Informational: Staff Report
January 4, 2017

Sandia Report: Kalaeloa Energy System Redevelopment Options Including Advanced Micro grids

Goal:

To respond to the Authority and the Kalaeloa stakeholder's request to pursue all potential solutions for achieving electrical energy resiliency in Kalaeloa and work to eliminate monthly electrical outages.

Background:

In 1999 Base Realignment and Closure of the Naval Air Station Barbers Point was initiated by the United States Navy (Navy). At the time the Navy met with the Hawaiian Electric Company (HECO) to convey the electrical system to HECO, but HECO determined that due to liability concerns they were not able to accept the conveyance. Since the Navy no longer has a mission in the district there has been no system upgrades, limited operations and maintenance funding, and no commitment to upgrade the system. This has resulted in consistent electrical outages that are impacting daily operations of all landowners and tenants within the district.

Since 2007, staff met on several occasions with the Navy and HECO to discuss the needs of the district and request that HECO would assume the Navy's electrical system. HECO again identified liability issues as the reason for not assuming the Navy's system.

In order to address consistent stakeholder complaints about electrical outages, staff pursued legislative appropriations to construct new HECO standard energy corridors in the district identified in the 2010 Kalaeloa Infrastructure Master Plan Update.

In 2012 the legislature appropriated $3.5 million for the Kalaeloa Easter Energy Corridor Project. The 12 kv overhead line extension between Franklin Delano Roosevelt (FDR) Avenue and Tripoli would replace the Navy's substandard equipment with HECO standard equipment. The Navy responded that in order to construct within their easements the Navy is required to charge fair-market-value. Because the easements is within the Barbers Point Golf Course it would cost $1 million per acre of which the project requires work within a total of eight acres of easement. HCDA completed design and all necessary environmental documents, but does not have the funding to pay for the Navy's easement charges.

In 2014 the legislature appropriated $7 million for the Kalaeloa Enterprise Energy Corridor Project. The 12 kv underground line extension between Kapolei Parkway and

Midway road fronting the Kalaeloa Airport will provide HECO standard duct lines to downtown Kalaeloa. When HCDA procured for construction the construction bids came back significantly higher. HCDA staff phased the project into two phases and requested an additional $6 million and the 2016 legislature appropriated an additional $3 million instead.

On February 2, 2016, Authority Member Shirley Swinney and staff met with Luis Salaveria, director of the Department of Business, Economic Development & Tourism to discuss infrastructure conditions and stakeholder feedback relating to electrical outages in Kalaeloa.

In response to Director Salaveria and Member Swinney's meeting HCDA staff conducted a district tour and briefing for the State of Hawaii Energy Office (EO) staff on July, 11, 2016. In an effort to explore potential renewable energy power solutions for Kalaeloa, the EO staff proposed that HCDA conduct a micro-grid workshop for Kalaeloa stakeholders. The workshop would be presented in partnership with the United States Department of Energy (USDOE) and Sandia National Laboratories (Sandia), who receives funding from the USDOE to expand renewable and sustainable energy opportunities throughout the country.

At its September 7, 2016 meeting, the Authority received an information item on the 6th Kalaeloa Landowners Summit (Summit), which would be held on October 2016. The Summit agenda included a panel of major landowners that provided a 15-minute presentation on the status of their perspective projects and activities that are occurring on their parcels. Each landowners' presentation also included their current and future energy needs and identified conditions/outages and development challenges as it relates to unreliable energy.

The Summit agenda also included workshops to focus on energy reliability and resiliency, including Kalaeloa's role in reaching Hawaii's energy goals, an overview of energy assurance and resilience trends and the potential for the use of an advance micro-grid technology for Kalaeloa. Information regarding the Summit's activities and goals were provided to Department Director Luis Salaveria, Department of Business, Economic Development and Tourism, who in turn, briefed Governor David Ige.

Sandia Report Projected Outcomes:

Sandia document findings in a subsequent publicly available report that will include the conceptual energy system designs and their rough (+/- 30%) cost estimates. (See Exhibit A)

Findings may be used by the USDOE, HSEO, HCDA, district landowners and/or other stakeholders to create a potential request for interest or proposal for the development of a Kalaeloa micro-grid system, the nexus for requesting funding for electrical infrastructure improvements, or any other efforts to provide reliable energy for Kalaeloa.

Authority:

§206E-4 Powers; generally. Except as otherwise limited by this chapter, the Authority may:

Paragraph (3) Make and execute contracts and all other instruments necessary or convenient for the exercise of its powers and functions under this chapter;

Paragraph (17) Do any and all things necessary to carry out its purposes and exercise the powers given and granted in this chapter;

[L 1976, c 153, pt of §1; am L 1990, c 86, §6; am L 1997, c 359, §3; am L 2000, c 253, §150; am L 2002, c 184, §4; am L 2009, c 18, §1; am L 2011, c 55, §2]

Potential Next Steps:

1. Pursue federal legislation allowing the Secretary of the Navy to convey all remaining assets in Kalaeloa to the Local Reuse Authority/HCDA which would include the electrical system.
2. Pursue planning, design and analysis funding from the 2017 legislature not to exceed $500,000.00. To establish the Kalaeloa Community Development District Micro grid Project (KAL Micro grid Project).
3. Pursue public-private partnerships for the design, build, own, operate and maintain the Kalaeloa Energy Company or establish a Cooperative not-for-profit organization that is owned and operated by its people for the KAL Micro grid Project.
4. Conduct a Kalaeloa Energy-Industry-Day to present the Sandia report which includes stakeholder priorities, district requirements and potential project district design for a Kalaeloa Micro grid Project to explore private developer interest in developing the KAL Micro grid Project.
5. Establish a full participation partnership between HCDA and the United States Rural Utility Service to utilize the Rural Energy Savings Program (RESP) to establish the Kalaeloa Energy Funding Program.

Exhibit A:	Sandia Report

FINAL DRAFT

SANDIA REPORT

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Kalaeloa Energy System Redevelopment Options Including Advanced Microgrids

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Exhibit A

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Abstract

In June 2016, the Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE) in collaboration with the Renewable Energy Branch for the Hawaii State Energy Office (HSEO), the Hawaii Community Development Authority (HCDA), the United States Navy (Navy), and Sandia National Laboratories (Sandia) established a project to 1) assess the current functionality of the energy infrastructure at the Kalaeloa Community Development District, and 2) evaluate options to use both existing and new distributed and renewable energy generation and storage resources within advanced microgrid frameworks to cost-effectively enhance energy security and reliability for critical stakeholder needs during both short-term and extended electric power outages.

This report discusses the results of a stakeholder workshop and associated site visits conducted by Sandia in October 2016 to identify major stakeholder and tenant energy issues, concerns, and priorities. The report documents information on the performance and cost benefits of a range of energy system upgrade approaches including; traditional electric grid upgrade options, advanced microgrid upgrade options, and combined grid/microgrid upgrade options. The cost and benefits of the different improvement options are then compared to see how well they address the various energy system reliability, sustainability, and resiliency priority needs identified by the Kalaeloa stakeholders.

ACKNOWLEDGMENTS

The following individuals were instrumental in supporting our technical efforts and facilitating interactions among a wide-range of constituents in Hawaii as part of this project. They include:

Stephen Walls - DOE Office of Energy Efficiency and Renewable Energy
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Kevin Chock – RHA Energy Partners/Federal Bureau of Investigation Building
Kena Via – Veterans Administration/Cloud Break Community Housing
Derek Kimura – Hawaiian Home Lands
Thomas Lee – Military Affairs Liaison, Office of the Governor

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FIGURES

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NOMENCLATURE

BESS	Battery Energy Storage System
CCHP	Combined cooling heating and power
DHHL	Department of Hawaiian Homelands
DOE	Department of Energy
FAA	Federal Aviation Administration
FBI	Federal Bureau of Investigation
HARNG	Hawaii Army Reserve and National Guard
HCDA	Hawaiian Community Development Authority
HDOT	Hawaii Department of Transportation
HECO	Hawaiian Electric Company
KHP	Kalaeloa Heritage Park
HSEO	Hawaii State Energy Office
Hunt	Hunt Companies
KIMPU	Kalaeloa Infrastructure Master Plan Update
KMP	Kalaeloa Master Plan
KV	Kilovolt
kWh	kilowatt hour
M	Million
MW	Megawatt (1,000,000 watts)
MWh	Megawatt hours
O&M	Operations and maintenance
Parks	City and County of Honolulu Department of Parks and Recreation
PCC	Point of Common Coupling
PPA	Power Purchase Agreement
PV	Photovoltaics
R	Reclosers
ROM	Rough Order of Magnitude
RUS	Rural Utility Service
Sandia	Sandia National Laboratories
SSA	Substation A
SSB	Substation B
VA	Veterans Affairs
USCG	United States Coast Guard
USDA	United States Department of Agriculture
WWII	World War II
$	Dollar
%	Percent

1. EXECUTIVE SUMMARY

The Kalaeloa Community Development District (Kalaeloa) is an approximately 3700-acre redevelopment parcel established on the former Naval Air Station-Barbers Point in West Oahu, Hawaii. The Naval Air station was closed in 1999 through the Department of Defense Base Realignment and Closure (DoD BRAC) process. Because the Navy no longer has an active military mission at Kalaeloa, they want to transfer the electric system to another entity, with a current goal of selling or transferring the electric gird in its entirety in the next two years. At transfer, the entity that obtains the electric grid will be required to maintain service to the current users, while also upgrading the system to modern commercial electric utility operational and safety standards.

Since the 1999 BRAC, the Navy has not fully maintained the electric system, making repairs only as needed, such that the current system does not meet industry standards and the overall reliability of the system is considered of marginal quality by the current tenants. Most tenants complain of multiple power outages each month that often last more than an hour, and sometimes as much as eight hours, with most tenants experiencing approximately 40 hours of power outages a year. Replacement of the existing electrical system is needed, which will be significant from a cost, time, and electric service reliability standpoint to anyone taking over control of the electric grid. These issues have been a major stumbling block over the last two decades in the timely redevelopment of Kalaeloa.

To support Kalaeloa in identifying innovative approaches to move the District forward and accelerate redevelopment, the Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE) initiated a collaboration in July 2016 with the Renewable Energy Branch for the Hawaii State Energy Office (HSEO), the Hawaii Community Development Authority (HCDA) at Kalaeloa, the United States Navy (Navy), and Sandia National Laboratories (Sandia) to 1) assess the current functionality of the energy infrastructure at Kalaeloa, and 2) evaluate options to use both existing and new distributed and renewable energy generation and storage resources within advanced microgrid frameworks to efficiently and cost effectively accelerate redevelopment of the electric system to enhance overall energy system reliability, and improve critical tenant operational resiliency and performance especially during extended power disruptions.

For this project, Sandia was tasked to assist staff from HSEO, HCDA, and the Navy to:

- Assess and gather data on Kalaeloa's electrical distribution system, existing backup generation, and renewable generation use and opportunities,
- Conduct a workshop with Kalaeloa Stakeholders in cooperation with KCDA at the 6th Kalaeloa Landowners Summit "Establishing Energy Reliability and Resiliency Workshop" (Summit) on October 18, 2016 to:
    - Discuss current energy system issues and challenges, and

    - Help identify emerging energy system sustainability, reliability and cost goals and expected implementation timeframes and plans
- Conduct tenant site visits to better understand current challenges and priorities,
- Visit the Hawaiian Electric Company (HECO) and discuss Kalaeloa energy system design and collaboration needs to ensure delivery and operational safety compatibility with the larger Oahu grid.

