

# **Recommendations for Technologies for Microgrids on the Big Island**

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**Report itemizing recommendations for technologies to be used  
in future installation of Big Island microgrids**

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# **Report itemizing recommendations for technologies to be used in future installation of Big Island microgrids**

*Subtask 2.2 Deliverable #4*

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# **Recommendations for Technologies for Microgrids on the Big Island**

## **1.0: Background**

In 2004, studies conducted for the U.S. Department of Energy by the Hawai‘i Department of Business, Economic Development and Tourism (DBEDT), with Sentech, Inc., Hawai‘i Electric Light Company (HELCO), and Hawaiian Electric Company (HECO) looked at the potential benefits of microgrids and energy storage on the Big Island of Hawai‘i. The studies employed production cost and distribution load flow models, together with examination of feeder loads and customer mix, to perform screening evaluations of different grid reinforcement options for HELCO to meet anticipated high load growth, especially on the west side of the island.

A subsequent and recently concluded study, “Evaluation of Future Energy Technology Deployment Scenarios for the Island of Hawai‘i,” was conducted by the Hawai‘i Natural Energy Institute (HNEI), General Electric Company (GE), HECO, HELCO, and Sentech. This study used comprehensive, detailed power system modeling (production cost and system dynamics) to evaluate the effects of the Big Island’s anticipated increased penetration of electricity generation using as-available renewable energy, primarily wind and solar, in addition to existing or increased geothermal.

Based on the more detailed power system analysis of the second study, this report provides an evaluation of whether evolving technologies and load growth patterns offer new options for microgrids on the Big Island. This evaluation applies the original findings and technical assessments of the microgrid study with the more detailed electric system modeling and updated conclusions of the HNEI Big Island energy study. The HNEI study, however, did not look at the distribution system and potential contributions to the bulk power system of distributed technologies (e.g., microgrid-sited distributed generation and storage) dispatched as a microgrid. The original microgrid study can help fill this gap.

The objective of this analysis is to identify the characteristics and capabilities of microgrid-sited technologies that could have significant benefits in grid stability, production economics, reliability, and/or power and voltage quality for the Big Island. The analysis is based on the Big Island energy studies, and includes three task areas:

- Summarize findings of the previous studies.
- Update the list of candidate microgrid technologies based on: 1) technical and cost improvements since 2004; and 2) recent changes in load growth, generation, transmission, and energy policy on the Big Island.
- Provide recommendations for microgrid technologies and locations to be considered in HELCO system plans.

## **2.0: Summary of Previous Studies**

### **2.1: DBEDT Microgrid and Energy Storage Studies**

HELCO is faced with the challenge of providing electricity to a growing load on the west (Kona) side of the island, while most of its generating resources are on the east (Hilo) side. Adding to this issue is the large and growing amount of electricity provided by non-dispatchable renewable energy sources (geothermal, wind, and photovoltaic -- PV). The wind and PV generation are as-

available, meaning their output varies in a non-predictable manner. The geothermal generation is not load following, and according to the power purchase agreement (PPA), only 10% (3 MW) can normally be curtailed. Specific challenges HELCO faces are:

1. The need to reinforce or construct Kona side feeders and substations to meet load growth.
2. Having to start up Kona side generation early – out of economic dispatch order – during morning load ramp up for reliability reasons.
3. Fully loaded cross-island transmission lines during peak loads, which could result in low voltage and the need for emergency load shedding within minutes during a contingency of loss of one of the cross-island lines.
4. Having to curtail wind at night due to must-run and regulating units' combined capacities exceeding minimum system load.

Microgrids could potentially address issues #1, 2 and 4 above. Energy storage could address issues #2, 3 and 4. The technical options for microgrids in the study included distributed generation (including combined heat and power – CHP) and thermal or electric energy storage on Kona-area feeders. The potential for thermal energy storage (TES) is limited because there is not a large air conditioning or heating load. CHP was seen to be most applicable to resorts with significant domestic hot water or pool/spa heating loads. Bulk electrical storage at substations was examined, but small electric storage on feeders (in customer facilities) was not considered.

Given the constraints on the island's electric network, installing distributed energy resources (DER) (including CHP) at certain customer sites appeared to have many advantages, including improved efficiency and thermal energy utilization, potential reduction or deferment of investment in distribution system expansion, reduced loading of cross-island transmission systems, and improved electric and thermal reliability. In order for these benefits to be fully realized for the HELCO electric system, the utility must be able to monitor and control the DER systems to ensure the units can be dispatched to meet system needs as well as customer economics. This could be accomplished if HELCO:

- Owns and operates the DER,
- Co-owns the DER with the customer and is able to dispatch it, or
- Develops a service contract with the customer that enables HELCO to monitor the DER and dispatch it if system conditions warrant.

