UNIVERSITY of HAWAI'I® SYSTEM

David Lassner
President

DEPT. COMM. NO. 141

December 20, 2017

The Honorable Ronald D. Kouchi,
President and Members of the Senate
Twenty-Ninth State Legislature
Honolulu, Hawai'i 96813

The Honorable Scott Saiki, Speaker
and Members of the House of Representatives
Twenty-Ninth State Legislature
Honolulu, Hawai'i 96813

Dear President Kouchi, Speaker Saiki, and Members of the Legislature:

For your information and consideration, the University of Hawai'i is transmitting one copy of the Annual Report from the Hawai'i Natural Energy Institute (Section 304A-1891, Hawai'i Revised Statutes) as requested by the Legislature.

In accordance with Section 93-16, Hawai'i Revised Statutes, this report may be viewed electronically at: http://www.hawaii.edu/offices/government-relations/2018-legislative-reports/.

Should you have any questions about this report, please do not hesitate to contact Stephanie Kim at 956-4250, or via e-mail at scskim@hawaii.edu.

Sincerely,

David Lassner
President

Enclosure

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UNIVERSITY OF HAWAI‘I SYSTEM ANNUAL REPORT

REPORT TO THE 2018 LEGISLATURE

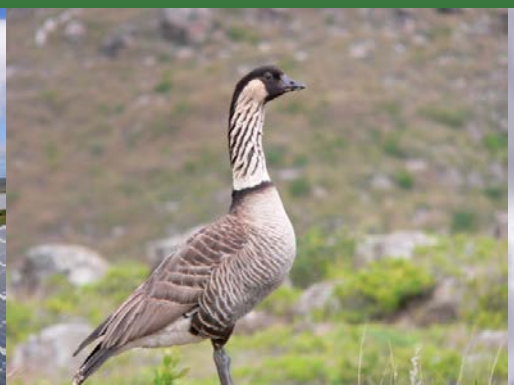
ANNUAL REPORT FROM THE
HAWAI‘I NATURAL ENERGY INSTITUTE

HRS 304A-1891

December 2017

Hawai‘i Natural Energy Institute

School of Ocean and Earth Science and Technology
University of Hawai‘i at Mānoa
Annual Report to the 2017 Legislature
HRS 304A-1891


SUBJECT:

Annual Report on Activities, Expenditures, Contracts Developed, Advances in Technologies, Work in Coordination with State Agencies and Programs, and Recommendations for Proposed Legislation, required in accordance with HRS 304A-1891 (Act 253, SLH 2007).

SUMMARY:

The Hawai‘i Natural Energy Institute (HNEI) conducts essential energy research relevant to Hawai‘i and the world. Research projects focus on identifying technically sound, cost effective solutions and practical strategies that can be implemented to deliver commercially viable renewable energy, improve grid reliability and resilience, and enhance energy efficiency. The ultimate goal is to achieve a stable and cost-effective energy mix for Hawai‘i, while reducing Hawai‘i’s dependence on oil and other fossil fuel resources.

HNEI brings together people from a wide range of disciplines and different types of organizations to tackle the urgent and complex sustainable energy needs of the state and the nation. Analysis, research, engineering, economics, and policy are integrated to develop technology, strategies and policies that will have significant positive impact on the energy mix.

HNEI is committed to supporting the State, Federal agencies and industry in planning and implementing clean energy initiatives. HNEI’s activities can be grouped into five core functions:

- Research & Development
- Technical Validation & Implementation
- Analysis & Modeling
- Education & Training
- State Energy & Policy Support

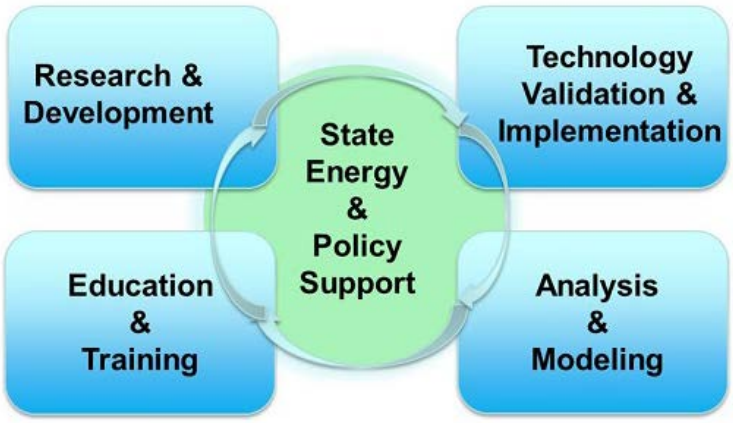


Figure 1. HNEI’s inter-related functions used to maximize collaboration and leverage resources.

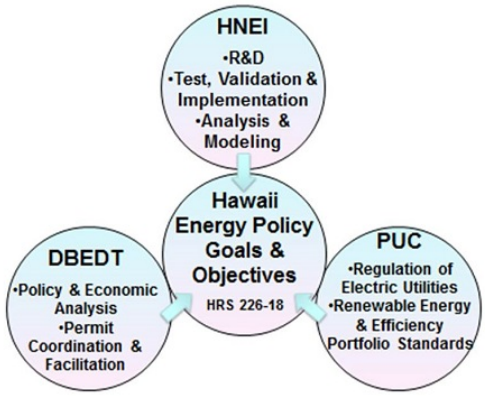
State Energy & Policy Support

HNEI was established in 1974 to coordinate and undertake the development of natural energy sources for Hawai‘i.

In 2007, ACT 253 established HNEI by statute and expanded its mandate to explicitly include coordination with state and federal agencies; and the demonstration and deployment of efficient end use technologies including those that address peak electric demand issues.

Act 253 also established the Energy Systems Development Special Fund (ESDSF) and directed that it be managed by HNEI. Three years later, in 2010, Act 73 authorized 10 cents of the $1.05 tax imposed on each barrel of petroleum product imported into Hawai‘i be deposited into the ESDSF. HNEI, in collaboration with the State Energy Coordinator, develops expenditure plans for the ESDSF to maximize the value of these funds to meet needs and opportunities within the state, and to capitalize on matching funds from federal and private sources.

In executing its mandate, HNEI has assumed an important role within the state to reduce Hawai‘i’s dependence on fossil fuels, serving as the implementing organization for several large, public-private partnerships to develop, deploy and demonstrate renewable energy systems. HNEI continues to forge strong partnerships with industry, state and national organizations creating a thriving synergy that expands resources and accomplishments for all involved. HNEI works closely with federal funding agencies, industry, the State Energy Office, State legislators, Public Utilities Commission and the Congressional delegation, providing stability and enhancing the benefits afforded to residents of Hawai‘i and beyond.



HNEI has become recognized as an independent organization providing trustworthy and practical information to support the safe, reliable, and economically viable development of renewable energy technologies and systems. The foundation of HNEI’s strength lies in its people and partners. The diversity of talents, education, experience, and the entrepreneurial spirit of this team creates flexibility in performing a range of renewable energy development responsibilities. HNEI also serves as a critical bridge between State and Federal initiatives, supporting for example the State’s 100% renewable portfolio standard and clean transportation initiatives. In summary, HNEI’s responsibilities go beyond traditional academic research, playing a significant role in public-private partnerships and supporting analyses for state energy policies.

Research & Development (R&D)

As an Organized Research Unit within the University of Hawai‘i at Mānoa (UH), HNEI has maintained a strong core research effort. HNEI’s faculty and staff are truly multidisciplinary, with a wide diversity of backgrounds. For efforts requiring additional expertise, HNEI also works closely with other units on campus, including the School of Ocean & Earth Science & Technology (SOEST), College of Engineering, College of Tropical Agriculture and Human Resources, and College of Social Sciences. This strategic collaboration allows HNEI to conduct increasingly comprehensive and complex research. With a deliberate focus on remaining flexible to support the dynamic needs of renewable energy development, HNEI’s direction continues to evolve.