Based on the information collected, Sandia identified several energy system upgrade options ranging from traditional to non-traditional energy system upgrades to quantify ways to accelerate the improvement of the Kalaeloa electric system and enhance energy reliability, sustainability, security, and reduce costs. The cost and performance benefits of the different options considered are summarized in this report, and include the following major recommendations:

1. HCDA should work with USDA/RUS or other entities to establish a cooperative framework to fund and manage the operations and maintenance of the current electric system and implement the upgrades required over the next 10 years.
2. Within the next two years, integrate advanced microgrids and distributed generation resources at four priority Kalaeloa locations – USCG, Downtown and Airport, Hunt, and HARNG to reduce average outage times from 40 hours per year to less than and hour per year, at a cost of approximately $20M. Planned energy improvements by these groups can be leveraged to reduce overall implementation costs.
3. Accelerate the development of up to four 5-MW solar energy projects at Kalaeloa specifically for onsite energy use using Power Purchase Agreements with solar developers. Integrate with the advanced microgrids to support lower upgrade costs and compatibility with future electric feeder load limits. At full electric system build out, Kalaeloa would have about 25-30% renewable penetration.
4. In the next three years, add a new 40-MW, 46-kV substation at the Northwest end of Kalaeloa, with up to six 12-kV underground feeders to support electric upgrades for current and new tenants in western Kalaeloa. Integrate these improvements with the new microgrids to enhance reliability and full-utilization of identified renewables generation.
5. In the next 5-10 years as needed, add a second 40-MW, 46-kV substation at the Northeast end of Kalaeloa with up to six 12-kV underground feeders to support the electric system upgrades needed for both new western and eastern tenants. This will provide a total Kalaeloa energy import capacity of 80-MW, with and 20-MW of on-site renewables.

If the electric feeder, advanced microgrid, and on-site distributed and renewable generation upgrades suggested are implemented, they would significantly improve Kalaeloa energy reliability and resiliency, reducing critical load outages from 40 hours per year to only a few minutes per year. The associated costs for a Kalaeloa operated system would range from $0.35/kWh for years 1-5, $0.33/kWh for years 5-10, and $0.30/kWh for years 10-15 and beyond. By years 10-15, the system would be fully updated, and could be sold to HECO or another entity, with the sale price used to reimburse the tenants for the infrastructure capitalization, effectively reducing the overall operational costs to the tenants and the district.

2. CURRENT KALAELOA POWER SYSTEM CHALLENGES

Both the Navy and Kalaeloa stakeholders provided extensive background information on the Kalaeloa electric power system for this effort. HCDA provided Sandia with the 2006 Kalaeloa District Master Plan (KMP) and the 2010 Kalaeloa District Infrastructure Master Plan Update Draft (KIMPU). Both plans provide a good overview of the redevelopment priorities proposed, but the details of the specific infrastructure redevelopment plans and approaches have not yet been fully developed.

The KMP suggests a redevelopment peak load of about 45-60 MW for the expected full development of the site, which is expected to take place in phases over an approximately 7-year to 20-year time horizon. An additional build out of a proposed additional 11 million square feet in the district with a similar mix and load profile as the current tenants would increase the load to about 45 MW from the current 22 MW load. Increasing square footage or adding more energy intensive development would lead to the higher power demand estimate. Therefore, Sandia discussed potential development and load growth with current tenants and landowners to identify the likely load growth trends, focusing on near-term development. These discussions are summarized as part of the landowner visits.

The Navy provided Sandia with one line diagrams for the current electrical system in Kalaeloa, as well as provided maps of feeder and substation locations. Unfortunately, as observed during a tour of the site, not all of the maps are up to date, and many abandoned lines and substations are not noted on the drawings. The Navy also provided load, line loss, and power outage information for the different feeders and areas in Kalaeloa District. The Navy currently provides about 20 MW of power to Kalaeloa through two 46 KV substations, with power provided by the Hawaiian Electric Company (HECO).

Since the 1999 BRAC, the Navy has not fully maintained the electric system, making repairs only as needed, such that the current system does not meet current utility standards and the overall reliability of the system is considered of marginal quality by the current tenants. The reason is that the Navy wants to dispose of the energy system and all other utilities at Kalaeloa and puts as little maintenance funds into Kalaeloa as possible. Therefore, the current electric system at Kalaeloa experiences routine scheduled power outages that can last 4 to 12 hours, and several monthly non-scheduled outages that can last 1-4 hours, with some tenants seeing outages of as much as 40 hours per year. Replacement of the existing electrical system is needed, which will be significant from a cost, time, and liability standpoint to anyone taking over control of the electric grid. These issues have been a major stumbling block over the last two decades between the Navy and HECO, and in the timely redevelopment of Kalaeloa.

2.1 6th Kalaeloa Landowners Summit “Establishing Energy Reliability and Resiliency”

The Summit took place on Tuesday, October 18, 2016 at the University of Hawaii West Oahu Campus. The Summit was attended by about 60 stakeholders including; tenant, landowner representatives, Navy, state agency and elected official representatives, developers, and electric utility providers. The Summit was divided into morning and afternoon sessions.

The morning session was designed to provide:

- Presentations by the seven major landowners on their redevelopment goals and energy issues, challenges, needs, and opportunities;
- A presentation by Sandia on emerging energy assurance and resiliency design approaches, such as the use of advanced microgrids, and how they are being used to improve renewable and distributed energy generation and storage resource use, while also enhancing local energy reliability, sustainability, and resiliency, and;
- A presentation by Sandia on examples of similar redevelopment efforts, such as the evaluation of advanced microgrids at the Philadelphia Navy Yard redevelopment.

The afternoon session included two major breakouts sessions where the Summit attendees were separated into three small discussion groups. The groups discussed and identified:

- Energy system redevelopment priorities and goals – such as energy reliability, quality, cost, safety, renewable integration, etc.;
- Priority near-term and long-term energy redevelopment needs, and;
- Redevelopment zone priorities for energy infrastructure improvements.

At the Summit, the seven major landowners including the Navy, U.S. Coast Guard (USCG), Veterans Affairs/Cloudbreak Communities (VA), Hawaii Army National Guard (HARNG), Hawaii Department of Transportation – Kalaeloa District Airport (Kalaeloa Airport), Department of Hawaiian Home Lands (DHHL), Hunt Companies (Hunt). Other landowners that participated in the Summit but did not give presentations, included the Federal Bureau of Investigation (FBI), the Federal Aviation Administration (FAA), the City and County of Honolulu Department of Parks and Recreation (Parks), the Kalaeloa Heritage Park (KHP) and HECO.

As noted above, Breakout Session 1 was designed to discuss energy system priority performance goals and stakeholder needs. The three different discussion groups identified surprisingly similar priority energy goals. These included:

- Stakeholder Priority System Performance Goals
    - Higher power reliability - reduce number of power interruptions and outage durations.
    - Higher power quality – reduce voltage frequency variability.
    - Reduce/stabilize electric power cost and cost structure.
    - Make sure critical loads are served during any power outage.
    - Safety operations and public safety are requirements of all improvements.
- Additional interests of stakeholders and state government representatives
    - Ability to support the larger Oahu grid.
    - Integration of renewable generation resources to support State of Hawaii statutory requirement of 100% Renewable Portfolio Standard by 2045 for the electricity sector.

The second part of Breakout Session 1 was set up to identify priority areas to focus initial energy surety improvements. Overall, the consensus of the three groups was also similar and their suggestions are shown in Figures 1 and 2. The highest priority areas identified for initial and near-term energy improvements (Years 1-3) included:

- Area A - Beach front – Navy bungalows, USCG, State Parks East Beach campground, HCDA and C&C Honolulu Property
- Area B - Downtown – Hunt, Hawaiian Homelands, VA, National Guard, Kalaeloa Airport
- Area C - Coral Sea/Saratoga – FAA outer marker
- Area D - Roosevelt/Saratoga corridor west of Enterprise – FBI, Hunt

Follow on energy improvement (Years 3-10) priority areas identified by the stakeholders included:

- Area E - Roosevelt/Saratoga corridor east of Enterprise – FBI, Hunt, new development, C&C Honolulu Parks - WWII memorial, Stables and Navy golf course
- Area F – West of airport – Hawaiian Homelands, Airport hangar expansion, new development
- Area G – Coral Sea renewable energy corridor

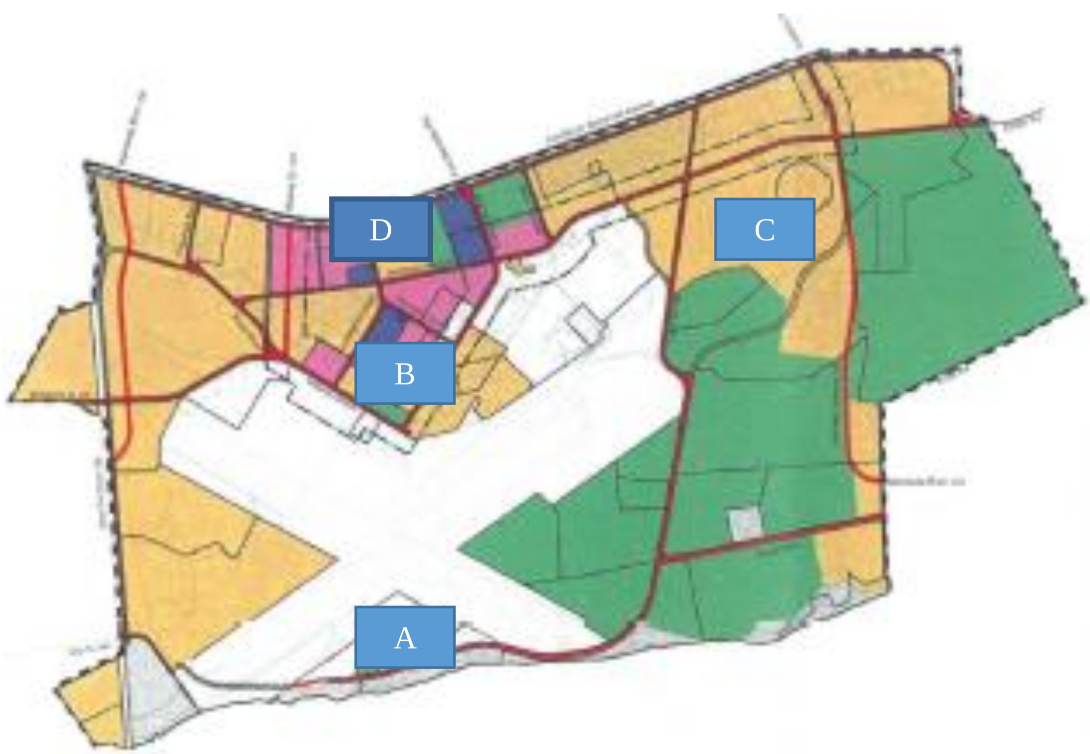

Figure 1. Identified Initial Priority (Years 1-3) Energy Improvement Zones

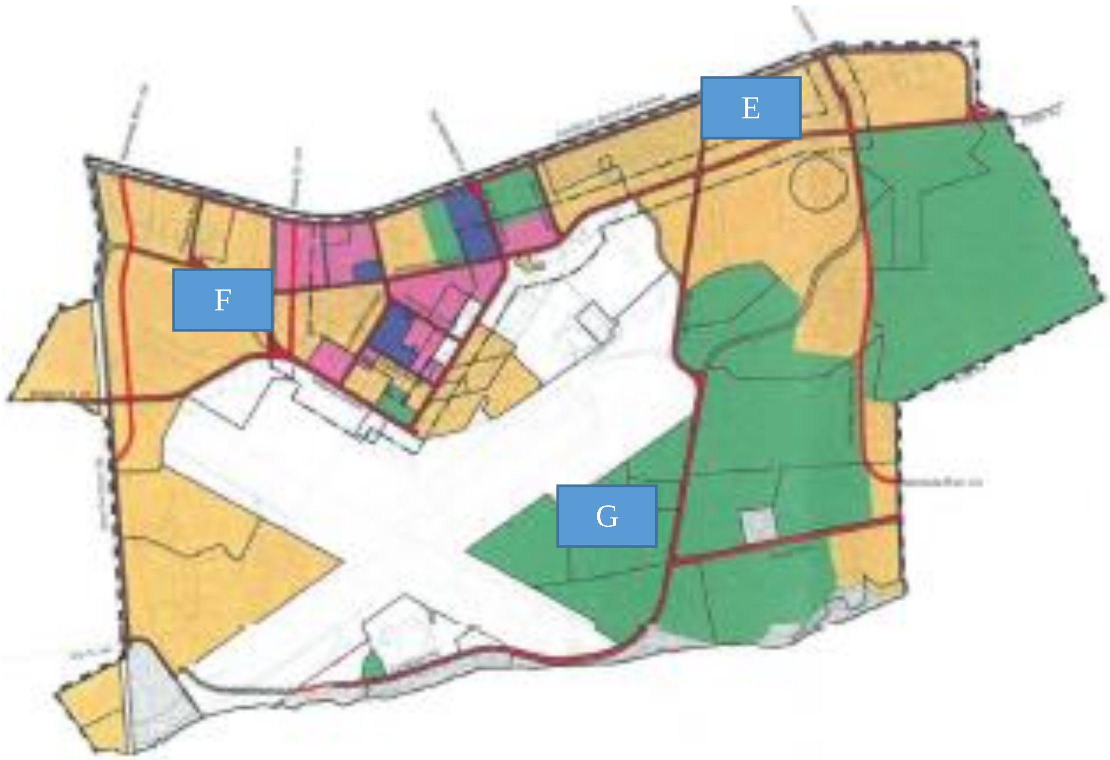

Figure 2. Identified Year 3-10 Energy Improvement Zones

Breakout Session 2 was designed to discuss stakeholder input on the existing KMP relative to energy system needs and development timelines. Again, the three discussion groups identified similar priorities which included:

- Kalaeloa redevelopment opportunities and needs are significantly nearer term than the current KMP and KIMPU suggest. More like 1-10 years vs the current 7-20 years focus.
- The current infrastructure issues are significantly hampering redevelopment:
  - Water, wastewater, electric power, and roadways are the biggest concerns.
  - Currently the Navy is divesting the water and wastewater systems to a private operator. Therefore, an improved electric power grid is the largest priority to support future development.
  - Energy reliability is a big need to facilitate the expected growth.
  - Energy assurance is a major need for Kalaeloa landowners who have significant improvement and expansion plans for their holdings (i.e. FBI, military rapid deployment operations, commercial airport operations, etc.)

Overall, the stakeholder summit included a very wide range of stakeholders and state representatives and provided a fairly uniform consensus of the needs and directions for the redevelopment of Kalaeloa. There was a strong need to accelerate energy system upgrades to meet existing energy reliability concerns so the district can attract additional tenants and better support the regional growth and development needs in the West Oahu area.

2.2 Kalaeloa Landowner Site Visits

Sandia and HSEO staff conducted site visits of major landowners on Wednesday and Thursday, October 19 and 20, 2016. Sandia reviewed existing site distributed generation, facility load data, identified critical mission loads, and discussed planned energy improvements and additional load requirements. Table 1 provides estimated projections for current and future power demands for the various landowners and areas.

Table 1. Current and Expected Kalaeloa Electric Power Demands

Landowner/Location	Current Power Demand	Mid-term Power Demand	Future Power Demand	Current On-site Generation
Hunt	2 MW	4 MW	6 MW	0 MW
Kalaeloa Airport	1 MW	2 MW	5 MW	0.5 MW
HARNG	4 MW	6 MW	8 MW	4 MW
USCG	1 MW	2 MW	3 MW	0.8 MW
FBI	1 MW	1 MW	1 MW	1 MW
VA	1 MW	2 MW	3 MW	0 MW
Downtown	1 MW	3 MW	7 MW	0 MW
DHHL	1 MW	3 MW	7 MW	0 MW
Eastside	1 MW	1 MW	5 MW	0.5 MW
Total	13 MW	24 MW	45 MW	6.8 MW

The results suggest that the mix of major tenants and their load requirement projections added to the 10 MW for other minor tenants, suggests a 55 MW projection should be used to estimate expected load demand and unit power costs over time at Kalaeloa. On the other hand, the system design should account for this accelerated growth over a shorter time horizon, likely 10-15 years.

All of the tenants considered energy reliability and the age of the existing system as issues they believe are negatively impacting their operations. Most tenants complain of multiple power outages each month that often last more than an hour, and sometimes as much as eight hours, with most tenants experiencing approximately 40 hours of power outages a year. In general the tenants believe that the current system needs to be replaced and updated to function appropriately.

The site visits highlighted several major additional issues, including:

- There is a significant deficiency of distributed generation resources for many landowners to meet even existing critical energy needs, much less meet future increased critical power projections, as noted in Table 1.
- Emerging energy upgrades at some locations, like the USCG and the HARNG, need to be coordinated with future Kalaeloa energy improvements to leverage costs and improve overall energy assurance for these and other landowners.
- The estimated 55 MW build out at Kalaeloa is similar to the values identified in the KMP of 60 MW, and suggest that two 46 kV substations (capable of 40 MW each, but can be

upgraded to support additional capacity) are required to meet industry standard energy distribution system designs over the long term. These substations would support up to six 12-kV feeders at each substation that could be utilized to provide 6-10 MW each of power to all parts of Kalaeloa depending on the type of conductor selected.

- An approach to address current and even some mid-term energy demands would require between 6 - 10 MW of additional distributed and renewable generation if a series of advanced microgrids was developed to improve power reliability while electric system improvements were made.
- The additional distributed generation, if located properly, could also be used to support critical mission loads for the different landowners as part of the long-term electric system improvements, helping to improve energy reliability and critical operational assurance.
- Current Navy energy demands for the district are about 22 MW, suggesting that while the major stakeholders use over half the power, smaller users must be considered in making future improvements to insure their power reliability and quality is also maintained during the upgrades.

2.3 Kalaeloa Energy Issues and New Solutions

It is clear that the Kalaeloa electric infrastructure will inevitably be transitioned from the Navy and ultimately turned over to a permanent electrical provider, whether it be the utility – HECO, an independent operator like a power cooperative, or a third party manager that could manage and make upgrades and eventually turn it over to utility or an independent operator. A standard approach would be that a new owner/operator of the existing system inherit the existing system, make modifications as needed, connect to the local utility (HECO) at the current locations, and run the system as is.

However, this isn’t a permanent solution even if it were possible. Due to age, the existing system is not adequate to continue long-term service without major line and equipment overhauls, which essentially entails replacing the entire system. Additionally, the current KMP requires underground distribution lines rather than an overhead distribution system, meaning that the current distribution system will need to be eventually replaced anyway. Additionally, the existing distribution feeder system was designed for customers and loads associated with the layout of the former Barbers Point Naval Air Station. So even if the same lines could be used, they are likely inadequately sized or inefficiently routed to meet new stakeholder and user needs as outlined in the KMP and KIMPU, or the changes likely needed in the face of accelerated new development and new tenant opportunities at Kalaeloa.

Therefore, Sandia worked with HSEO and HCDA to try and develop innovative approaches to improve the Kalaeloa energy system from both a utility management and utility upgrade approach that could accelerate reliability and cost improvements tenants and stakeholders need and want, and create a better climate to attract future tenants. The major options identified and associated benefits are discussed in the following sections of this report.

3. KALAELOA ENERGY UPGRADE OPTION ANALYSES

Based on the energy system data provided by the Navy, the directions in the KMP and KIMPU, results of the Summit breakouts, stakeholder site visits and discussions, and meetings with HECO, Sandia identified a range of options that could accelerate energy system improvements in a way that would enhance current stakeholder energy reliability while also reducing both short-term and long-term capital and operating costs and stabilize tenant overall energy rates.

Because the Navy wished to dispose of the Kalaeloa energy system in total and not piece meal, we were limited to innovative solutions that could be done district-wide almost simultaneously, in a brown-fields redevelopment rather than a green-fields development, which is much more difficult. This is especially true when the electric infrastructure needs to be replaced while all the tenants need to retain access to high reliability power. We considered three approaches that we think provide information on three opportunities to reduce costs and increase energy reliability. These included:

- Consideration of a phased approach to traditional energy infrastructure upgrades, such as new substations, feeders, and distributed generation integration. In this approach, rather than do all upgrades simultaneously, we would focus on improvements in higher priority development areas first (years 1-3) to increase reliability in these areas first, then adding additional upgrades as other areas grow (years 5-10). This does not try to upgrade all parts of the Kalaeloa energy grid at the same time, but can leave some groups without high reliability power, which will be lower cost, but an issue with those tenants that are in a later upgrade phase.
- Consideration of several advanced microgrid approaches utilizing various types and levels of distributed and renewable energy generation resources. Advanced microgrids can easily support higher energy reliability, often at lower costs because of a major focus on good integration of local generation. But again, these efforts would be focused on priority development areas first, leaving some areas with lower reliability power. With microgrids, the sizes can be varied to a single independent Kalaeloa microgrid using only on-site power, or several smaller microgrids that are networked but also using on-site distributed and renewable generation. With some microgrid systems, power quality can be an issue, which was addressed in the conceptual design evaluations.
- Consideration of combinations of traditional and advanced microgrid energy system upgrades. This allows lower-cost distributed energy improvements to be implemented in some areas to support high energy reliability at some Kalaeloa areas while distribution system upgrades are constructed. This would provide high energy reliability for most of the district as a whole, while the more traditional distribution system upgrades could be developed.

Therefore, Sandia developed conceptual upgrade designs and layouts for these various options. These conceptual designs will require additional engineering analysis to be able to be able to be fully implemented, but can be used to assess the relative cost and performance benefits of each approach. The cost estimates provided are Rough Order of Magnitude (ROM) estimates of +/-

30%. But the analyses do include the consideration of capital, construction, engineering, and contingency costs to provide a consistent framework of the expected implementation costs for energy system upgrade approaches at Kalaeloa, whether traditional or non-traditional. There are additional costs or incentives that should be considered in more detail in the future, such as environmental, permitting, taxes, or future renewable incentives are not well known but could drive the optimization of future designs. But the results can be used to assess general viability associated with each of the different options considered.

3.1 Phased-Feeder Conceptual Design

A phased feeder approach to provide power to Kalaeloa is a traditional approach that was identified to consider as a good baseline. This approach is similar to other approaches entertained by HCDA, such as studies looking at adding new energy corridors proposed by HECO, or studies to develop various energy corridors to meet the needs of particular customers. For example, a general energy infrastructure improvement and development plan suggested by HECO acknowledges the need for two 46 kV substations and proposes a series of future combined 12kV and 46 kV temporary overhead distribution lines compatible with the proposed redevelopment plans highlighted in the 2010 KIMPU. At later dates these new lines would be replaced with underground lines in accordance with the KMP.

The concern with a traditional approach like this is the amount of funding needed up-front to complete the upgrades. To save funds, any distribution system temporary upgrades will need to be eventually replaced at a later date, increasing the full redevelopment costs. Therefore, Sandia tried to establish a slightly different traditional upgrade approach using phased-feeder upgrades that can save time and costs, while improving major Kalaeloa tenant energy reliability and fastest growth areas first during the proposed upgrades.

The Sandia phased feeder approach can be summarized as follows:

- Continue to utilize the existing Navy grid to feed current landowners until more reliable energy corridors are developed.
- In parallel, phase in reliable energy corridors, consisting of new 46 kV distribution substations and 12 kV distribution feeders, based on which landowners will need the additional power demands first, until the entire district is provided with power from the new energy corridors.
- Priority upgrades would be in focused first in areas A, B, and D shown in Figure 1.
- This would be followed by upgrades in areas C, E, F, and G as shown in Figure 2.
- Upgrades would be coordinated with groups like the HARNG, Airport, Hunt, and the USCG that are already evaluating and trying to fund or funding energy system upgrade projects.

- As completed, the Navy grid can be abandoned or refurbished in completed areas, if and where appropriate.
- The improved areas will have a customer base and design that may make it attractive to transfer to a utility provider. The funding from the sale or transfer of the upgraded infrastructure to an operational utility provider could then be used to fund the second phase of the Kalaeloa energy system upgrades. This approach reduces up-front costs and spreads the funding requirements for the upgrades between public and private sources.
- The phased feeder approach does not include costs associated with obtaining right-of-way from the Navy, so obtaining the electric system from the Navy and the associated easements is necessary to install these new feeders most cost-effectively.