A microgrid solution requires identifying a technically feasible control system and generation configuration to perform the dispatch and control of the distributed generation (DG) resource. There are also complicated system protection issues that must be addressed before considering the DER as part of the dispatchable generation resources from the transmission system perspective. The reliability of distributed generators being encountered at other microgrid test sites would need to be improved. HECO considered installation of DG and CHP at customer sites and utility substations and filed a docket with the State of Hawai'i Public Utilities Commission (PUC). The purpose of the docket was to actively pursue this option where detailed engineering studies identified specific locations where DER technologies would be cost-effective and could benefit the individual customer, while improving HELCO's system reliability and lowering its service costs. However, the PUC did not approve the docket, citing an unfair advantage HECO would have over potentially competing CHP developers. In stakeholder interviews conducted as part of the HNEI sustainable energy roadmap study, this was seen as a

major impediment to CHP. Customers were reluctant to install CHP unless the utility was able to offer technical support. One resort removed its CHP installation after the private developer who installed it did not provide adequate technical and maintenance support.

The microgrid and energy storage options were not as effective economically or technically as the proposed re-conductoring of the cross-island transmission lines in addressing issue #3. However, microgrids were seen as a possibility to provide voltage support along a feeder. About 10-20 MW of energy storage of some type can be essential for HELCO in coping with large penetrations of as-available generation. Otherwise, the regulating reserves needed to support such generators would exceed the minimum load at night. As a result, HELCO was reluctant to guarantee enough energy purchases from potential new wind farms for those wind developers to secure financing.

An important observation from these studies is that HELCO's production cost did not vary much over the course of the day; therefore, the traditional economic justification for energy storage or for distributed generation (or CHP) of avoiding high marginal cost peak power purchases does not apply. Instead, DERs, including energy storage, must be justified by their value to support grid stability or relieve distribution overloading.

One recommendation of the DBEDT studies was to perform more detailed site-specific cost analyses, load flows, production cost and unit commitment studies, system reliability analyses, and wind speed simulation studies. The purpose of these studies is to determine the optimum size and location of energy storage or other distributed energy resources, the effects on revenue requirements, and the resulting degree of dependence on fossil fuels.

## **2.2: HNEI Sustainable Energy Study**

This study constructed and validated detailed power system simulation models of the HELCO system, and examined the system performance (economics and reliability/stability) of the forecasted future HELCO system, scenarios with increased as-available generation, and scenarios with energy storage introduced to mitigate the problems caused by large amounts of as-available generation.

Two primary simulation tools were used in this study: GE MAPS™ Production Cost Simulation was used to assess unit commitment, unit dispatch, operating economics and the environmental impact for each scenario, and GE PSLF™ Dynamic Simulation was used to assess grid stability and dynamic performance in response to grid events and/or the variability of renewable energy. Jointly, these tools were used to assess the economics, environmental impact and performance of each electricity infrastructure scenario in various timescales of power system operation:

- Seconds-to-minutes (regulation and frequency control),
- Minutes-to-hours (load following, balancing), and
- Hours-to-days (unit commitment, production cost).

The HNEI study concurred with the DBEDT study that energy storage and/or other types of system response technologies (such as faster-responding generator controls and certain demand management strategies) would be essential to manage the HELCO system if large amounts of additional as-available generation were to be installed. The appropriate energy storage was found to be of two types:

- Fast response, low-energy-capacity electric storage to manage the minute-by-minute or more rapid fluctuations in generation and load. This would help reduce the required regulating reserves (now provided primarily by diesels).
- Higher-energy-capacity storage, able to provide up to 30 minutes worth of capacity. This would manage the unit commitment problem posed by 15- to 60-minute trends in as-available generator output. Such storage would act as a spinning reserve, giving the system dispatcher additional time to observe load and generator availability before having to start up additional fossil-fueled units.

Other pertinent observations from the stakeholder interviews in the HNEI study were:

- A critical prerequisite for customers to install CHP or DG is to have adequate technical support. Large customers see HELCO as being best able to provide such support and prefer to develop DER in partnership with HELCO.
- There are some critical loads that are now seen as candidates for DG. This includes some public safety and service facilities that were out of service after the October 2006 earthquake, resorts and hotels whose kitchens and living quarters were in demand after the earthquake, and some critical water pumps on the west side of the island.