Technology Validation & Implementation (TV&I)

HNEI faculty and staff have been successful in transferring patented HNEI technology in a variety of areas to demonstration scale, and even commercial implementation. An important aspect of HNEI's TV&I mission is to transition innovative solutions through the development phases, including "proof of concept", demonstrations, and finally into commercialization and adoption of technologies that can support Hawai‘i's energy goals.

HNEI identifies technologies of interest and then validates and assesses their practicality and applicability for Hawai‘i's infrastructure. These activities are frequently informed by internal analysis and modeling efforts and supported by HNEI R&D activities. HNEI's TV&I projects usually involve industrial partnerships and often include cost share. An example is the ongoing effort to evaluate emerging grid scale and distributed battery energy storage technologies as a solution for transmission and distribution level constraints associated with high penetration of intermittent renewable energy technologies.

Analysis & Modeling

HNEI conducts and supports analyses and modeling to forecast scenarios for Hawai‘i's energy mix. These analyses are critical to identifying optimal and realistic pathways toward meeting Hawai‘i's clean energy goals. Results from these studies are used to inform state policy and help identify innovative demonstration and validation projects in areas such as biofuels, grid integration, and hydrogen.

Education & Training

As a research institute, HNEI does not have its own academic program but has active partnerships throughout the university. Faculty members develop and present courses for academic units in SOEST, the College of Engineering, and the College of Tropical Agriculture and Human Resources. HNEI faculty support and supervise graduate students and post docs across these departments. HNEI also supports the Asia-Pacific Technology and Education Partnership (APTEP), funded by the Office of Navy Research (ONR).

Summary of Activities, 2017

Hawai‘i Natural Energy Institute

School of Ocean and Earth Science and Technology

University of Hawai‘i at Mānoa

Director: Richard E. Rocheleau

Staffing:		
	Permanent Faculty (FTE)	9
	Other permanent staff (APT)	3
	Temporary Faculty	21
	Other temporary staff (APT, RCUH)	15
	Training (a)	16

(a) Includes post-doctoral fellows, graduate and undergraduate students, and visiting scientists.

SUMMARY OF CONTRACTS AND ACTIVITIES:

HNEI is a nationally acknowledged research leader with major activities in areas such as hydrogen and fuel cells, biofuels, ocean resources, and grid integration. While continuing to conduct conventional and applied research, HNEI has, in accordance with HRS 304A-1891, also undertaken a pivotal role within the state including identification, evaluation, and testing of advanced energy technologies and systems aimed at reducing Hawai‘i’s dependence on fossil fuels. HNEI serves as the implementing and/or managing partner for several major public/private partnerships to deploy and demonstrate renewable energy systems to meet Hawai‘i’s energy needs. These efforts support both the goals of the State of Hawai‘i and HNEI’s project partners.

A synopsis of select HNEI activities follows:

HNEI Energy Policy and Innovation

In 2017, HNEI created a priority focus of energy policy and innovation to guide Hawai‘i and the Asia Pacific regional energy transition efforts. The vision for this concentration of focus is through energy policy, innovation, and technology integration, HNEI will contribute to economic growth, energy security and a cleaner environment. This will be accomplished by the strategic integration of analysis, research, engineering, economics, and policy to achieve an optimal energy transformation in Hawai‘i and to support similar efforts throughout the world.

Work Products

HNEI was successful in 2017 in creating analytical work products and strategic alliances towards energy transition efforts. The following analyses and associated issue briefs, reports, presentations, symposia and strategic alliances were intended to help the players in the energy value chain make the most effective and efficient policy, investment and deployment decisions on energy transitions. The audience for HNEI work products is government at all levels, public and private sector developers of energy systems and infrastructure, and the public.

HNEI submitted a paper in the second quarter of 2017 entitled “*Hawaii’s Progress and Lessons Learned in Reaching a 100% Renewable Portfolio Standard*.” The paper was presented at the 30th Annual Western Conference - Advanced Workshop on Regulation and Competition in Network Industries, Center for Research in Regulated Industries in Monterey, California, on June 30, 2017. HNEI was also invited to provide a chapter in a Smart Grid book published by Seoul National University in October of 2017 as an addendum to its 2013 International Conference on Smart Grid: Smart Grid Test Beds. Mark Glick also co-authored with Kotub Uddin and HNEI’s Matthieu Dubarry, “The viability of vehicle-to-grid operations from a battery technology and policy perspective,” to be published by the journal *Energy Policy* in February of 2018. The article provides clarity on how methodologies to manage battery degradation can reliably extend battery life and reviews the associated technology and policy implications of better managing battery use in vehicle and electrical grid applications. Such applications are anticipated as Hawai‘i expands the use of EVs for transportation and grid services in the near future.

HNEI also focused on efforts to attract funding from abroad to conduct energy innovation and grid safety, resiliency and reliability testing, and ultimately renewable energy project development. This is possible because Hawai‘i’s isolated, independent grid systems on each island provide an unparalleled opportunity for domestic and foreign manufacturers to market technologies tested in Hawai‘i, and throughout the

world. HNEI’s 2017 project with Seoul National University (SNU) was one such effort to take advantage of Hawai‘i’s unique test bed status. The HNEI-SNU project is a two-step initiative intended to showcase the most viable integrated microgrid/smart grid and renewable generation technology platform and approach in three test sites in Hawai‘i.

In the first step, the feasibility of specific approaches and platforms at the three sites will be evaluated in terms of providing reliable, resilient and affordable energy self-sufficiency in growth markets applicable to island and remote states in the Asia Pacific region, the Caribbean, and North America. Growth market applications include ship-to-shore power and shore-side operations in government-owned and operated marine center and renewable energy testing laboratory on Hawai‘i’s most populated island (Pier 38, O‘ahu), and microgrid and renewable energy/energy storage system configuration for critical operations within a governmental owned and operated industrial park (NELHA, Hawai‘i) and a hospital (North Hawai‘i Community Hospital).

HNEI’s partners in this effort are SNU’s Electric Power Research Institute (SEPRI). Other participating organizations include the SNU’s Center for Energy & Environmental Law and Policy (CEELP), LG Corporation, and POSCO ENERGY ITC. Primary functions of these participating organizations will be to review economic feasibility of the integrated microgrid and generation options at the energy grid sites, and offer recommended packaged energy systems to be built, reviewed and tested during the second step of the project at one or more of the three sites. The second step of the project would occur in 2018-2019 and consist of the build-out and evaluation of the preferred commercial approaches and platforms recommended in the first step.

Topics of the evaluation in the first step will include:

- Potential for reduced electricity costs
- Life expectancy and degradation of energy storage systems (ESS)
- Power control quality
- Optimal mix of distributed energy resources and ESS
- Reliability of electricity service to critical loads
- Impacts of various microgrid controllers
- Potential for achieving net zero energy and a free carbon environment.

Asia Pacific Regional Energy System Assessment:

HNEI was recently awarded $13 million from the Office of Naval Research for the Asia Pacific Regional Energy System Assessment (APRESA). The objective of this five-year award is to develop comprehensive energy system assessments that include strategy, policy, technology options, and implementation plans for energy

system transitions in select locations throughout the Asia Pacific region, based on the specific requirements or needs of the targeted jurisdictions and strategic alliances. The program aligns with and supports Navy and Department of Defense strategic energy plans as well as the State of Hawai'i's RPS goals. As with Hawai'i, renewable energy has grown steadily in the Asia-Pacific region as the energy mix is diversified from imported fossil fuels. The approach of APRESA is to develop partnerships with national, regional or local jurisdictions, and private and public stakeholders (including universities and other research organizations) in the regions of interest. Selected technologies may be initially tested and validated in Hawai'i before deploying them to lesser developed or remote locations in the Asia Pacific region. These technological developments or processes may potentially include elements across the spectrum of energy technologies ranging from production to end use (e.g., fuel cells; batteries; harvesting and conversion of wind, solar, biomass, or ocean resources; power grid load management; lighting standards; energy resilience support functions; fuel performance; and fueling).