Figure 3 illustrates where specific energy corridors can be located relative to current landowners' parcels and address the high priority development and energy reliability areas of Kalaeloa. Figure 3 illustrates one of several potential routes or options for getting new power into Kalaeloa. It shows where new 46 kV substations (SSA and SSB) as well as distribution feeders from these substations (A1-A4 and B1-B2) could be routed based on available corridors (following streets, avoiding historical areas, airport, etc., where distribution lines can't be located). There are several potential alternate routes and locations for the main 46 kV substations, which won't be evaluated, since the main purpose of this report is to show a general concept for incorporating higher reliability power while the Navy distribution system continues to operate and is eventually retired. Note that Feeder A2, A3 and A4 follow the same energy corridor from SSA, so A3 is longer than A2, and A4 longer than both A2 and A3. Other specific variations of this approach are appropriate and should also be evaluated to look at ways to minimize the overall implementation costs of this concept.

As discussed, the approach provides Kalaeloa with new energy corridors consisting of 46 kV substations and 12 kV distribution feeders over time. Sandia has suggested this combination of 46 kV substations and 12 kV feeders, because it aligns with providing power to the priority areas first and at the lowest capital cost. As these customers are connected to the new feeders, existing service feeders can be retired or refurbished.

A phased feeder approach allows Kalaeloa to implement new power distribution infrastructure to the most immediate existing and new sets of expected growth, and then add additional infrastructure as more growth occurs, while maintaining service to existing customers with the current Navy system. This may make it easier to justify and obtain funding for the improvements, since they will be brought on line to service specific needs. Sandia fully recognizes that this is only one way to prioritize the development of new infrastructure, and it is up to HCDA as well as landowners to determine priorities and the types of structured coordination necessary to implement them. It is intended to map out how a phased infrastructure improvement plan could be done.

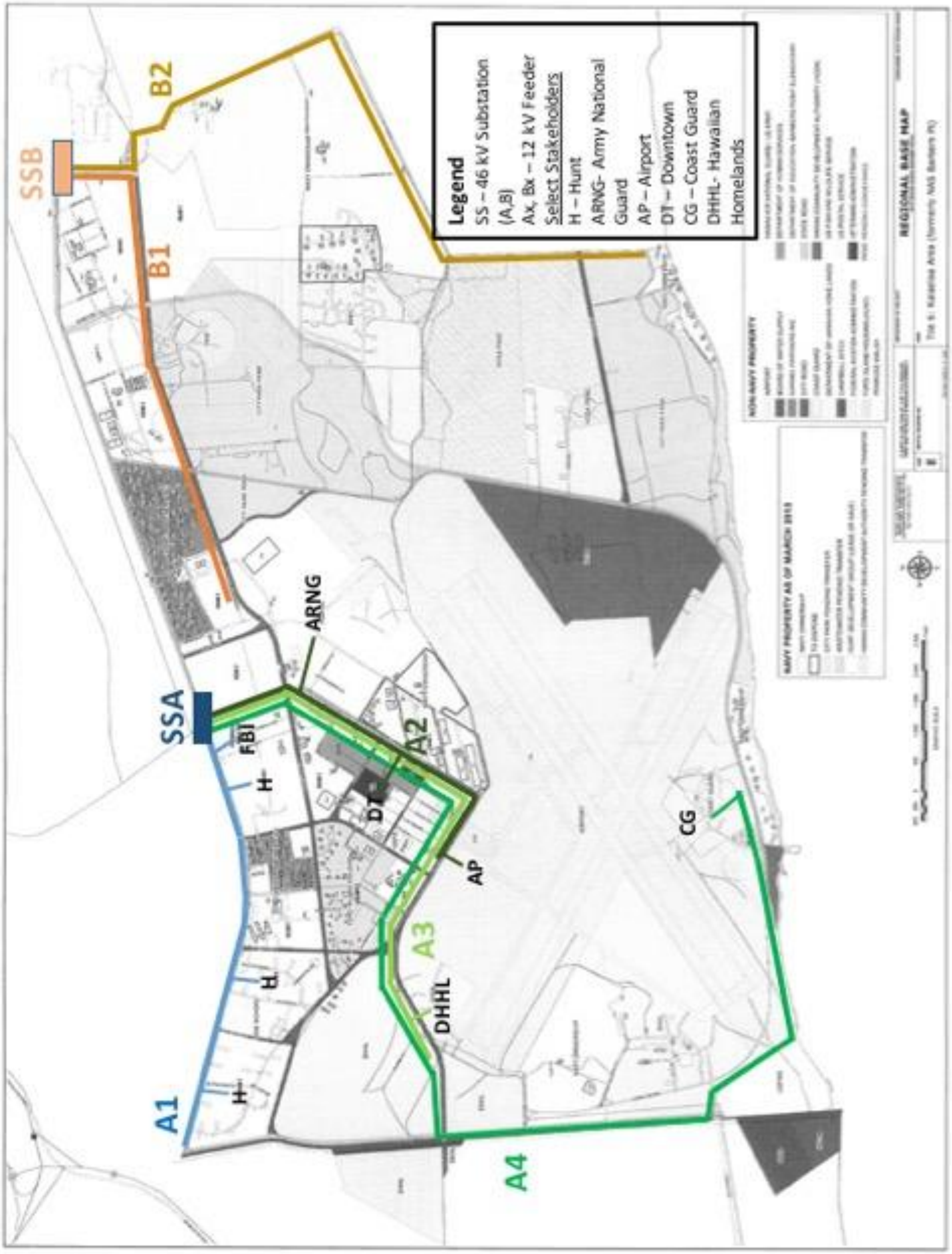

Figure 3. Phased Feeder Approach for Kalaeloa

One of the major assumptions in this approach is that new distribution energy corridors will be placed underground, primarily because of provisions in the KMP though existing customers are serviced by overhead lines. Sandia also assumed that the infrastructure would be built in accordance with HECO standards and guidelines, even if HECO doesn't become the owner/operator of the infrastructure. Utilizing HECO standards will make it easier to connect to the HECO grid as needed, though this doesn't require that HECO be the builder or owner of the system.

We received information from HECO for typical sizes for underground conductors and substations to use in our analyses. Essentially 12 kV conductors have different capacities depending on the conductor and wire size. A high capacity rated 12kV underground conductor has the capacity for about 11 MW according to HECO, but can vary in size depending on the conductor used. Costs estimates for feeders and substations include:

- A 12 kV underground feeder cost of $4.3M/mile,
- A 46 kV distribution substation that can support up to 4-6 feeders cost $11M.

We used these values for estimating phased feeder costs, so the longer the feeder, the higher the cost.

One likely phased approach based on the corridors shown in Figure 4 would include two substations. Substation A (SSA) is built at 46 kV to support Feeders A1-A4 at 12kV and serves as the primary input from the HECO grid. Feeder A1 supports the expected new Hunt development and existing FBI building plus other loads along this corridor. Feeders A2-A4 run along the Enterprise Corridor on Enterprise Avenue. Feeder A2 supports the most critical loads of the National Guard, loads for facilities in the downtown area such as the VA, and the existing Airport loads. Feeder A2 could utilize the partially built Enterprise Corridor.

Feeder A3 running along the same corridor would support the remaining less critical National Guard loads, and Airport and Downtown expansion. Feeder A4 also running along the same corridor would support further expansion, but is primarily to pick up Department of Hawaii Homelands, and to provide primary power to the Coast Guard, as well as other new and existing loads in the southwest portion of Kalaeloa.

Substation B (SSB) would be built later at 46 kV to support Feeders B1-B2 at 12kV and serves as the primary input from the HECO grid for the east and northeast part of Kalaeloa. Feeder B1 supports later expected Hunt development on the east side, the city part and other loads along the northeast portion of Kalaeloa. Feeder B2 running along the eastern edge of the Kalaeloa, supports all the new and existing loads for the eastern side of Kalaeloa. This would reserve two additional feeders to be utilized in the future to support either renewable energy development or even the Downtown area.

The phased approach is to build out SSA and Feeders A1 –A4, followed by SSB and Feeders B1-B2, is only one example approach that could be considered. A more detailed final analysis should include a more complete understanding of expected new loads so that feeders are sized with adequate capacity, and routed to make the most efficient use of resources. The phased approach shown is based on expected initial concentrated load growth and locations in Kalaeloa for where power reliability most needed. This approach allows for sequential implementation of newer and more reliable feeders where needed first, while the existing system remains running to support tenants during a multi-year upgrade and construction plan.

Table 2 provides an estimate of base infrastructure costs for the substation and feeder trunks to these areas. Costs include feeder taps as well as step-down transformers, metering, and the design, construction, and engineering oversight. These additional costs are commonly about twice the capital equipment costs. So SSA and feeders and equipment, along with SSB and feeders and equipment will probably cost close to $150M for the system over a 5-7 year period.

Table 2. Base Infrastructure Costs for Phased Feeders

Equipment	Infrastructure Cost ($M)	Service
SSA	11	46 kV Distribution Substation for Feeders A1-A4
Feeder A1	5	Hunt new development, FBI
Feeder A2	5	ARNG (part), Airport (Existing), Downtown
Feeder A3	8	ARNG (remaining), Airport (Expansion), Downtown (expansion)
Feeder A4	19	Airport (Expansion), DHHL, Coast Guard
Feeder A5+		Additional feeders to support further expansion
Total Equipment plus Connections	**$48x2 = $96**	**Substation A plus 4 – 10MW, 12 kV Feeders (Construction years 1-3)**
SSB	11	46 kV Distribution Substation for Feeders B1-B2
Feeder B1	7	Hunt later development, City Park, WWII Park
Feeder B2	11	East portion of Kalaeloa District – golf course, new development
Feeder B3+		Additional feeders to support further expansion
Total Equipment plus Connections	**$29 x2 = $58**	**Substation B plus 2 – 10 MW, 12 kV Feeders (Construction years 3-7)**

Further reliability enhancements such as looped feeders, where one feeder can back feed and support another, as well as advanced metering of feeders and end use in buildings would add some additional costs. Not identified are existing and new large PV developments at Kalaeloa that could be integrated with the new feeders to help support renewable energy development and help meet renewable portfolio standards. This might help reduce overall costs through various renewable incentives, power incentives, and renewable energy siting cost recovery financial structures.

HECO has estimated power system upgrades at Kalaeloa to be between $300-400 M. Part of the difference in our evaluation is that in our approach the substations are on the perimeter of

Kalaeloa, reducing the underground utility costs of 46 kV feeders to the substations. We have also eliminated a transmission substation. We have chosen to use a larger number of smaller feeders to address loads and to be more compatible with the options for generally 5 MW solar PV installations.

This proposed approach does not do anything immediately to reduce current power reliability issues. But as the upgrades take place, the tenants will be connected to a newer and smarter electric system over a 3-7 year time frame, which will inherently improve power reliability over time.

Assuming an operations and maintenance contract for the district to meet the Navy's current approach in transferring the entire system at one time to an operating entity, the electric system upgrade cost that would have to be paid by the tenants would include:

- Annual operational and maintenance costs,
- Financing costs for energy upgrade funding, and
- Bulk energy costs from purchases from HECO or onsite renewable PPAs
    - assuming little initial renewable energy PPA's for on-site solar power,
    - increasing to 30% on-site renewable penetration with a 25% capacity factor by the end of the 7th year.
- Power demands of 20MW for years 1-3, 30 MW for years 4-7, 40 MW from year 7 to 15, and 60 MW for years 15 to 40.

The different costs we estimated included:

- Financing – 3% interest for 35 years
- HECO bulk energy costs of $0.21/kWh, renewable PPA at $0.21/kWh
- O&M costs – 15-20% of bulk power costs

Based on the estimated costs and the build out for the approach identified in Table 2, we identified that over the 3 to 15 year time frame, the delivered energy costs at Kalaeloa would range from an initial cost of approximately $0.34/kWh, to $0.32 by year 7, and $0.29/kWh by year 15.

