | 0.79%                          |                                    |
| Auwahi Wind                          | 21                        | n/a                           | 4.84%                  | n/a                            |                                    |
In 2017, MECO reported that its fuel mix for generating electricity came primarily from oil (79%) with approximately 21% being generated from renewable resources (primarily wind energy).

| Fuel Sources          | Maui Electric (Islands of Maui, Molokai, and Lanai) |
|-----------------------|-----------------------------------------------------|
| Oil                   | 79.02%                                              |
| Coal                  | 0                                                   |
| Biofuel               | 0.08%                                               |
| Biomass               | 0.37%                                               |
| Geothermal            | 0                                                   |
| Hydro                 | 0.08%                                               |
| Solar                 | 0.06%                                               |
| Solid Waste           | 0                                                   |
| Wind                  | 23.50%                                              |
| **TOTAL:**            | 100%                                                |

*Percentages are based on amount of electricity generated by Maui Electric Company and purchased from independent power producers in 2017, excluding energy produced by customer-sited PV systems

Adapted from: Hawaiian Electric Company, Inc. 2019

When taking into account customer-sited solar electricity generation, MECO reported that approximately 34% of County-wide electricity generation came from a mix of renewable energy resources. Although this positively contributes to achieving the goal of 100% clean energy by 2045 established under the HCEI and the Aloha+ Challenge, the high penetration of intermittent renewable energy resources and their potential exposure to damaging impacts from natural disasters does not necessarily positively contribute to increasing Maui’s energy resilience. The HiPER Comm research team recommends integrating energy resilience criteria into future renewable energy systems deployment, as well as into upgrades and future deployment of firm power energy infrastructure.
Figure 1: Renewable Energy and Firm Power Generating Capacity in Maui County (2017)

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Source: Hawaiian Electric Company, Inc. 2019b

The United States Fourth National Climate Assessment (NCA) states there is a high likelihood that sea level will rise between 1 to 4.3 feet in 2100 compared to 2000 levels, with high end estimates indicating a possibility of up to 8 feet of sea level rise (USGCRP, 2017). MECO’s Maalaea power plant (aka generating station) is situated within the tsunami evacuation zone, as well as being prone to flooding resulting from sea level rise.

Figure 2: Tsunami Evacuation Zone Surrounding MECO Maalaea Generating Station

Adapted from: NOAA 2019.

According to the Hawai'i Climate Change Mitigation and Adaptation Commission (2017), sea level rise of 3.2 feet would result in more than 11 miles of major coastal roads on Maui becoming impassible and would jeopardize critical access to and from many communities. This includes impacting coastal roads near MECOs Maalaea Generating Station. In its 2017 sea level rise report, the Commission recommends that sea level rise adaptation measures, such as major flood proofing or relocation, be considered within the context of long-term cost savings when compared to the cost of maintaining and repairing vulnerable critical infrastructure. The report further reinforces that “sea level rise projections greater than 3.2 feet are “physically plausible” by the end of the century, based on the latest climate science (Sweet et al. 2017; Le Bars, Drijfhout and de Vries 2017)”. Although the
Commission report provides modeled scenarios of impacts from sea level rise of up to 3.2 feet, the National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management has modeled passive flooding scenarios with up to 6 feet of sea level rise in their Sea Level Rise Viewer (NOAA 2019b).

Figure 3: 4ft Sea Level Rise in Region Surrounding MECO Maalaea Generating Station

Adapted from: NOAA 2019b

Figure 4: 8ft Sea Level Rise in Region Surrounding MECO Maalaea Generating Station

Adapted from: NOAA 2019b
As can be seen in the above map, the Maalaea Generating Station falls within the FEMA Flood Zone A defined by the U.S. Federal Emergency Management Agency (FEMA) as a high risk area “with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage” (FEMA 2017). The Commission’s sea level rise report (2017) emphasizes that further impacts associated with climate change will include increased risk of hazard event-based coastal flooding from tropical storms, hurricanes, and tsunamis exacerbated by sea level rise. The confluence of such hazard events with sea level rise will have a multiplier effect on the severity of their impacts in affected communities. In alignment with the Commission report, the HiPER Comm research team recommends undertaking more detailed analyses of vulnerability and adaptation options for critical infrastructure to assess options such as hardening or relocating critical infrastructure to more secure locations, resulting in improved community resilience. Such an analysis should include detailed estimates of the economic loss that would result from varying degrees of damage to critical infrastructure such as the Maalaea Generating Station. The site visit to the Maalaea Generating Station was a valuable educational experience for participating HCWG members that increased their level of understanding of the complexity and vulnerability of Maui’s critical energy infrastructure.

3.3. Community Survey
In order to triangulate and deepen the research team’s understanding of Maui Island residents’ perceptions and knowledge about Maui’s state of energy resilience, a survey questionnaire was developed over the course of several weeks and then administered in October 2017 as a part of a multi-day community event known as the Maui County Fair. The HiPER Comm research team developed a list of ten suggested questions for the proposed survey and then engaged the HCWG to provide feedback on the suggested questions, including submitting additional suggested survey questions as desired. After collecting feedback from the HCWG, the HiPER Comm research team, along with community stakeholder Maui Economic Development Board (MEDB), narrowed the survey questions to a final selection of four key questions. Based on prior experience administering surveys at this event, MEDB recommended four questions as being an ideal number of questions to improve participation rates by fair goers. With MEDB as the lead organizer for implementing the community survey and analyzing its results, HCWG members were invited to participate in the survey implementation as volunteers. The participation of HCWG members in this activity was intended to further encourage a sense of ownership by the HCWG in the HiPER Comm project. Over the course of
the four day event 1,111 survey responses were collected by MEDB and HCGW volunteers. The questions selected for the questionnaire and the associated results of the community survey were as follows:

Question 1: How prepared do you feel our community is to cope with extended (multi-day) power outages that could occur as a result of a natural disaster such as a hurricane, earthquake or tsunami that could lead to a disruption of critical community services?