Asia-Pacific Research Initiative for Sustainable Energy Systems*:* The APRISES initiative, funded by the Office of Naval Research (ONR), includes programs across a broad range of technologies, including electrochemical power systems (fuel cell and battery), seabed methane hydrates, technology for use of biofuels and hydrogen, ocean energy technologies (wave and Ocean Thermal Energy Conversion (OTEC), building efficiency, and grid integration In 2016 HNEI was **awarded an additional $8.7 million to continue these activities** with increasing emphasis on testing and evaluation of renewable generation and power system controls for smart and micro-gird applications. This program has provided substantial support for various smart and microgrid research activities with ongoing efforts on Moloka'i, Coconut Island, and various projects on Maui.

GridSTART***:*** Building on its systems analysis experience and growing technical expertise in the area, HNEI established its Grid Systems Technologies Advanced Research Team (Grid***START***) to develop, test and evaluate advanced grid architectures, enabling policies, and new technologies and methods for effective integration of renewable energy resources and power system optimization. Grid***START*** serves to integrate HNEI efforts across all its technology areas and has developed strong partnerships with state, federal, and international agencies, organizations and businesses, especially in the Asia-Pacific region. Its funding sources include the Office of Naval Research, NavFAC (via the Applied Research

Laboratory at the University of Hawai‘i – ARL-UH), USDOE, Hitachi, and the State of Hawai‘i. The following five sections briefly describe a few of the projects Grid***START*** is managing and/or supporting.

- ***Hawai‘i Naval Base Grid Modernization:*** In September, 2014, the Office of Naval Research, through **a $2.5 million task order via ARL-UH**, funded HNEI to develop a power grid modernization strategy and action plan to meet the future needs of the Navy in Hawai‘i, with a special focus on the reliability and power quality demands of electrical service to the shipyard. As part of this task, a renewable energy integration action sub-plan will be developed to help the Navy meet its renewable energy goals in a manner that maintains electrical service reliability and stability, ensuring continuity of mission critical activities. This work is expected to be completed in December of 2018.

- ***Guam Naval Base***: **A 2016 task order for $182,000 via ARL-UH** funded HNEI to provide analyses and engineering support to NavFAC Marianas for a system renewable integration and interconnection study being conducted in collaboration with the Guam Power Authority. This work will also take into consideration the impacts of the proposed development of several very large scale new solar PV projects on Guam.

- ***Smart PV Inverter Project:*** In a project that closely supported the Maui Smart Grid efforts, an HNEI-led team led this USDOE Sunshine Program to develop and demonstrate new “smart grid-enabled” PV inverters. This project, announced in September 2011, was intended to facilitate higher penetrations of solar PV systems by demonstrating technology to mitigate circuit level issues resulting from variability of PV systems. HNEI used $400,000 from the Energy Systems Development Special Fund to meet a critical funding shortfall and to insure efforts to secure the federal funding. Original project partners include Fronius, which supplied the advanced PV inverters, Silver Spring Networks for advanced metering infrastructure; and Maui Electric Company and Hawaiian Electric Company as host sites.

  Under the USDOE funding the HNEI team completed development of the technology and purchased hardware for deployment and testing. The recently completed testing of this hardware on the Maui grid was

supported by the Office of Naval Research. A paper describing the testing and results will be available in early 2018.

Smart Grid Inverters for High Penetration PV
$ 400,000 ESDSF
$ 3,108,600 US Dept of Energy
$ 3,130,800 Industry Cost Share

- ***Grid-Scale Battery Energy Storage System (BESS) Projects:*** Projects on Moloka‘i and at the Campbell Industrial Park (CIP) generating station on O‘ahu have joined the Hawi project on the Big Island in demonstrating and testing the capabilities of battery systems to provide services to the grid.

  The 1MW Hawi BESS has been operating since 2013 to help regulate the energy output fluctuations of the Hawi wind farm and to regulate frequency on the Big Island electric grid.

  On Moloka‘i a 2MW BESS has been installed to help stabilize the grid which has a high proportion of PV generation. Innovative changes to control strategies are expected to enable this system to provide fast response operating reserves for disturbance management. The system is currently being tested for this purpose, and may also be used for frequency regulation, power smoothing and peak shifting services.

  The 1MW CIP BESS completed installation in September 2016, and is the first utility-scale system on O‘ahu. It will provide power smoothing, voltage support, and frequency regulation for an industrial circuit with a high penetration of PV.

  These HNEI-BESS projects are allowing the testing of control algorithms and providing a wealth of data to determine the systems’ safety, operating characteristics, and effectiveness in helping to integrate more renewable energy onto Hawai‘i’s island grids, while maintaining reliable service.

- ***Micro-grid Projects:*** HNEI’s GridSTART team is participating in a microgrid project on Coconut Island in Kāne‘ohe Bay to demonstrate and test innovative technologies for the reliable operation of grids including operation of critical loads in isolation from the larger electric system.

Coconut Island, a UH owned island facility with a marine research laboratory will be used as a demonstration site for a high efficiency DC microgrid including the demonstration of innovative controls for critical loads with a need for high energy reliability. The facility has a large amount of rooftop PV. The persistent coastal wind and highly corrosive environment are typical of conditions in many island nations, and will provide an ideal test site for the testing of advanced clean energy technologies and integrated control strategies.

Hawai'i Hydrogen Program:

Since 2003, HNEI has conducted work to develop and deploy hydrogen infrastructure at multiple sites on O'ahu and Hawai'i Island in support of both DOD and civilian transportation projects. These efforts, have been supported from a variety of sources including USDOE, ONR, USAF (via HCATT), and the state of Hawai'i (via the Hydrogen Capital Investment fund and barrel tax).

Hydrogen Energy Systems for Grid Services: Fuel Cell Electric Bus
Hydrogen Energy Systems for Grid Services: Hydrogen Transport Trailers
$ 1,105,000 ESDSF
$ 4,480,000 ONR
$ 1,996,000 US DOE
$ 1,000,000 Federal Transit Authority
$ 2,500,000 SOH H2 Capital Investment Fund

Dollars shown represent total investment in Big Island hydrogen production and refueling infrastructure and vehicles. Project outcomes include central H2 production/grid services facility at NELHA, satellite refueling infrastructure at HAVO, 3 advanced transport trailers, 3 FC-battery hybrid shuttle buses

Specific activities are summarized below.

Hydrogen Energy System as a Grid Management Tool: This joint USDOE-DOD-HNEI project is intended to test the dynamic operation of an electrolyzer to evaluate its potential to provide frequency control in support of additional renewable generation, while also providing fuel for two transportation demonstration projects. The system was delivered to the NELHA facility in Kona in November 2016 and will be installed and commissioned when site improvements have been completed. It is expected to be fully operational by May 2018.

Figure 4: Sitework underway at NELHA December 2017

County of Hawai‘i Fuel Cell Electric Bus and Hydrogen Transport Trailer:

HNEI assisted with the purchase of one (1) hydrogen fuel cell electric bus that is being converted by US Hybrid. The bus has been completed and will be shipped to Hawai‘i when the hydrogen fueling infrastructure has been installed and commissioned at NELHA in early 2018. The bus will be operated by the County of Hawai‘i Hele-on bus system and will be used to demonstrate hydrogen technologies to the public in Kailua-Kona. The bus leverages technology developed by HCATT. HNEI has also purchased three hydrogen transport trailers to support multiple fueling sites from the NELHA hydrogen production site. Current plans are to support refueling at Hawai‘i Volcanoes National Park and NELHA.