3.2 Advanced Microgrid Approaches for Kalaeloa

Since it would take time to fully implement and phase in a set of new energy corridors to provide more reliable power to Kalaeloa, other options were considered. Development of advanced microgrids to serve particular landowners with more reliable power than the current Navy system is one option. Advanced microgrids enable utilization of existing backup generation and new distributed or renewable generation to allow these resources to function as a networked system. This approach can more efficiently and cost effectively provide higher reliability power since the distributed generation is grid-tied rather than building-tied, enabling better use and management of generation resources to optimize operations and provide redundant power options in case of the failure of a single distributed generation resource. If a generator for example was not to operate, other generators could pick up the load. If the generators are only building tied, the load could not be picked up by other generators if they are only building tied and not networked.

Sandia has developed many advanced microgrid designs at over 30 sites and communities. The use of advanced microgrid systems have several benefits to energy assurance as well as better supporting distributed and renewable energy use, including:

- Improved energy assurance for critical mission needs,
- Enhanced energy resiliency for extended power outages,
- Improves the utilization of distributed and renewables generation during power outages,
- Can help reduce congestion of transmission and sub-transmission grids, and
- Reduces the capital costs of emergency generation systems.

There are several different microgrid design approaches, each having their own pros and cons that are summarized below.

3.2.1 Grid-tied and Islanded Operations

In this case, the microgrid is developed on the distribution system, making modifications predominately to the distribution system. All local distributed generation resources - renewables, energy storage, diesel or natural gas gen-sets, etc. - are tied to the local distribution system and the local distribution system is tied to the sub-transmission system through a point of common coupling (PCC). Therefore, as shown in Figure 4, you have flexibility in the size of the microgrid, being able to create one that is a partial feeder, full feeder, or even a full substation microgrid, depending on individual site needs.

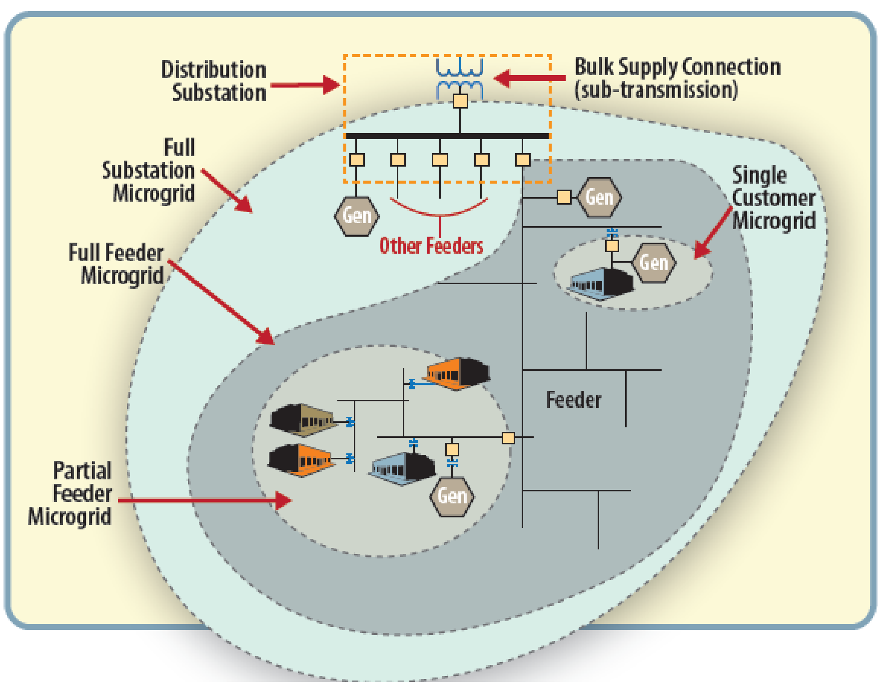

Figure 4. Advanced Microgrid Approaches

Microgrids have been considered before at Kalaeloa, HECO has even developed a conceptual microgrid approach for Kalaeloa. Their conceptual design considered a two full substation microgrid with two looped segments on the east and west side of Kalaeloa connected to a transmission substation in the center of Kalaeloa. At large sites like Kalaeloa, it is not uncommon to develop many small microgrids at military sites or for a community, each being a different size depending on the size of the critical loads and services that require high reliability and the local distribution infrastructure topology.

The major operational benefit of the microgrid approach is that the distributed generation on the microgrid is used primarily to support the microgrid loads if the grid goes down. In this way the general energy costs are minimized by using often lower utility cost power most of the time, but using the integrated renewable and distributed generation resources when appropriate – power outages, peak shaving of power demand to lower costs, and better use of renewables when the power goes down, for example. This is often the lowest cost, highest reliability approach and allows a reasonable level (20-40%) of renewable energy penetration without expensive electrical energy storage.

There is minimal operations and maintenance often needed for the microgrid since is uses the common distribution system infrastructure which is supported by the utility provider. It also often has the most flexibility in managing load and generation resources together as situations vary, and is often used to improve local energy assurance and resiliency during both short and extended power outages, enhances the ability to use renewables during power outages, enables load shedding for the utility when grid-tied by running the distributed generation, and can provides ancillary services for congested transmission feeders by operating their distributed generation as needed. These types of microgrid systems can be an inexpensive upgrade option, often paying for themselves during a single major power outage because of limiting the economic loses of key critical mission operations, but also providing revenue by providing ancillary services to the local utility as needed.

3.2.2 Islanded Microgrid Systems

In this option, all distributed generation resources, renewables, energy storage, diesel or natural gas gen-sets, etc. are tied to the local distribution system, but is not tied to a sub-transmission system or a grid. Therefore, the system operates as an islanded system, and the microgrid manages all generation and load management. This is a common approach on island communities or for islanded applications, such as college or industrial campuses, where both electric power and heating and cooling loads can be efficiently managed locally.

For other than Combined Cooling Heating and Power (CCHP) systems, this is often a more expensive approach because the use of distributed and renewable generation resources often requires extensive energy storage systems to be able to maintain high quality power without the spinning reserves of a large grid, and maintain high reliability power for an extended power outage. In this approach, all O&M costs are born by the microgrid operator, and the fuel costs can often cause higher energy rates than a normal large utility unless the economies of combined heat and power are integrated within the islanded microgrid system.

If an all-renewable islanded microgrid is required, then the costs can be even higher. This is because the use of intermittent renewables such as wind and solar have extra generation and extensive energy storage requirements to provide the high reliability and high quality electric power needed. This need is highlighted in Figure 5 for a 2 MW fully solar PV powered microgrid system design that requires significant energy storage and large PV arrays to address the power needs for morning and evening power loads, and loads for a few days without sunshine.

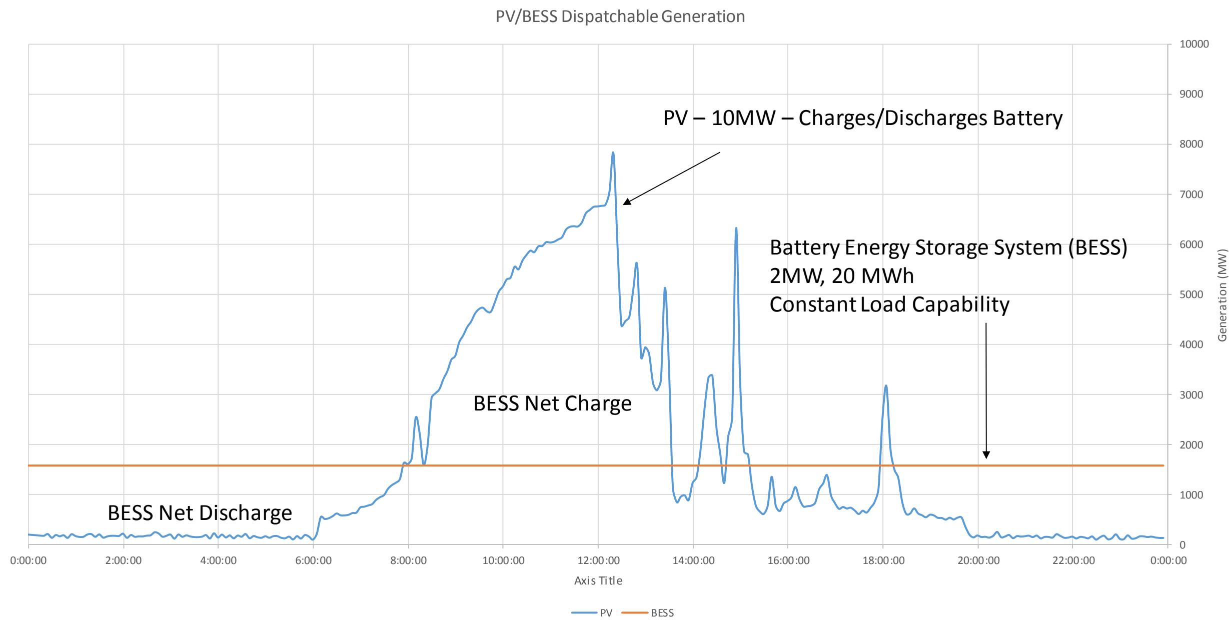

Figure 5. PV/BESS Dispatchable Generation System

If the only source of generation is PV, the capacity of the PV system and Battery Energy Storage System (BESS) would need to consider the possibility of days with low or a lack of solar irradiance. Thus, the total PV output needs to support not only a full 24 hour demand, but also needs a battery that can support the full power demand for a potential one or two day power outage. Essentially, the BESS supplies generation to the system when the PV is unavailable, and is charged with the excess power provided by the PV, when available, so the total system can act as dispatchable generation, similar to a diesel or natural gas generator.

3.3 Islanded Microgrids Conceptual Design

Given the uncertainties of transition of the Navy distribution system, and reconnection with a new provider such as HECO, Sandia has provided an energy system upgrade option utilizing islanded microgrids as a possible mechanism for providing reliable power to Kalaeloa. An alternative approach to installing new feeders and substations is to install advanced microgrids which can be coupled together over time to provide efficient and reliable power through sharing resources – generation and feeder connections. The approach can support connections with PV farms along with a Battery Energy Storage System (BESS) to provide power quality smoothing for renewable resource spikes, for example.

The approach can be summarized by the following:

- Utilize the existing Navy grid to feed current landowners until new phased coupled advanced microgrids are developed, and Navy services are decommissioned,
- Each phased microgrid includes 2MW of new generation, with a 10MW capacity feeder, and supplies prime power to the users within its jurisdiction. Designing with higher feeder capacity allows future growth to occur in each microgrid without need to replace the distribution system,
- Islanded microgrids would be built in phases to meet new demand growth
- Islanded microgrids can be built with new underground infrastructure, or if possible utilize the existing Navy 12kV infrastructure by refurbishing, as possible
- Some islanded microgrids can support combinations of up to 5MW PV and 2MW BESS
- Linking islanded microgrids can create a microgrid network so that generation can be shared so distributed and renewable resources are most efficiently utilized,
- Additionally, the coupled advanced microgrid approach does not prevent connectivity with HECO, any or all of the microgrids could be eventually interconnected with HECO with the proper controls, to provide an additional generation resource, and more resilience to Kalaeloa.

Figure 6, shows a possible framework for coupled islanded microgrid systems. This is one of several possible alternative frameworks where microgrids could be developed and distributed generation would include PV and BESS resources. Alternative layouts and locations are appropriate and can be evaluated in the future to determine the most efficient and economical. In the example configuration shown, the advanced microgrids labeled FA, FB… FH, are developed in phases with distributed generation to support up to 2MW of load and fully cover all the load within its jurisdiction, and as load grows, more generation would be added.