### **3.0: Changes in Big Island Loads and Resources**

Since the 2004 studies, there have been significant changes in the Big Island's energy sector:

- With the recent economic downturn, load growth has slowed considerably.
- The State has adopted an aggressive renewable portfolio standard setting a goal for the electricity sector to be 40% of net electricity from renewable energy by 2030.
- The PUC is investigating the possibility of implementing feed-in tariffs to encourage installation of renewable energy-powered electric generation. The PUC has also modified PPA terms to move away from requiring the utility to pay independent power producers (IPPs) the marginal-avoided cost of electricity. (The requirement had the effect of tying the price of renewable generation electricity to the cost of oil. Hawai'i residents did not directly receive the economic benefit or price stability of replacement of petroleum with renewable energy sources.) The PUC is also studying modifications to the energy cost adjustment clause of the electricity tariff to make the utilities absorb some of the risk of rising oil prices.
- Another 30 MW nameplate capacity of wind-powered generation has been added and significantly more is expected. HELCO has had to "detune" its automatic generation control (AGC) to be able to tolerate some frequency excursions to absorb wind generation. Even so, there have been several incidents of unacceptably large frequency deviations caused by wind variability.
- There has been a significant increase in residential photovoltaic (PV) installations. Many of these have been installed without the necessary permits, so HELCO is unaware of the total amount of PV systems on its grid. Most PV installations do not include battery storage, but there are some areas on the island where groups of homes do have PV systems with batteries. Because inverters are set to disconnect during a disturbance (anti-islanding provision of IEEE-1547), and the large amount of wind generation on the island has led to more frequent frequency excursions, HELCO has seen system disturbances exacerbated as PV inverters drop out. As a result, HELCO is requiring larger PV installations to be able to



- HECO has started a demand side management (DSM) program. At present, it is focused mainly on control of electric water heaters, but air conditioner cycling (turning the A/C off for 15 minute periods) is also included. After the DSM program is successfully implemented in O‘ahu, a similar DSM program is planned for the Big Island.
- The State has encouraged plug-in hybrid electric vehicles (PHEV), and Better Place is proposing to install battery-charging infrastructure on the islands.
- The Puna geothermal facility will increase its capacity by about 8 MW. It has a permit for an additional 30 MW. It is expected that the newer units would use more advanced technology and be capable of load following. Another geothermal site on the Kona side is also being investigated.

#### **4.0: Developments in Energy Technologies**

There are three energy technology developments particularly relevant to the Big Island:

- Advances in inverters promise to improve their ability to ride through disturbances. One method uses a power line carrier signal injected at the substation. If the inverter detects the carrier, then it knows it is still connected to the grid’s power. Failure to detect the carrier indicates an interruption in supply. This has implications for the utility being able to control inverters. Stopping the carrier signal would shut off the inverters, while supplying some measure of down regulation for the grid. Another inverter advance is the capability to vary the power factor of its output. In this way, the inverter could supply Vars as well as watts.
- A current DOE/OE Renewable and Distributed Systems Integration (RDSI) study on the island of Maui is developing and demonstrating a distribution management system that controls and dispatches DER – distributed generation, energy storage, responsive loads – to support grid stability.
- PHEVs are receiving considerable interest. Improvements in battery technology and charging infrastructure and control are resulting in PHEVs becoming not just a load on the electric system, but also a resource to provide peaking power, back-up power, or ancillary services (including up or down regulation). HNEI is currently funded to test these vehicles.

#### **5.0: Recommendations**

The primary question is “are there are additional opportunities for DER and/or microgrids to address some of HELCO’s system operation or resource planning needs?” The scope has been expanded from “microgrids” to “DER and/or microgrids” because the microgrid itself is comprised of DER, distribution equipment, and customer loads. Therefore, the microgrid’s potential support to HELCO relies on being able to manage DER technologies. As “Smart Grid” technology configurations and procedures are developed (e.g., the RDSI Maui project), it becomes apparent that DER could be managed either locally in a microgrid configuration or at the system level as a Smart Grid augmentation to the HELCO Energy Management System (EMS). Thus, the recommendations that follow for enhanced DER and associated controls on the Big Island could also be used in other than microgrid configurations. There are five such scenarios worthy of further investigation. These are not completely separate since the proper

approach to evaluating potential microgrids on the Big Island is to look at sites where the potential resources/loads and the largest possible benefits of the proposed functions coincide.

### **5.1: Control of Advanced Inverters Serving PV**

Advanced inverters now being developed and deployed include the following capabilities:

- Use of a power line carrier (PLC) signal as a permissive control for anti-islanding. (If the inverter can detect the substation-injected signal, then it is not in an islanded mode.) By controlling the PLC injection from the substation (turning it on and off), the utility can enable or disable the PV inverters on the feeder.
- Ability to output watts and Vars. Inverters can be controlled to produce power at a power factor less than or greater than unity.