Figure 5: County of Hawai‘i Fuel Cell Bus and Hydrogen Transport Trailer

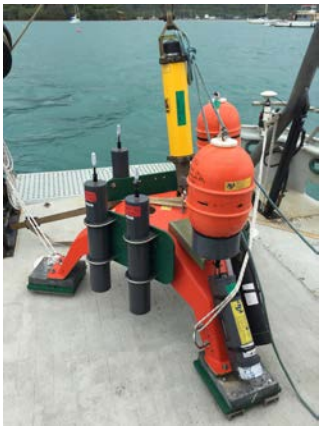
Marine Corps Base Hawai‘i (MCBH) Hydrogen Fueling Station at Kāne‘ohe Bay:

HNEI developed a rapid fill hydrogen fueling stations for MCBH in support of five General Motors (GM) Equinox Fuel Cell Electric Vehicles (FCEVs) leased by ONR. The station successfully completed over 400 fueling operations between November 2014 and August 2015 when GM recalled the vehicles back to CA. Efforts are underway to acquire or lease Toyota Mirai fuel cell electric vehicles to be supplied by Servco however procurement of the Mirai has been delayed due to delays in the Servco Toyota dealership building its own hydrogen fueling station (a Toyota corporate requirement). HNEI is also seeking other options for the MCBH hydrogen station including deploying it to a new location.

Hawai‘i National Marine Renewable Energy Center (HINMREC): In 2009, USDOE executed a five-year agreement with UH - HNEI to establish HINMREC to facilitate the development and implementation of commercial wave energy converter (WEC) systems, and to advance Ocean Thermal Energy Conversion (OTEC) technology. The HINMREC coordinates engineering and science efforts to address industry needs and leverage U.S. Department of Defense (DOD) interest in Hawai‘i energy projects. The USDOE awarded multiple year funding (2008-2015) to HINMREC of approximately $8 million.

This USDOE funding and an additional $12.8 million contributed by the Naval Facilities Engineering Command (NAVFAC) in 2014 and 2016, through the University of Hawai‘i’s Applied Research Laboratory, is being used to support testing activities at the United States’ first grid-connected wave energy test site (WETS) at Marine Corps Base Hawai‘i. The fully permitted site has three grid tied berths at different depths. Northwest Energy Innovations deployed its Azura in June of 2015 for one-year at-sea testing. A second WEC device, the Fred Olsen “Lifesaver,” was deployed in March 2016 by Sound and Sea Technology also for one year at-sea testing.

Figure 6: Azura and Lifesaver wave energy converters deployed off of Marine Corps Base Hawai‘i.



HNEI is working with NAVFAC and USDOE to support 1) independent WEC device performance analysis; 2) environmental impact monitoring including measurements and analyses of device acoustic signature, device and cabling electromagnetic fields (EMF) and changes in device/mooring-induced sediment transport, seawater chemistry, and ecological environment; and 3) marine services support for the vendors which also serves to document system maintenance and reliability.

Figure 7: Acoustic device deployed at wave energy test site.

Support to U. S. Navy Wave Energy Test Site (including USDOE Marine Test Center)

$ 500,000 ESDSF
$ 7,999 900 US Department of Energy
$ 775,000 Office of Naval Research
$ 12,750,000 US Navy to UH-HNEI

ESDSF investment was critical to meet required cost share from USDOE. Navy investment resulted in part as result of the USDOE effort. Navy investment shown does not include additional NavFAC investment in infrastructure at MCBH)

Solar Initiatives: HNEI is continuing work with USDOE and ONR to conduct high-fidelity resource forecasting and testing of emerging solar technologies, with the objective to understand the performance of PV in differing environments. Multiple test sites are operational, and additional test sites are being developed.

Fuel Cell and Battery Testing: HNEI researchers conduct testing and modeling to develop advanced battery system diagnostic and prognostic technology to further understanding of the performance of advanced fuel cells and batteries for use in electric vehicles and renewable energy storage applications. Funding sources include the US Department of Energy EERE Office and the Office of Naval Research. HNEI has recently initiated a major effort to conduct testing to better predict the lifetime of grid-scale battery energy storage technologies.

Ceiling Fan Selection and Controls Study: In a collaboration with contractor MKThink and UH affiliated Environmental Research and Design Laboratory, HNEI is conducting a detailed assessment of state-of-the-art ceiling fan technologies, evaluate design and performance, and provide a design, selection and application guidelines to be used by state agencies, including Department of Education, in selecting ceiling fans to maximize comfort in non-conditioned spaces.

Desiccant Dehumidification pilot: In 2016, HNEI prepared a report investigating the potential for the integration of desiccant dehumidification into mechanical cooling systems to reduce energy consumption.

In the 2017 phase 2 of this project HNEI has been working with vendors to design a system using available components. HNEI completed a detailed design for a scalable pilot demonstration project selecting the most appropriate of desiccant technologies.

Crissy Field Phase 2 Small Scale Wind Turbine Testing: Between 2010 and 2015, HNEI supported the implementation and monitoring of (5) 1 kW vertical axis wind turbines installed at Crissy Field in San Francisco. In 2016, HNEI funded a second phase with the replacement of previous turbines with four new turbines including new work to evaluate the impact of urban wind conditions (environment-induced turbulence) relative to idealized (laminar) wind conditions under which turbines are tested and rated. Construction of the project was completed in June 2017, with performance monitoring ongoing.

Net Zero Buildings: Since 2010 HNEI has built five net zero test platforms for evaluation of advanced building technology. The final two, commissioned in September 2016 on the University of Hawai‘i at Mānoa campus for the College of Education are the first two net energy neutral building on campus. HNEI has been using these working classrooms as research platforms to develop and test energy technologies that include advanced lighting controls, air conditioning controls and emerging occupancy sensing technologies. These buildings are monitored for energy flows as well as environmental conditions, helping to test design concepts that may be applied to other state facilities such as classrooms.

EXPENDITURES: General Funds $ 1,256,674
Tuition and Fees S Funds $ 6,405
Research and Training Revolving $ 574,636
Extramural Awards $ 10,017,028

Due to new or expanded programs in ocean energy, hydrogen, and grid integration, and including the interest of the Office of Naval Research (ONR) to utilize Hawai‘i as a site for alternative energy testing in the Pacific region, HNEI has consistently been able to capture significant extramural funding (over $10 million for FY 2017 based on a 3 year rolling average).

All of these funds support the research and training activities described above. We anticipate 2018 extramural funding levels to be comparable to those from 2017. The rate of expenditure is expected to be similar to that of 2017.

CONTRACTS DEVELOPED: HNEI has developed many subcontracts under its existing extramural federal funding. Contracts using the Energy Systems Development Special Fund are described in the section below on the specific projects funded by ESDSF. HNEI coordinated and planned for ESDSF expenditures with the State Energy Coordinator.

ADVANCES IN TECHNOLOGY: HNEI continues to conduct research to advance renewable energy technologies and system integration. HNEI has patent applications and/or patents in the areas of battery charging, conversion of biomass to charcoal, solar production of hydrogen, novel filtration for operation of fuel cells in harsh environments, and conversion of waste streams to valuable bioplastics in the processing of ethanol. Licensing discussions are ongoing in all of these areas.

COORDINATION WITH STATE AGENCIES: HNEI works closely with DBEDT and other agencies on a variety of renewable energy and energy efficiency projects and continues to seek new opportunities and means to do so. Projects initiated or ongoing in 2015 and 2016 which involve strong collaboration/coordination with state agencies include the following:

- **Hawai‘i Hydrogen Power Park:** The hydrogen power park is funded in part by USDOE and in part by the Hydrogen Investment Capital Special Fund through DBEDT. HNEI is the implementing partner and works closely with DBEDT in the execution of this project. Associated projects, including development of the Hawai‘i Hydrogen Plan and development of Hydrogen Fueling infrastructure at MCBH also leveraged state partnerships.