If feeder capacity is exceeded, new parallel feeders can be added to the system. Each advanced microgrid is segregated from others via points of common coupling (PCCs) designated in Figure 6 as reclosers (R). These PCC devices when open separate each microgrid from the rest of the system and pick up the loads within each microgrid. When PCC devices are closed, they connect microgrids with each other, so power can be distributed and shared between microgrids. Each microgrid will contain its internal controls and monitoring, as well as distributed controls between microgrids, so that when microgrids are interacting, all generation resources can be dispatched efficiently across the entire Kalaeloa, and the system as a whole when complete will have multiple redundant paths to obtain power, in case of outages.

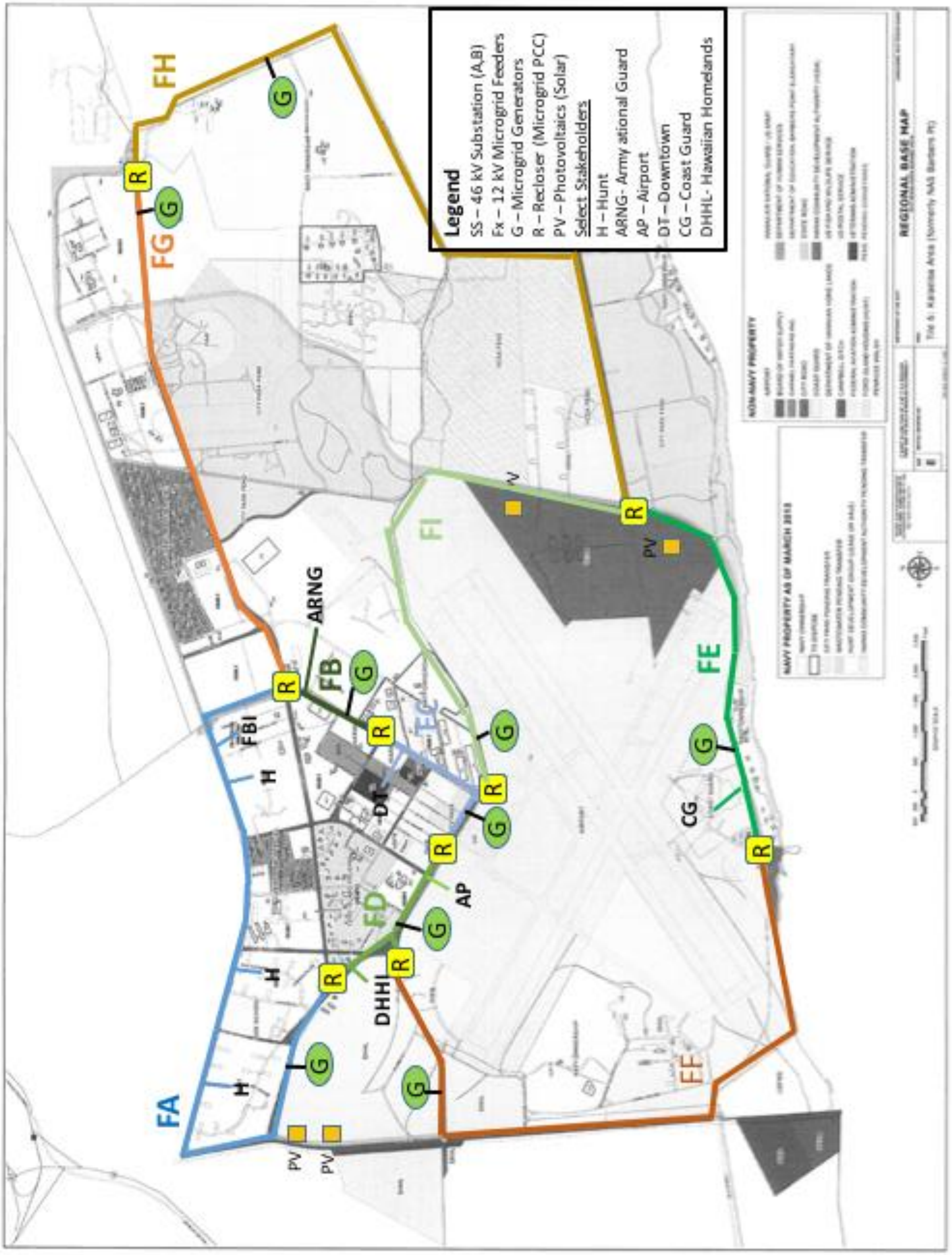

Figure 6. Islanded Networked Microgrid Approach for Kalaeloa

For example, microgrid FB, can obtain power from FA, FG, or FC, so is much more resilient and reliable than it would be if it operated by itself. Because most of the time, except for failures, which would be greatly reduced and restricted through these redundant paths, efficiencies and benefits would be shared by the entire Kalaeloa community. This is why they are termed coupled advanced microgrids.

Another benefit to the networked islanded microgrid approach is that it allows for HECO to feed into the advanced microgrids in the future. Provided proper controls are implemented, power can be purchased from HECO or sold to HECO in an arranged manner to help HECO with ancillary demand support during high demand periods, and reduce costs to Kalaeloa when power can be purchased for less, without loss of reliability.

Figure 6 shows each of the 12kV size advanced microgrids, each initially built with a 2MW generation capacity. Some locations where PV systems have been proposed are shown as well. We evaluate options of supplying each 2MW of distributed generation with diesel generators, PV/BESS, or both as described below. This generation represented by a green circled G in Figure 6, supports each microgrid, but the locations for the generation is not set at the locations shown, they are put there to show generation supporting each microgrid. In this proposal, FA, FB,…FH are built in sequence, or independently to provide power to existing landowners and new load growth, to support landowner loads noted in Table 1.

As each microgrid is completed, and the landowners in the region are now fed by each microgrid, the existing Navy system can be demolished or be replaced. This coupled approach allows each microgrid to be built as needs exist. And the entire extent of each microgrid does not need to be developed entirely. Only when two microgrids connect, will coupled microgrids exist and allow sharing between areas. It is better if these activities are coordinated to occur in sequence, but not strictly necessary. For example, parts of FA, for Hunt, FB for Air National Guard, and FE for the Coast Guard could be constructed with smaller feeder lengths than shown in Figure 6, and then expanded later when growth occurs, to connect the systems together as needed.

3.3.1 Islanded Networked Microgrid Base Infrastructure Cost Estimates

Two sets of cost estimates were made for the islanded microgrids – one for the base infrastructure costs and one for the generation/fuel costs. The base infrastructure cost represents the capital costs for feeders, switchgear, controls, etc., necessary to support the islanded microgrids. These costs are decoupled to compare both the costs of underground versus overhead base infrastructure, and to compare cost for different suites of generation – diesel generators, diesel and PV/BESS and PV/BESS only. For initial cost estimates, some basic cost assumptions outlined below are used.
For reclosers with controls we relied upon estimates of recent costs for these kinds of equipment. We utilized HECO provided costs for overhead and underground 12kV feeders. We made assumptions for refurbished overhead conductors, versus new conductors, that it would cost ~1/3 less per mile to refurbish existing lines than rebuild new ones. Another major assumption is that

the total cost is 2X the equipment costs, to account for all of the other costs for the base infrastructure for the microgrids – other equipment, A/E, construction, engineering, etc. The actual costs may be higher or lower depending on the nature of these costs. These base infrastructure costs were evaluated the same way as for the phased feeder approach in Table 2.

Cost Assumptions for the infrastructure upgrades include:

- Underground Microgrid Conductors – 12 kV, 10 MW capacity, \$4.5M/mile (includes \$4.3M/mile for conductor and \$0.2M/mile for communication and controls)
- Refurbished Overhead Conductors – 12 kV, 10 MW capacity, \$0.8M/mile (includes \$0.7M/mile average for refurbished lines (new overhead lines are \$1.1 M/mile) and \$0.1 M/mile for communications and controls)
- Non-Refurbished Overhead Conductors – 12 kV, 10 MW capacity, \$1.2M/mile (includes new overhead lines at \$1.1M/mile and \$0.1M/mile for communications and controls)
- Reclosers – 12 kV, 10 MW interrupt capability, \$0.2M/each including communications and controls
- Total Costs –2X total equipment costs – includes additional infrastructure, A/E, engineering contractor, construction contractor, taxes, etc. (sum of infrastructure costs)

We did two sets of calculations for the base infrastructure, costs of islanded microgrids built for the infrastructure with entirely new underground feeder infrastructure in Table 3. We also show the costs (in parenthesis) of 5MW PV/ 2MW BESS additions to these microgrids to show the impact of these costs.

Table 3 shows the cost of using completely underground feeders for Kalaeloa District for an estimate for the base infrastructure is \$128M. With new overhead feeders the ROM for base infrastructure is \$37M and with refurbished overhead feeders it reduces to \$27M. Not all areas have corridors which can be utilized and refurbished in a microgrid, so they might not be available to be done in this manner.

This means, assuming that a 2X cost factor for total costs is reasonable, that costs for each advanced microgrid will likely range between values shown in Table 3 if part of the advanced microgrids can be refurbished and the rest must be installed underground. As stated, each microgrid can be initially built to cover a smaller footprint, for example if the FA feeder is much more restricted initially, its feeder costs, and overall costs will reduce accordingly. This provides up to 90MW capacity for Kalaeloa, but with networking and sharing, the load capacity would be reduced. Overall though the islanded microgrid load capacity is similar to the phased feeder approach discussed previously.

Table 3. Islanded Microgrids Infrastructure Costs - Underground versus Overhead

12 kV Microgrid	Underground Cost ($M)	Overhead Cost ($M)	Overhead Refurbished Cost ($M)	Service
FA	23	7	5	Hunt new development, FBI, DHHL
FB	3	1	1	ARNG
FC	5	2	1	Downtown
FD	5	1.5	1	Airport, Hunt
FE	12	4	3	Coast Guard, HCDA
FF	22	6.5	5	DHHL, Southwest Kalaeloa District
FG	16	4	3	Hunt later development, City Park
FH	26	7	5	East portion of Kalaeloa District
FI	16	4	3	Mid – East portion of Kalaeloa District
Total	**128**	**37**	**27**	**9 – 10 MW Max Capacity Advanced Microgrids**

3.3.2 Islanded Microgrid Generation Cost Estimates

Next we evaluated the generation costs for each of the advanced coupled microgrid using either diesel generation, PV/BESS systems or a hybrid approach using both. We assume each coupled microgrid starts with 2MW of capacity. HCDA requested an evaluation of the costs for each of these options, using only standard baseload distributed generation, PV/BESS or both.
2MW Capacity Generators evaluated for each coupled microgrid:

- Diesel Generator s Only - 2MW of diesel generation
- PV/BESS Only – 10MW PV, 2MW/20MWh BESS to make dispatchable (see Figure 5 example)
- Hybrid – 1MW diesel generation/ 5MW PV,1MW/10MWh BESS – half of each used; 50% PV penetration

Below are cost assumptions made for generator options, based on recent cost data for typical installed costs for each of these generation resources. To compare costs equally, we include diesel generator fuel costs for 35 years at $4/gal running at 2MW capacity, to PV/BESS systems which don't include fuel costs.

- PV - $2.3/W
- BESS (Battery Energy Storage System) - $2/Wh
- Diesel Generation - $0.7/W
- Diesel Fuel Costs - $2.5/W ($4/gal diesel fuel)
- Switchgear/Controls - $0.3/W – for either diesel, PV/BESS or both
- Construction/Overhead 1.2X total costs (sum of generation costs including fuel if required)

Per 2 MW generation units, over 35 years diesel generators cost \$107M (\$105M fuel costs for 35 years, \$2.4M generator installed cost), PV/BESS systems cost \$83M/year and hybrid systems, using both cost \$95M/year installed using these assumptions. Hybrid costs are higher, because of diesel fuel costs. When fuel costs are included, PV/BESS costs are still more expensive than conventional diesel generators, but are closer.