Figure 6: Results of Question 1 (above)

Source: Maui Economic Development Board (MEDB), Focus Maui Nui Program

Question 2: How prepared do you feel that your household is to cope with extended (multi-day) power outages that could occur as a result of a natural disaster such as a hurricane, earthquake or tsunami?

Figure 7: Results of Question 2 (above)

Source: Maui Economic Development Board (MEDB), Focus Maui Nui Program

Question 3: What are your primary sources of information during an emergency event such as a natural disaster? (Check all that apply)
Figure 8: Results of Question 3 (above)

Source: Maui Economic Development Board (MEDB), Focus Maui Nui Program

Question 4: Are you aware of any existing programs and community efforts focused on increasing Maui island’s energy resilience in the face of natural disasters such as hurricanes, tsunamis and earthquakes?

Figure 9: Results of Question 4 (above)

Source: Maui Economic Development Board (MEDB), Focus Maui Nui Program

Overall, these survey results provide insight into community members’ perception that, both at the individual household level and at the community level, there is room for improving readiness and resilience in the face of multi-day power disruptions. Additionally, community members are mostly unaware of community efforts and programs aimed at addressing energy resilience for Maui. Both of these findings point to an opportunity and a need to raise awareness and increase engagement of community members around energy resilience. In addition to in-person events and forums, social media, television and radio broadcasts are identified as avenues that could be used and may be preferred by community members for communicating about energy resilience.

3.4. Community Forum
A further commitment made by one of the HCWG stakeholders was to co-organize a community forum on energy resilience in collaboration with the HiPER Comm research team. Maui Electric Company (MECO) representatives collaborated with the HiPER Comm research team over the course of a few months to formulate the concept of the community forum, identify major themes to be addressed and select and invite subject matter experts to serve as presenters and panelists at the event. The purpose of the forum was to help increase community awareness and understanding of energy
resilience within a Maui context and to provide members of the public with an opportunity to engage with subject matter experts in order to allow community members to raise questions, identify priorities and acquire new knowledge. The event was advertised via several social networks and held in November 2018 at a central venue within the community. The event was well attended with approximately 60 people from the general public in attendance. The event was video recorded and then broadcast on community television in order to increase the impact of outreach within the community. The local press also covered the event. The major themes of the conference centered on models for organizing communities around energy resilience (i.e. HiPER Comm), current and emerging threats to energy infrastructure and community resilience, best practices in hazard mitigation, preparedness, response and adaptation, and current and emerging solutions for addressing risk and vulnerabilities of community energy resilience. Attendees were very engaged and actively participated in submitting questions to the expert panelists. Many of the audience questions centered around better understanding the risks and vulnerabilities to energy resilience for Maui Island and possible approaches to addressing them so as to increase local energy resilience.

4. Conclusions and Recommendations

In its efforts to increase energy resilience for Maui Island, the HiPER Comm research team and the HiPER Comm Working Group (HCWG) have catalyzed around community participatory engagement approaches intended to encourage and facilitate the Maui community to take ownership of their local energy resilience. These approaches include: creating a community working group of local stakeholders known as the HCWG; using SWOT analysis to identify Maui’s strengths, weaknesses, opportunities and threats with regard to energy resilience; using educational site visits to raise local stakeholders’ awareness and increase their understanding of energy infrastructure within the context of community resilience; developing and implementing a community survey to gauge community awareness and understanding of energy resilience; and organizing a community event to serve as a public forum for engaging the local community on the topic of energy resilience. This bottom-up approach to furthering community adaptive resilience is a critical pathway to increasing Maui’s overall energy resilience. As a critical mass of community stakeholders and local actors engage in this process, it is the hope of the HiPER Comm research team that community ownership of this effort will exponentially grow and that the risks and vulnerabilities of the Maui community in the face of climate change impacts and natural disasters such as hurricanes, tsunamis, earthquakes and floods will be increasingly mitigated and reduced. Once a baseline vulnerability assessment has been conducted on the potential impact of natural disasters to Maui’s power supply system, the HCWG with support from the HiPER Comm research team can then engage major economic and social sectors (e.g. healthcare, education, public safety, agriculture, tourism/hospitality, local government, etc.) by sharing and discussing these assessed vulnerabilities with each of them. As a next step, the research team could then engage with each sector to assess potential impacts specific to their respective functionality, operations and services. The research team and working group could then work collaboratively to assess the interactions of vulnerabilities across the various sectors. This way, common understanding of potential impacts of natural disasters on Maui’s energy infrastructure could be developed. This approach would also create an opportunity to assess impacts and vulnerabilities on shared infrastructure, which could lead to an increase in collaborative efforts to mitigate these risks and vulnerabilities so as to increase the resiliency of shared energy systems.

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