- **National Marine Renewable Energy Center:** HNEI is working closely with DBEDT to attract technology providers to the state to participate in this project and to provide assistance in the permitting process.

- **Hawai‘i Public Utilities Commission support:** HNEI has been coordinating with the PUC on developing assumptions and scenarios for the RPS Studies (described in the ESDSF section below) to support their need for independent modeling and analysis of utility systems and their capabilities, constraints and planning needs.

- **Hawai‘i State Energy Office Support:** HNEI is working with the Hawai‘i State Energy Office in DBEDT to support programs in energy efficiency, renewable energy, test bed development, and energy education and outreach.

RECOMMENDATIONS FOR PROPOSED LEGISLATION: Generally, HNEI does not initiate legislation, but is a member of the Hawai‘i Energy Policy Forum and works closely with this group to review legislative initiatives in the energy area. Via federal funds and the ESDSF, HNEI also financially supports the University of Hawai‘i’s Hawai‘i Energy Policy Forum for outreach and analysis efforts.

ENERGY SYSTEMS DEVELOPMENT SPECIAL FUND

The Energy Systems Development Special Fund (ESDSF) was established in 2007, but went unfunded until 2010, when the Hawai‘i Legislature established a barrel tax and authorized that 10 cents of the $1.05 tax on each barrel of petroleum product imported into Hawai‘i be deposited into the Fund. This has amounted to approximately $2,300,000 per year of barrel tax funding for the ESDSF. HNEI works in collaboration with the State Energy Coordinator to develop an expenditure plan to maximize value of these funds to meet near term needs and opportunities within the state; and maximize leveraging of federal and private dollars.

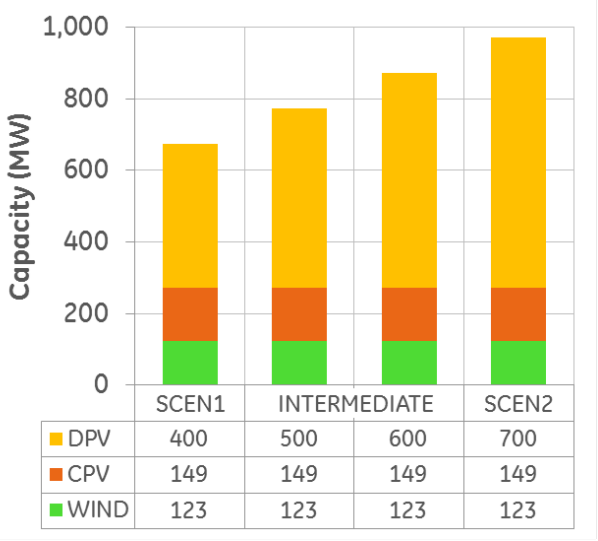
Below is a description of projects that were supported by money committed from the ESDSF and were ongoing or completed in FY 2017, and newly initiated and planned projects.

New/Continuing/Completed Projects

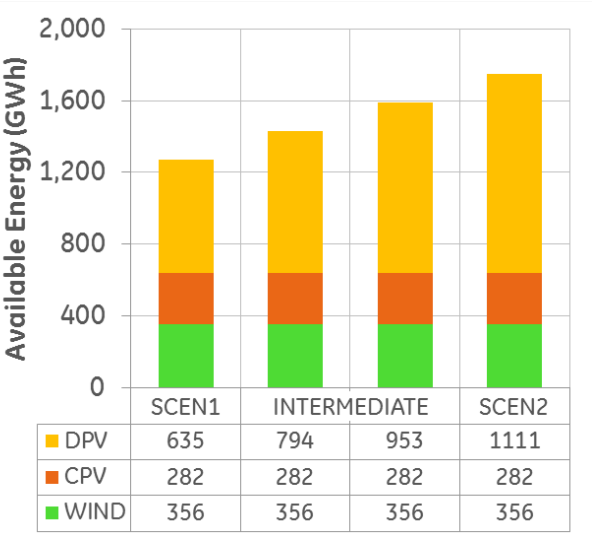
GRID MODELING/ANALYSIS

Charting the Path Towards a Renewable Future: Renewable Portfolio Standards Study II

HNEI continued its modeling efforts with GE to provide independent assessments of issues critical to policy development and infrastructure investment. The analyses further evaluated impacts of increasing renewables, system challenges, mitigations and the costs and benefits of various solutions.



	SCEN1	INTERMEDIATE		SCEN2
DPV	400	500	600	700
CPV	149	149	149	149
WIND	123	123	123	123



	SCEN1	INTERMEDIATE		SCEN2
DPV	635	794	953	1111
CPV	282	282	282	282
WIND	356	356	356	356

This study was structured to be conducted in smaller pieces to provide results and findings on a more regular basis, and to allow enough flexibility to meet rapidly evolving state energy analysis needs in a timely way. Regular calls with stakeholders including the PUC, the State Energy Office, the Consumer Advocate, the utilities, the National Renewable Energy Labs, and independent industry experts helped to guide the study, vet assumptions and methods, and review results.

In the study, production cost simulations, which are able to assess technical and economic impacts of hourly grid operation with high levels of renewables, are being run in conjunction with dynamic simulations, which look at the systems short-term (seconds, and fractions of a second) response to critical events, such as the loss of a large generator. In an iterative process, challenges and potential mitigations found in the dynamic simulations are then run back through the production cost model to determine longer-term system and cost impacts.

In 2016 and 2017 reports were released describing the O‘ahu electric grids’ ability to respond to large generator or load losses while operating with high amounts of distributed PV on the system, and a third report on grid strength. A final report on battery energy storage and its value to the grid will be released at the end of 2017. The study also evaluated distribution level challenges and mitigations including further distributed PV growth, frequency response, ride through capabilities and the ability of

other distributed resources (e.g. smart inverters) to address these challenges on O‘ahu and other island grids.

Charting the Path Towards a Renewable Future: Economic Study of Hawai‘i’s Renewable Portfolio Standard

In an effort related to the RPS Study II, HNEI is supporting the University of Hawai‘i Economic Research Organization (UHERO) to assess the economic implications for the State of achieving high penetration levels of renewable energy focusing on policy mechanisms and economic outcomes. UHERO is identifying load profiles based on changes to factors such as rate design and storage capacity that may be used as inputs to GE modeling analyses, and will use results from GE modeling analyses to assess the broader economic impacts to the State under various scenarios.

Charting the Path Towards a Renewable Future: Renewable Portfolio Standards Study Phase III

HNEI is continuing its modeling efforts with General Electric Energy Consulting to provide ongoing independent assessments on issues that are critical to policy development, and infrastructure investment. The work will focus on issues related to planning, grid-operations, cost-benefits, capital investments, and grid stability impacts associated with high penetrations of renewable resources. A portion of the work under this Agreement is to assist HNEI in providing technical and decision support services to the HPUC as described above.

Analyses have been performed to assist the HPUC in its review of the demand response and distributed energy resources dockets. Future, analyses will include issues related to the impacts of utility RFPs and major capital projects on grid stability, system operations and cost-benefits.

Under this Agreement GE has updated its models inputs and assumptions to reflect the current state of the island systems and the utilities most recent plans, and will continue supporting HNEI’s efforts to develop and improve its in-house modeling capabilities.

O‘ahu Distributed PV Grid Stability Study

The movement toward high penetration of intermittent renewables on the grid has introduced significant concerns regarding system stability and reliability. In this context,

HNEI and GE Energy Consulting completed a technical assessment of the O‘ahu power grid quantifying the impact of various penetrations of distributed photovoltaic (DPV) on the stability of the grid. The study resulted in new approaches for analyzing dynamic stability across an entire year of grid operations. These tools, which are receiving national and international recognition, have been adopted by HECO’s Transmission Planning Team and were incorporated into the utility’s latest Power Supply Improvement Plans.