Table 4. Islanded Microgrids Generation Costs

12 kV Microgrid	Diesel Generators Only (\$M)	Hybrid (\$M)	PV/BESS Only (\$M)	Service
FA	107	95	83	Hunt new development, FBI, DHHL
FB	107	95	83	ARNG
FC	107	95	83	Downtown
FD	107	95	83	Airport, Hunt
FE	107	95	83	Coast Guard, HCDA
FF	107	95	83	DHHL, Southwest Kalaeloa District
FG	107	95	83	Hunt later development, City Park
FH	107	95	83	East portion of Kalaeloa District
FI	107	95	83	Mid – East Portion of Kalaeloa District
Total	**963**	**855**	**747**	**9 – 2MW Advanced Microgrids**

Each advanced microgrid allows connectivity with existing backup generation with some modifications to the generators as well as switching devices to provide enhanced generation above and beyond the 2 MW new generation provided by each microgrid. We do not take into account costs associated with using existing generators and other infrastructure in making these initial estimates. We discuss some of these potential considerations in Section 3.4 on the hybrid microgrid options.

3.3 Summary of Feeder and Islanded Microgrid Upgrade Costs

We have outlined both a phased feeder approach and a phased advanced microgrid approach for Kalaeloa District. The preliminary cost for the base infrastructure for the phased feeder approach is \$153M, and Tables 3 and 4 outline base infrastructure and generation costs for the coupled phased advanced microgrid approach. Next we want to translate these installed costs in to equivalent costs in terms of \$/kWh to make further comparisons. Any project will require funding allocated in order to pay back loans or PPA agreements for contractors who construct facilities for the phased feeder approach or coupled microgrid approach. So in order to assist making these evaluations, we make a few assumptions in order to calculate these costs such as:

- Pay period: 35 years
- Interest Rate 3%
- O&M and Profit Costs 11% per year

Table 5 below summarizes the installed costs for the various options, translated into an equivalent cost in terms of \$/kWh. The 35 year finance costs per year are the calculated yearly costs to finance the construction, O&M and profit costs, for a 35 year loan at 3% interest rate.

Table 5. Cost Comparison of Phased Feeder and Islanded Microgrids

Approach	Total Installed Cost ($M)	35 year Finance Cost per year ($M)	Average Load (MW)	Equivalent Cost ($/kWh)	Description
Phased Feeder Base Infrastructure	153	24	20	0.14	Cost of phased feeder base infrastructure to support 20MW of load (generation supplied by HECO)
Islanded Microgrid Base Infrastructure - Underground	128	20	20	0.11	Cost of islanded microgrid base infrastructure with underground distribution to support 20MW of load excluding generation costs
Islanded Microgrid Base Infrastructure - Overhead	37	6	20	0.03	Cost of islanded microgrid base infrastructure with overhead distribution to support 20MW of load excluding generation costs
Islanded Microgrid Base Infrastructure – Overhead Refurbished	27	4	20	0.02	Cost of islanded microgrid base infrastructure with refurbished overhead distribution to support 20MW of load excluding generation costs
Diesel Generation (35 year)	107	3	2	0.17	Per unit costs for 2MW diesel generators in each islanded microgrid
PV/BESS Generation (35 year)	83	13	2	0.74	Per unit costs for 2MW PV/BESS in each islanded microgrid
Hybrid (35 year)	95	8	2	0.46	Per unit costs for 2MW hybrid diesel/PV/BESS in each islanded microgrid

Note that although diesel generation costs are higher than PV/BESS or hybrid costs, the equivalent $/kWh are much lower, because the vast majority of the costs with diesel generators are fuel costs, which are paid yearly, at $4/gallon rather than requiring financing. However, if diesel fuel costs were to increase significantly, then the equivalent costs would increase accordingly. To identify total costs required adding the infrastructure and generation costs together. From Table 5, total cost of the underground feeder, islanded microgrids will vary from $0.28/kWh to as high as $0.85/kWh.

The base infrastructure costs for the phased feeder approach, are greater than those for islanded microgrids, primarily because they include 46KV substations which aren't included with the islanded microgrids, and they are all installed underground. The big issue with the generator approach is environmental permitting issues and local noise issues.

The generation costs for islanded microgrids are those in which each microgrid uses diesel generation, PV/BESS or a combination to supply each microgrid. Overall costs for each of the combination of resources are high, because without being connected to the grid, they must supply power 24/7, as a utility system is designed to do. Diesel generator costs are high, primarily because they are driven primarily by diesel fuel costs. Not shown, gas generator costs are slightly lower, in the $0.15/kWh range as a comparison. PV/BESS costs are high if used as dispatchable generation, because these systems require higher levels of battery storage to supply power 24/7 when PV isn't running, due to PV intermittency.

Costs for approaches using only diesel power, PV/BESS or a hybrid combination will be higher as more feeder capacity is needed, and more generation is required to support increased loads. For example, if upgrades require doubling the base infrastructure capacity, the costs to do this will be approximately a linear function of the increased infrastructure needs and overall costs will double accordingly, but the per unit costs will not increase since it supports a larger capacity load. Similarly, generator costs, per unit do not increase as more generation is required, as more generation is added, because they are distributed across an equivalent load to receive the generation, even if actual costs increase as a function of the amount of new generation installed.

An important takeaway is that it is expensive to run systems fully using diesel generators because of the high costs of diesel fuel, if no backup utility system exists and systems are run as fully islanded grids. Equally, it is expensive to run islanded systems using only PV with BESS, due to the intermittency of PV as well high costs of large batteries. While costs for standard diesel generators, PV, and BESS continue to go down, for the near term future, they remain high when relied upon to cover systems 24/7 independent of a reliable utility.

3.4 Hybrid Feeder/Advanced Microgrids Conceptual Design

We also looked at another option, which is a hybrid system that has the advantages of both approaches, implementing phased feeders with a few strategically placed advanced microgrids, that can utilize PV/BESS systems as well as new and existing diesel generators (or other resources like gas generators), but not 24/7, so the fuel costs, and need for extensive battery storage is greatly reduced, making them more a potentially more cost effective option.

A hybrid phased feeder with select advanced microgrids approach to provide power to Kalaeloa is defined below. This approach still has similarities with other approaches entertained by the HCDA, such as studies associated with adding new energy corridors with or without microgrids proposed by HECO, or studies for development of various energy corridors in various areas of the Kalaeloa District, to meet the needs of particular customers, but combines benefits provided by the phased feeder and islanded microgrid approaches outlined above.

In this case, multiple advanced microgrids are selectively developed on the distribution system using local distributed generation resources - renewables, energy storage, diesel or natural gas gen-sets, etc. - tied to feeders through a point of common coupling (PCC). In this application, the advanced microgrids are used to provide energy to priority community tenants during a power outage, while the existing distribution infrastructure or sub-transmission infrastructure is being improved, modified or displaced by new infrastructure. Using this approach, the microgrid capital improvements, such as controls and distributed and renewable generation resources, are designed to be incorporated into and function with both the microgrid initially, and then with the new upgraded power infrastructure as appropriate.

This enables the modification of the energy infrastructure to be phased while power quality is assured locally in high priority areas using microgrids. We have used this approach at military bases and communities, where the funding for a full improvement is prohibitively expensive and needs to be staged over a 5 or 10-year period. The approach tries to optimize the use of the existing distribution grid were possible to support improved energy assurance as the distribution grid is being improved. Using this approach, the microgrid capital improvements, such as controls and distributed and renewable generation resources, are designed to be incorporated into and function with both the microgrid initially, and then with the new upgraded power infrastructure as appropriate.

The approach can be summarized by the following:

- Utilize the existing Navy grid to feed current landowners until a more reliable energy corridor is developed.
- In parallel, (a) phase in reliable energy corridors, consisting of new 46 kV distribution substations and 12 kV distribution feeders, according to which landowners will need power demand first, and (b) install advanced microgrids to serve critical customers and corridors when power is lost until power is provided with the new energy corridors. The Navy grid can then be abandoned (or parts of it can be connected to the energy corridors if refurbished)
- The advanced microgrids will connect to both the existing Navy system and new energy corridors, be able to operate in both grid tied or islanded mode, and will utilize both conventional diesel/gas generators, and PV/BESS to supply energy. The microgrids will remain fully operational to provide emergency power to the priority system critical loads but controlled to reduce fuel use and maximize the use of renewable energy resources.

Figure 7 illustrates where advanced microgrids would be located to maximize priority energy assurance. Figure 7 maps these corridors and microgrids over a current map of the Kalaeloa area, which shows partitions of current landowners' parcels in the area. Figure 7 illustrates one of several potential variant routes for getting new power into some of the initial high density and developed areas in Kalaeloa following the routes proposed for both the phased feeder and advanced microgrid approaches. It shows where a new 46 kV substations (SSA) as well where coupled advanced microgrids could be routed based on available corridors (following streets, avoiding historical areas, airport, etc., where distribution lines can't be located) along these

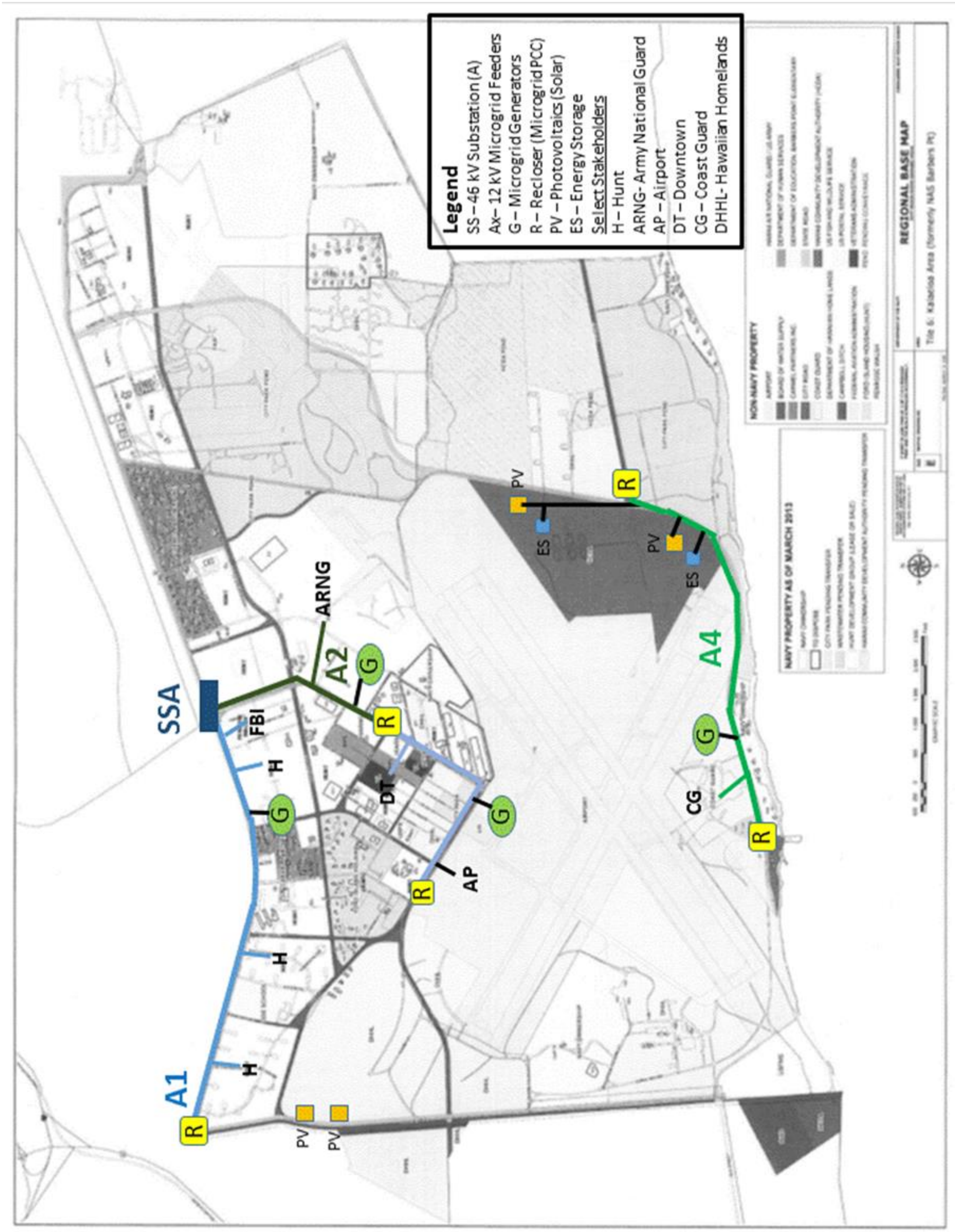

Figure 7. Hybrid Feeder/ Advanced Microgrid Approach for Kalaeloa

areas. As with other options, there are other potential alternate routes and locations for the main 46 kV substation, as well as the feeder routes which won't be evaluated, since the main purpose of this report is to layout one additional option for incorporating high reliable power while the Navy distribution continues to operate and is eventually retired using both new corridors and advanced coupled microgrids.