If HELCO requires future PV inverters to utilize the permissive PLC signal for anti-islanding, the DER/microgrid functions HELCO could consider are:

- Turning off the PLC signal injected in the substation to provide down regulation from PV. Since HELCO is monitoring PV output from sample panels in its substation, if it knows the connected PV load on the feeder, it will know how much down regulation the PV could provide.
- If the PLC signal is deliberately turned off, then turning it on will enable the PV inverters on the feeder, providing up regulation. Since HELCO is monitoring PV output from sample panels in its substation, if it knows the connected PV load on the feeder, it will know how much up regulation the PV could provide. It would also know how much energy (kWh) the PV panels would have provided when they were disabled, and could pay PV owners for that “available PV.” This, in effect, enables the utility to obtain ancillary services for the price of its renewable energy purchase agreement.
- Control of the power factor of the inverter output will enable the utility to better manage the voltage along the feeder. Providing a leading power factor from the inverters during peak loads could substitute for switched capacitors. While the DBEDT study shows that using DER to provide additional voltage support for feeders will not likely enable HELCO to defer planned feeder reinforcement, it might improve the voltage quality of the feeder without the transients caused by switched capacitors.

Two requirements for implementing this DER/microgrid feature are: 1) the utility must be able to control the inverter, and 2) there needs to be a tariff structure and power purchase agreement that supports it. Currently, the objective of customer-owned PV is to maximize the energy produced. Thus, where possible, PV panels are positioned to produce the most energy over the year based on position of the sun. (There are some tracking PV systems on the island, but very few because of the extra cost.) However, PV generated along the feeder by customer-owned panels may be more valuable to HELCO when it is at the time of system peak (to reduce transmission loading) or at the time of feeder peak (to reduce getaway loading or to provide voltage support).

Since Hawai‘i is investigating feed-in Tariffs (FITs) for renewable energy sources, the recommendation is to also consider FITs that vary by time-of-use. This would affect how PV arrays are positioned in order to maximize the customer’s revenue (as well as improve the systems benefits to HELCO). This would be primarily implemented on the Kona side of the island since this location has more need for generation and load control during morning ramp-up

and evening ramp-down. Also, this side of the island has the most PV. However, there are significant numbers of residential PV systems *with battery storage* on the Hilo side of the island. Not only would the functions described above be appropriate for these installations, but increased utilization of the customer-owned energy storage as part of a micro-grid (a function planned to be included in the RDSI Maui project) through utility monitoring and control may give additional benefits to HELCO and revenue to the home owner.

## **5.2: Distributed Generation and Storage for Critical Loads and Infrastructure**

The DBEDT study showed a limited opportunity for DG and CHP at customer locations. The large resorts appear to be the best candidates for CHP to address air conditioning (absorption chillers) or water heating (pools, spas, laundry, other domestic hot water) end uses. The interviews with key stakeholders for the HNEI project revealed two pertinent facts:

- Resorts did not want to install DG or CHP unless they had reliable technical support. They felt that HELCO-supported installations offered the only viable option for this.
- The Hawai‘i County planning department felt there was a critical need to install more back-up generation for critical water pumping, wastewater treatment, and non-government emergency services such as could be provided by the island’s resorts (e.g., food and shelter after the last earthquake-caused outage).

As the County of Hawai‘i updates its emergency response plans, opportunities for DG, CHP and energy storage should be identified, especially on the west side of the island. The possibility of using these DER/microgrid resources for grid support and operations should be evaluated.

Specific functions to be considered are:

- Potential for improved production heat and electricity economics,
- Voltage support on feeders,
- Providing regulation, and
- Improving economic dispatch of bulk power assets during morning ramp up or evening ramp down of system load. Consider unit commitment scheduling, relieving transmission loading to provide for contingencies, and supplying regulating reserve.

To be capable of these functions, any DER must be monitored and controlled by HELCO.

## **5.3: Demand Response Capability on a Feeder**

HECO is developing and pilot testing demand response (DR) functions on O‘ahu. The successful DR programs will be implemented on HELCO’s system. The largest benefit of DR on the Big Island may not be to reduce system peak. Instead, it may be:

- Providing regulation, especially down regulation.
- Providing operating reserves.
- Reducing feeder load to support voltage along the feeder.
- Shedding non-critical loads when necessary.
- Managing demand so as to better accommodate fluctuations in as-available energy.
- Helping to maintain frequency by better matching load and DG on a microgrid feeder.