Analysis of Battery Energy Storage for O‘ahu

Battery energy storage systems (BESS) are one of several emerging technologies under consideration to provide grid services under high renewable penetration scenarios. In this project, HNEI and GE performed a benefit-cost analysis of BESS to provide several grid services including reserves and energy arbitrage. The analysis shows that BESS can be economically viable in the O‘ahu resource mix. BESS with higher power ratings were shown to be particularly valuable due to their availability for providing reserves.

Grid Services for High Penetration Renewables

As renewable energy continues to displace power produced by traditional power generation, it also displaces the essential reliability services provided by traditional generation. In previous studies, HNEI evaluated specific technologies, (e.g. battery energy storage systems) and specific services (e.g. operating reserves) within a limited research scope. With this study, HNEI is expanding the scope to review and evaluate a wide range of essential reliability and ancillary services for Hawai‘i, across a range of technologies. This study is supported by and directly supports the Hawai‘i Public Utilities Commission.

Charting the Path Towards a Renewable Future: The Hawai‘i RPS Study
O‘ahu Distributed PV Grid Stability Study
Analysis of Battery Energy Storage for O‘ahu
Grid Services for High Penetration Renewables (in early stages of work)
$1,512,700 ESDSF
$ 187,250 US Dept of Energy
$50,000 HPUC
UH in-kind

Assessment of the Variability of the Energy Resource for Solar and Wind Power on O‘ahu

Also related to the RPS Study II, this assessment by the UH Department of Meteorology is analyzing the variability of the solar and wind energy resource on the Island of O‘ahu over periods of seconds, minutes, hours, days, months, years, and decades. Current models are based on wind and solar resource data from only one or two years. A clearer understanding of the actual variability of these resources over multiple timescales is critical for both accurate forecasting and planning.

Assessment of Resource Variability
$104,000 ESDSF
$130,000 US Dept of Energy
In-kind UH salary

Pathways to an Open Grid: O‘ahu

HNEI is partnering with Kevala (an Elemental Excelerator funded startup) to engage stakeholders in a collaborative process to identify scenarios and accessible data sets that can be used in Kevala’s Network Assessor software tool. The goal of the project is to create web-accessible tools that allow users to explore a map of O'ahu’s current grid infrastructure and determine where distributed energy projects could add benefits to the grid and how to maximize those benefits by combining types of distributed energy resources under various resource adoption scenarios. The tools are intended to be more transparent than anything currently available to customers and used to assess and analyze distribution circuit hosting capacity and locational net benefits of distributed energy resources. Through the engagement of a broad range of market participants and stakeholders via a series of workshops, the POG project is attempting to support better, quicker decision making by developing tools, techniques and shared data to better understand both the local impacts and potential value of increasing distributed solar generation and other distributed energy resources. Kevala is contributing $125,000 to HNEI for its support of the effort.

Pathways to an Open Grid: O‘ahu
$100,000 ESDSF
$225,000 ONR
$75,000 industry in-kind

GRID DEMONSTRATIONS

Maui Virtual Power Plant Demonstration Project

Using Barrel Tax funds and leveraging BESS equipment installed as part of the JUMPSmart Maui project, HNEI is in the process of implementing the Hawai‘i BESS+PV Virtual Power Plant (VPP) Demonstration Project. This project will demonstrate and assess the technology application, and the prioritization of alternative use cases based on stakeholder interests and functional/economic trade-offs in VPP dispatch (e.g., customer versus utility grid benefits). The project will also quantify the business value proposition of combined BESS+PV resources. The systems will be deployed at two locations; at Haleakalā Solar’s business offices and operations center, and at Maui Electric Company’s operations base yard, both located in Kahului, Maui. These distributed resources will be collectively operated as a VPP utilizing the Sunverge Software Platform (“SSP”) and Sunverge Solar Integration System (“SIS”) BESS units.

Maui Virtual Power Plant Demonstration (planned, estimated allocations)
$ 50,000 ESDSF
$ 150,000 Office of Naval Research
$ 100,000 Estimated value industry donation

Moloka‘i Dynamic Load Bank

Moloka‘i has reached the PV hosting capacity of the system. As a result, no more PV is being allowed on the island and there is over 660KW of PV projects currently on hold as

a result. HNEI conducted an analysis that showed an additional 1,100 MWh of PV renewable energy could be allowed on the system if only 4 MWh of excess energy could be absorbed by storage to absorb the excess energy and shift it to the evening, Since the amount of excess energy is too small to justify the cost of the BESS that would be needed to address this issue, a dynamic load bank will be installed to safely absorb the excess energy. Although acting a “safety valve” to sink or discard the excess energy. This low-cost solution will allow a substantial amount of additional PV on the system and help maintain grid stability.

Over the longer term, there will be a breakeven point where the cost of consuming energy in the Load Bank would justify implementation of an additional integration solution, such as energy storage and/or control of the PV, with the subject Load Bank used as backup.

Renewable Moloka‘i Initiative: Dynamic Load Bank for Grid Resiliency
$ 50,000 ESDSF
$ 85,000 Office of Naval Research
$ 100,000 estimated utility cost share

ALTERNATIVE FUELS AND ENERGY TECHNOLOGIES

Hydrogen Fueling Transport Trailers

ESDSF money was used to purchase two hydrogen transport trailers to support multiple fueling sites from one production site. Current plans are to support refueling of two hydrogen fuel cell electric buses at Hawai‘i Volcanoes National Park (HAVO) and the Hele-On bus. The trailers carry over 100 kilograms of hydrogen at a pressure of 450 bar (6,600 psi). The trailers support the development of critical hydrogen delivery infrastructure on the Island of Hawai‘i. The trailers were completed in May 2014 and will to be delivered in early 2018 after they have been recertified by Powertech for operation on public roads.

Electric Vehicle Transportation Center Partnership

Figure 7. EV charging stations in Kailua, O'ahu.

HNEI is a partner in the Electric Vehicle Transportation Center (EVTC), a four-year, $9 million research effort to help create the nation's electric-vehicle transportation network, which is operated by the University of Central Florida's Florida Solar Energy Center (FSEC). The vision for the EVTC is to transform the country's transportation network into a fully integrated 'smart' electric vehicle deployment coupled with a 'smart' electric grid, achieved with maximum efficiency and minimum time and disruption. HNEI is concluding this research targeting the integration of electric vehicles (EVs) into power grids characterized by high penetration of intermittent renewable energy. Completed work includes EV battery performance and life time impact under everyday charging conditions, as well as when the EV battery is used for energy storage to support the power grid (vehicle-to-grid, V2G applications). A measurable impact was found on battery capacity loss when substantial energy was discharged to the grid. From this and other HNEI efforts, researchers have applied for a provisional patent to accurately estimate remaining capacity as batteries begin to age. Building on HNEI's power grid modeling with increasing penetrations of wind and solar energy, EV petroleum usage and emissions were quantified and compared with gasoline-powered vehicles under a variety of EV charging schedules. EV adoption levels were forecast, and the economic impact was estimated along with lifecycle cost for EV ownership in Hawai'i. Final reports are available on the HNEI website.

Electric Vehicle Transportation Center
$ 150,000 ESDSF
$ 748,185 US Dept of Transportation
$ 226,000 UH in-kind

ENERGY EFFICIENCY

Hawai‘i Department of Education- Heat Abatement Program Data Hosting

Many of the public schools in Hawai‘i do not have space conditioning nor do they have access to weather data that could inform decisions about activities impacted by weather in school facilities. Under this project, the Hawai‘i Natural Energy Institute (HNEI) is providing the State of Hawai‘i Department of Education (HIDOE) with the technical resources and expertise to support the delivery of energy and weather data that enables researchers, the community and design professionals to make data-driven decisions for designs and resource allocation.

The DOE Thermal Comfort Portal (http://hnei.hidoe-thermal-comfort.4dapt.com) is a research tool developed for HIDOE to implement their heat abatement program. In addition to providing data for current users, the intent is to broaden the program participants to include the sustainable design community, who can contribute to solutions but who are currently outside of the specific scope of HIDOE heat abatement program.