The approach consists of the following elements:

- SSA – 46 kV Substation
- FA – Feeder/Microgrid for Hunt
- FB – Feeder/Microgrid for ARNG
- FC – Feeder/Microgrid for Downtown/Airport
- FE – Feeder/Microgrid for Coastguard

These initial set of feeders and advanced microgrids show only the initial 5-10 years of a Kalaeloa development to demonstrate how a phased hybrid approach might work.
Each advanced microgrid will be evaluated with 2MW of generation capacity, either with diesel generators, PV/BESS or hybrid combinations of both, as listed below:

- Diesel Generator Only - 2MW of diesel generation (running 1% of time)
- PV/BESS Only – 10MW PV, 2MW/4MWh BESS to make dispatchable (running when available)
- Hybrid – 1MW diesel generation/ 5MW PV,1MW/2MWh BESS – half of each used; 50% PV penetration
- Optimized Hybrid – 1MW diesel generator/2MW PV, 100kW/200kWh BESS – smaller PV units with less costly BESS to provide support

Since diesel generators are still connected to the new phased feeder or existing Navy grid, the generators are only needed for backup power when the grid is out. It is assumed that it will occur a maximum of 1% of the time. Since the PV/BESS system is also connected to the grid, much smaller amounts of BESS are needed to support the BESS (modeled 1/5 the capacity of the previous approach – 4MWh vs 20MWh which would be required to make it dispatchable).
This allows the PV to run whenever available, with smaller BESS to smooth the PV and supply minimal storage as well.

With these assumptions, the base infrastructure costs for the set of feeders shown in Figure 7 are shown below in Table 6. The base infrastructure costs reflect all of the infrastructure costs necessary to supply power to the infrastructures it supplies, but not the generation costs.

Table 6. Hybrid Infrastructure Costs with Underground versus Overhead Feeders

12 kV Microgrid	Underground Cost ($M)	Overhead Cost ($M)	Overhead Refurbished Cost ($M)	Service
SSA	11	11	11	46 kV Substation to support feeder infrastructure
FA	1	3.5	3	Hunt new development, FBI, DHHL
FB	5.5	2	1	ARNG
FC	5.5	2	1	Downtown, Airport, Hunt
FE	14	4	3	Coast Guard, HCDA
Total	**37**	**22.5**	**19**	**4 – 10 MW Max Capacity Advanced Microgrids**

Table 7 shows that significant savings is obtained when diesel generators or PV/BESS systems are sized to run with a connected system, and not required to provide power continuously. Fuel costs of diesel generators are reduced significantly and PV with BESS costs go down since less PV is required if they are not primary power sources, and BESS don't need to be oversized to provide expensive power, but primarily function to smooth PV outputs and as an emergency power source.

Table 7. Hybrid Advanced Microgrids Generation Costs

12 kV Microgrid	Diesel Generators Only ($M)	Hybrid ($M)	Optimized Hybrid ($M)	PV/BESS Only ($M)	Service
FA	3	18	7	39	Hunt new development, FBI, DHHL
FB	3	18	7	39	ARNG
FC	3	18	7	39	Downtown
FE	3	18	7	39	Coast Guard, HCDA
Total	**12**	**72**	**28**	**156**	**4 – 2MW Advanced Microgrids**

Finally, when these costs are converted to equivalent costs in $/kWh with the same pay period and interest rate assumptions, the hybrid base infrastructure costs are reduced and the generation costs are reduced as well, compared to a system with coupled microgrids not connected to HECO or the Navy system, where generation is required to run continuously. These costs are shown in Table 8 below.

Table 8. Cost for Hybrid System including Generation

Approach	Total Installed Cost ($M)	35 year Finance Cost per year ($M)	Average Load (MW)	Equivalent Cost ($/kWh)	Description
Hybrid Base Infrastructure Underground	37	7.5	20	0.03	Cost of hybrid base infrastructure to support 10MW of load (generation supplied by HECO) + generators
Diesel generation only running 1%	3	0.14	2	0.01	Cost of microgrid operation during outages
Hybrid generation	18	3.5	2	0.15	Cost of hybrid microgrid per 2MW of generation
Optimized hybrid generation	7	2	2	0.06	Cost of optimized hybrid microgrid per 2MW of generation

The advantage of this hybrid approach is that funding could be obtained piecemeal for the substation, feeders, and generation in sequence, to meet loads in a way that both supplies reliable generation, PV and energy storage, while Kalaeloa is gradually removed from the Navy grid, and placed on new energy corridors. The advanced microgrids buffer the reliability concerns until an updated Kalaeloa reliable grid is constructed and fully operational.

Additionally the amount of diesel generation required can also be reduced by the use of any existing generation available in each of the microgrids, shown in Table 1 is about 6 MW. There would be costs associated with integrating these generators within each advanced microgrid, but that would offset the costs for more generation. For example, the Coast Guard inventory of backup diesel generators is ~800 kW, distributed across several units. Similarly, the Army National Guard has several MW of backup generation, and several more planned, that could be integrated a microgrid as well to offset the need and cost of additional generators.

If added to the base feeder approach, the costs to those tenants with advanced microgrids would be the overall costs of the small additional microgrid infrastructure and generation which has been evaluated to be slightly less than $0.01/kWh.

4. SUGGESTIONS AND RECOMMENDATIONS

To support Kalaeloa in identifying innovative approaches to move the District forward and accelerate redevelopment, Sandia worked closely with HCDA and the HSEO to;

- assess the current functionality of the energy infrastructure at Kalaeloa,
- evaluate options to use both existing and new distributed and renewable energy generation and storage resources within advanced microgrid frameworks to efficiently and cost effectively accelerate redevelopment of the electric system,
- develop conceptual designs for grid improvements that could enhance overall energy system reliability, and improve critical tenant operational resiliency and performance especially during extended power disruptions, and
- evaluate the cost and performance benefits of the general conceptual designs for the different options considered.

As discussed in this report, Sandia looked at several energy system improvement approaches, all focused on premise that the Navy would only dispose of the Kalaeloa energy system in its entirety, not phased over several years. This limited consideration of some simple phased solutions, and required consideration of more complicated approaches. Therefore, Sandia chose to look at a range of improvement options with variations of each, which included both rather traditional approaches and some innovative approaches such as advanced and networked microgrids. The major options reviewed included 1) a phased feeder approach, 2) an islanded microgrid approach, and 3) a hybrid advanced microgrid/phased feeder approach.

Included in the evaluation was the consideration of both on-site distributed and renewable generation equipment and opportunities that could be utilized to reduce costs and support enhanced energy assurance and energy sustainability for Kalaeloa. A summary of the estimated cost and reliability performance of each option and some variations is presented in Table 9 below. The results are shown in terms of expected energy costs in $/kWh and average power outage durations. The highlights of the summary include:

- While the phased feeder and hybrid feeder/advanced microgrids have similar costs, the hybrid feeder/advanced microgrid option provides higher reliability under nominal power outages. For extended power outages the reliability results are even better.
- The networked microgrids using on-site generation are a little to significantly higher in costs depending on if standard diesel generators or only renewable energy is used. Unfortunately, the total reliance on diesel generators will likely pose significant environmental permitting issues.
- The costs of the system are similar to the current HECO bundled cost of about $0.26 to $0.28kWh. At full build out by years 7-10, which would be about 60 MW of electric power demand, the overall system power costs would approach HECO power costs.
- Overall, the phased feeder/advanced microgrid approach provides the best cost/performance benefits for Kalaeloa.

Table 9. Summary Cost and Performance of Kalaeloa Energy System Upgrade Options

Option	Energy Load	Feeder Upgrade Costs	O&M Costs	Fuel Costs	Purchased Power Costs	Microgrid Costs	Total Costs	Outage Duration (hrs/yr)
Phased Feeder	20 MW	$0.020	$0.11	-	$0.21	-	$0.34	30
	60 MW	$0.020	$0.06	-	$0.21	-	$0.29	2
Islanded Microgrid	Diesel 40 MW	$0.030	$0.08	$0.17	-	$0.11	$0.39	<2
	PV and Battery 40 MW	$0.030	$0.08		-	$0.74	$0.85	<2
	Hybrid PV/Bat/ Diesel 40 MW	$0.030	$0.08	$0.04	-	$0.43	$0.58	<2
Hybrid Phased Feeders/Microgrids	20 MW	$0.020	$0.11	$0.001	$0.21	$0.01	$0.35	<1
	60 MW	$0.020	$0.06	$0.003	$0.21	$0.01	$0.30	<1

4.1. Recommendations

Based on Kalaeloa site information and stakeholder inputs on energy issues, the Sandia developed conceptual design for the hybrid phased feeder/advanced microgrids option provides the best opportunity to improve the energy system performance for the entire Kalaeloa set of tenants quickly at a cost comparable to current utility grid power costs.

To realize the benefits of this approach, the assumptions used in the conceptual design need to be implemented in the following recommended sequence:

1. HCDA should work with USDA/RUS and other entities to establish a cooperative framework to fund and manage the operations and maintenance of the current electric system and implement the upgrades required over the next 10 years.
2. Within the next two years, integrate advanced microgrids and distributed generation resources at four priority Kalaeloa locations – USCG, Downtown and Airport, Hunt, and HARNG to reduce average outage times from 40 hours per year to less than and hour per year, at a cost of approximately $20M. Planned energy improvements by these groups can be leveraged to reduce overall implementation costs.
3. Accelerate the development of up to four 5-MW solar energy projects at Kalaeloa specifically for onsite energy use using Power Purchase Agreements with solar developers. Integrate with the advanced microgrids to support lower upgrade costs and compatibility with future electric feeder load limits. At full electric system build out, Kalaeloa would have about 25-30% renewable penetration.
4. In the next three years, add a new 40-MW, 46-kV substation at the Northwest end of Kalaeloa, with up to six 12-kV underground feeders to support electric upgrades for current and new tenants in western Kalaeloa. Integrate these improvements with the new microgrids to enhance reliability and full-utilization of identified renewables generation.
5. In the next 5-10 years as needed, add a second 40-MW, 46-kV substation at the Northeast end of Kalaeloa with up to six 12-kV underground feeders to support the electric system upgrades needed for both new western and eastern tenants. This will provide a total Kalaeloa energy import capacity of 80-MW, with and 20-MW of on-site renewables.

If the electric feeder, advanced microgrid, and on-site distributed and renewable generation upgrades suggested are implemented, they would significantly improve Kalaeloa energy reliability and resiliency, reducing critical load outages from 40 hours per year to only a few minutes per year. The associated costs for a Kalaeloa operated system would range from $0.35/kWh for years 1-5, $0.33/kWh for years 5-10, and $0.30/kWh for years 10-15 and beyond.

By years 10-15, the system would be fully updated, and could be sold to HECO or another entity, with the sale price used to reimburse the tenants for the infrastructure capitalization, effectively reducing the overall operational costs to the tenants and the district.

5. REFERENCES

1. Belt Collins Hawaii, *Kalaeloa Master Plan*, Hawaiian Community Development Authority, March 1, 2006.

2. Belt Collins Hawaii, *Kalaeloa Master Plan – Infrastructure Master Plan Updates – October 2010 Draft*, Ford Island Ventures, October 2010.

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