The DR must be dispatchable on both a system and a microgrid (substation/feeder) basis. This capability is being developed and will be demonstrated on the Maui Electric Company (MECO) system, as part of the DOE/OE RDSI Smart Grid project, which includes installation of a distribution management system (DMS) that interfaces with the utility's bulk power energy management system (EMS).

The following loads are the best candidates for DR. They can be anywhere on the island:

- Electric service water heating.
- Adjustable thermostat for residential HVAC.
- Commercial building energy management systems, controlling thermostat settings for HVAC, reducing or turning off ventilation systems (short term control), interrupting non-critical lighting and space conditioning, electric energy storage, thermal energy storage.
- Shedding of non-critical loads in residences.
- Managing energy storage in buildings (residential, commercial, institutional) with PV capabilities.
- Energy storage, including vehicle-to-grid (V2G) operation of PHEVs.

Electric water heating is probably the most flexible and significant DR load, but in the context of Hawai'i's long-term energy roadmap, almost all domestic hot water (DHW) in the State should be solar powered (albeit with an electric back-up). However, studies of the benefits of controlling the electric back-up element of a solar water heater show very minimal demand response. Therefore, DR from electric DHW will be an ever-decreasing resource. It is recommended that to help motivate conversion to solar DHW, the PUC consider making participation in approved DR programs be mandatory, without additional compensation to customers, for any electric DHW. It should be noted that a recent law was passed requiring all new homes to have solar DHW.

#### **5.4: Integrated Volt/Var Control (IVVC)**

There are a few long or heavily loaded feeders on the HELCO system with voltage support issues. For those feeders, a distribution management system could provide volt/Var control utilizing microgrid assets of:

- Dynamic Var controllers in the substation,
- Controllable "smart" PV inverters along the feeder (note, these could supply Vars even at night when the PV panels do not supply energy),
- Switched capacitors,
- Regulators,
- Distributed generation and energy storage, and
- Demand response to reduce feeder loading.

IVVC of a microgrid can provide support to the bulk-power HELCO system as well as to individual feeders and substations. As with the DR functions, a distribution management system integrated with the utility EMS is required. Issues of control hierarchy, to decide when to dispatch Vars to support the grid instead of to optimize local microgrid feeder conditions, are being addressed in the RDSI Maui project.

## 5.5: Docked Ships as DER Assets?

Large cruise ships dock on the Big Island near Hilo. While in port, the ships keep their engines running to generate electricity. The ships could draw power from the utility when in port, but this is not done for the following reasons:

- It is complicated for the utility to develop a tariff and negotiate a service agreement with cruise lines, especially since they would only be intermittent utility “customers.”
- The utilities do not have the infrastructure to connect and serve a shipboard load when docked - typically about 2 MW.
- The ships may not have the capability of connecting to the utility for power.

There are several reasons to consider connecting docked cruise ships in Hilo to the HELCO grid:

- By increasing the nighttime minimum load, HELCO may be able to accept more renewable energy-based generation (wind and geothermal).
- The Big Island’s petroleum reserves can get low due to refueling demands of large ships. There have been times when fuel for HELCO generators was limited. Jet fuel may not be in storage for the required minimum time. Serving the ships’ electrical load with land-based generators might enable the engines to be turned off or throttled down significantly. An assessment of relative combustion/generation efficiencies between HELCO and shipboard generation could determine whether this can provide a net reduction in petroleum use.
- Cruise ships have very small energy storage (e.g., battery) capacity. However, if it were possible to manage the ships’ engine output and/or their battery charge/discharge, then the ships could potentially supply regulation to the HELCO grid.

If it is found that the electric utility’s serving docked ships’ electrical needs is justified, it is likely that the State would have to mandate that cruise ships participate because of anticipated net reductions in petroleum usage in the islands. Otherwise, it is unlikely that cruise ships would invest in the necessary on-ship infrastructure and controls.

## 6.0: Conclusion

Advances in microgrid, power electronics, and control technologies, together with changing conditions on the Big Island and evolving energy policies in the state of Hawai‘i, warrant a re-examination of the potential benefits of installing and utilizing DER and microgrids. While technical feasibility and cost-effectiveness cannot be guaranteed, more in-depth analyses are justified, particularly due to Hawai‘i’s aggressive petroleum reduction goals. However, a necessary condition for the full benefits of microgrids and DER to be realized is an integration of controls, monitoring, and communications between distribution management systems and the HELCO central dispatch center (SCADA/EMS). Such an integration of systems and procedures is the essence of the Smart Grid.