Publicly released in November of 2017, the HNEI website features the Thermal Comfort Portal as a research resource for microclimatic data across Hawai‘i as well as specific building performance of the public schools. HNEI will commence public outreach through workshops and webinars to promote the use of the portal. HNEI continues to work as a strategic advisor to HIDOE, MKTHink and Roundhouse One on the completion of the Thermal Comfort Portal.

Hawai‘i Department of Education Heat Abatement Program Data Hosting
$ 30,000 ESDSF
UH in-kind

Energy Efficient Home Design: Department of Hawaiian Homelands

Over the past 20 years, the State of Hawai‘i Department of Hawaiian Home Lands (DHHL) has built over 2,000 homes for low-income Hawaiian families. It currently owns over 200,000 acres of land on which it plans to construct another 875 homes over the next 5 years. This forthcoming residential construction presents an opportunity to

ensure efficient measures are incorporated into building plans that can further advance Hawai‘i’s energy initiatives.

To align with long term state energy goals, DHHL and University of Hawai‘i collaborated to determine the potential energy savings in housing and future communities that would result from improved energy efficient design and renewable energy utilization. HNEI and primary partner, UH School of Architecture’s Environmental Research and Design Lab (ERDL), are in the middle of an 18-month initiative to develop guidelines and provide recommendations for the DHHL to improve comfort and reduce energy use and electricity costs for occupants. This initiative will: (1) train UH system students in energy monitoring and building simulation, (2) result in quantified recommendations for design and operation of high-performance and net-zero site-built and packaged housing units, and (3) quantify the savings from energy efficient and net zero options for 1,000 site-built and packaged homes.

Energy Efficient Home Design: Department of Hawaiian Homelands
$ 53,000 ESDSF
UH in-kind salary

Advanced Energy Efficient & Renewable Technologies Training and Workshops

To achieve State energy goals and reduce Hawai‘i’s dependence on imported fossil fuel sources, Hawai‘i’s professional design community must be afforded opportunities to expand skill sets, be exposed to new energy technologies, and remain apprised of initiatives and developments in the state and energy industry. With this training initiative, HNEI and the School of Architecture’s Environmental Research and Design Lab (ERDL) have teamed up to provide technical training to professionals, advanced university students, state entities and community organizations on advanced energy efficient and renewable energy technologies. In support of this objective, HNEI and ERDL are developing and delivering a series of workshops, seminars, and webinars on building science and energy performance topics. ERDL is providing instructor and web-

based training opportunities for contractors, professionals, and students to inform sustainable design for Hawai‘i’s climate.

Advanced Energy Efficient and Renewable Training and Workshops
$ 40,000 ESDSF
UH in-kind salary

STRATEGIC POLICY ASSISTANCE

Hawai‘i Energy Policy Forum Support, HCEI Metrics

HNEI continues to support the Hawai‘i Energy Policy Forum and the Social Science Research Institute at the UH in their efforts to seek smart energy solutions for a clean and sustainable energy future through advocating policies and initiatives and promoting civic action. HNEI also specifically supported the Forum’s effort to develop a set of metrics to measure the State’s progress toward meeting the Hawai‘i Clean Energy Initiative’s requirements.

Hawai‘i State Energy Office Support

HNEI continues working with the Hawai‘i State Energy Office in DBEDT to support programs for:

- Hawai‘i Test Bed Development and Energy Education and Outreach
  - Design Planning for Innovation Center for energy system commercialization testing, innovation, advancement, and energy venture acceleration
  - Energy Education and Outreach to generate awareness of Hawai‘i’s clean energy goals and their contribution to economic growth
- Energy Efficiency – Technical Assistance for High Performance Buildings
- Renewable Energy
  - Enhance EnerGIS Renewable Energy Resource Tool
  - Online Self-Help Investor Development Tools
  - Energy regulation analysis and Technical Services
  - Environmental Compliance.

Technical and Decision Support Services to the Hawai‘i Public Utilities Commission

In May 2017 HNEI entered into an agreement with the HPUC whereby HNEI is providing support to the HPUC in the following areas:

- Conducting independent review of technical analyses and internal strategies to support HPUC staff review of regulatory filings
- Producing alternative, independent analyses to inform and support HPUC decision making
- Convening experts and stakeholders to address technical and policy issues in consultation with HPUC staff, and
- Organizing and leading professional development and training opportunities for HPUC staff

The initial work has included analyses and support in the Demand Response and Distributed Energy Resources Dockets and meetings with HPUC to begin an assessment of Hawai‘i’s policy development processes relative to state needs in the areas of renewable integration, distributed energy resources, planning and operations and grid modernization.

Under the agreement the HPUC is providing $99,000 to fund HNEI faculty and contractors and HNEI is committing $450,000 from the ESDSF to the effort. A portion of HNEI’s contribution has been committed to additional GE grid modeling work to support this agreement.

Appendix A contains additional information on select projects described above that were either completed, ongoing, or initiated during the past year. These include:

Grid Analysis

- Charting the Path Towards a Renewable Future: The Hawai‘i RPS Study
- O‘ahu Distributed PV Grid Stability Study
- Analysis of Battery Energy Storage for O‘ahu
- Grid Services for High Penetration Renewables
- Supporting HCEI’s Environmental Review Process
- Assessment of Resource Variability
- Pathways to an Open Grid: O‘ahu

Alternate Fuels

- Hydrogen Energy Systems for Grid Services: Fuel Cell Electric Bus
- Hydrogen Energy Systems for Grid Services: Hydrogen Transport Trailers
- Aviation Sustainability Center Federal Aviation Administration

Grid Demonstration

- Smart Grid Inverters for High- Penetration PV
- Renewable Moloka‘i Initiative: Dynamic Load Bank Technology for Grid Resiliency
- Maui Virtual Power Plant Demonstration
- Electric Vehicle Transportation Center
- Support to the U.S. Navy Wave Energy Test Site

Energy Efficiency

- Hawai‘i Department of Education Heat Abatement Program Data Hosting
- Energy Efficient Home Design: Department of Hawaiian Homelands
- Advanced Energy Efficient & Renewable Technologies Training and Workshops

Attachment A

GRID ANALYSIS

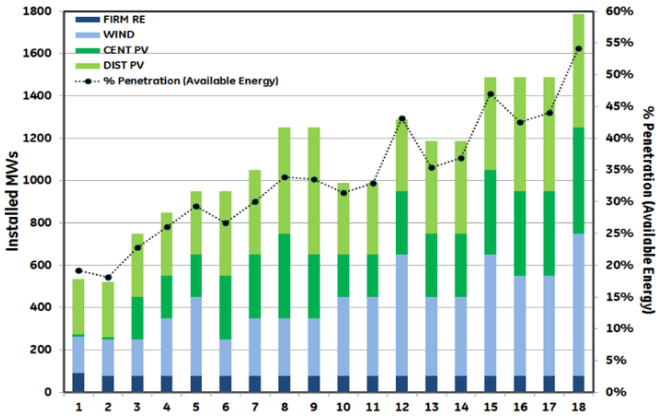
Charting the Path Towards a Renewable Future: The Hawaii RPS Study

Purpose and Scope

The Hawaiian electric power industry is at a critical nexus; intermittent renewable technologies such as wind and solar have gained an increasing share of the islands' overall energy mix, the Hawaii State Legislature instituted an energy policy requiring 100% of electricity be produced by renewable technologies by 2045, and the current utility planning calls for the installation of significant amounts of intermittent renewable generation. This study identified and analyzed various scenarios that would allow the islands of Oahu and Maui to surpass the 2020 and 2030 RPS targets (30% and 40%, respectively) while lowering costs. It evaluated cost-effective pathways to meet State RPS targets.

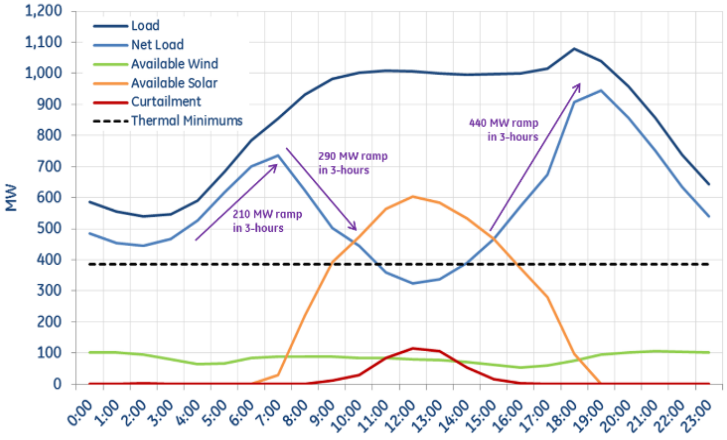
Key Findings

The study findings indicate that Oahu and Maui can surpass RPS goals and reduce operational costs by improving the operational flexibility of thermal units (e.g. commit units to optimize reserves), investing in infrastructure for grid reliability (e.g. new thermal units, EE and DR), procuring a balanced and flexible renewable generation portfolio, and adopting LNG as the primary fuel source on Oahu to achieve significant operational cost savings.



Summary of Recommendations

The 2015 Hawaii RPS Study developed recommendations for advancing Hawaii's renewable generation resource portfolio while remaining cost effective. First, reducing operating minimums on thermal units is critical for high levels of wind and solar penetration and removing must-run constraints to allow baseload unit cycling can increase system flexibility, decrease curtailment, and lower system costs.



Furthermore, the study found that adjustments to the procurement strategy of operating reserves (e.g. flexible non-spin reserves) can further reduce system cost and increase renewable penetration. Finally, the study revealed that wind and solar plants can provide ancillary services to the grid and can provide significant production cost savings to the system.

Several of these recommendations have been implemented or are being considered by the utilities. Based on the proposed path forward, additional studies, focused on grid stability and reliability have been initiated.

Full report available here: https://www.hnei.hawaii.edu/projects/hawaii-rps-study

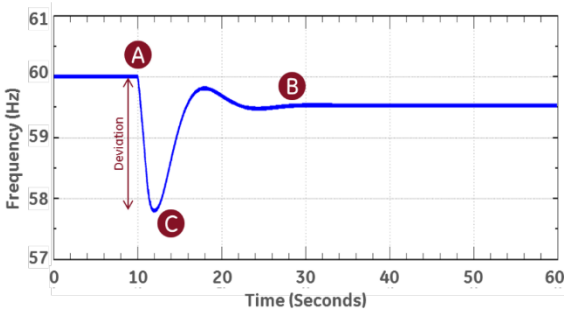
Oahu Distributed PV Grid Stability Study

Purpose and Scope

Hawaii's electric power grids are transforming quickly to achieve the state's Renewable Portfolio Standards (requiring 100% of electricity to be produced by renewable technologies by 2045), which are the most aggressive in the nation. This introduces significant concerns for system stability and reliability. In this context, HNEI and GE Energy Consulting performed a technical assessment of the Oahu power grid with the goal of utilizing power system models to understand and quantify the impact of various penetrations of distributed photovoltaic (DPV) on the stability of the grid. This study evaluated two system-wide issues, frequency stability and grid strength, critical to the reliability and resiliency of the grid and not addressed in traditional interconnection studies. The study resulted in new approaches for analyzing dynamic stability across an entire year of grid operations. These tools, which are receiving national and international recognition, have been adopted by HECO's Transmission Planning Team and were incorporated into the utility's latest Power Supply Improvement Plans. The results of the work are document in three reports (see below).

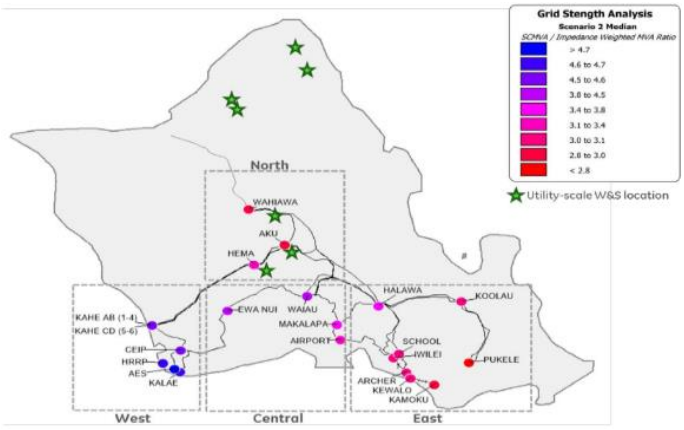
Project Overview

As more PV is interconnected to the electric grid, it introduces new frequency dynamics as it displaces traditional rotating generators. When unplanned events such as the loss of generators and loads occur, the frequency of the grid is disrupted and can lead to power outages. A typical loss of generation response is shown in the figure below. DPV is affected by and contributes to these dynamics. In Parts 1 and 2, HNEI and GE performed an in-depth analysis of the interactions between the grid frequency and DPV, including factors such as inverter ride-through capability and under frequency load shedding (UFLS) setpoints, to evaluate and help improve the resiliency of the grid during a loss of generation and/or load.



DPV also affects grid strength, or the ability of the grid to maintain voltage within specifications during extreme load variances. Grid strength is critical in order to maintain system stability and trigger local fault protection under events such as short circuits. In Part 3, HNEI and GE studied the effect of DPV on grid strength to determine the grid strength at various locations on Oahu (figure below) and provided recommendations on the use of synchronous condensers and the need for further development of PV inverter technology.

Application of Study Results



To perform this work, HNEI and GE developed higher fidelity methods, tools, and metrics for grid analysis, which are receiving national and international recognition. The study's novel approach to analyze dynamic stability across an entire year of operation has been adopted by HECO's Transmission Planning team and incorporated into the latest PSIP filing, Appendix O System Security Analysis. Throughout the process, HNEI and GE engaged a diverse group of stakeholders including HECO, the National Renewable Energy Laboratory, industry experts, and Hawaii's Public Utilities Commission (PUC), Department of Business, Economic Development & Tourism (DBEDT), and Division of Consumer Advocacy (DCA). For more details, please see the following reports (dates represent dates of draft reports:

1. Oahu Distributed PV Grid Stability Study, Part 1: System Frequency Response to Generator Contingency Events, GE Energy Consulting, March 2016.
2. Oahu Distributed PV Grid Stability Study, Part 2: System Frequency Response to Load Rejection Events, GE Energy Consulting, May 2016.
3. Oahu Distributed PV Grid Stability Study, Part 3: Grid Strength, GE Energy Consulting, July 2016.

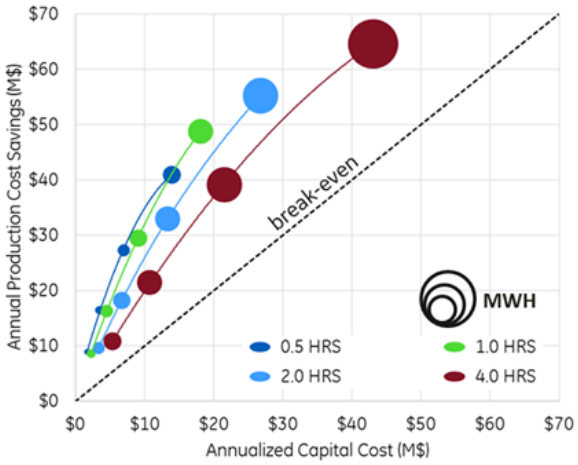
Analysis of Battery Energy Storage for Oahu

Purpose and Scope

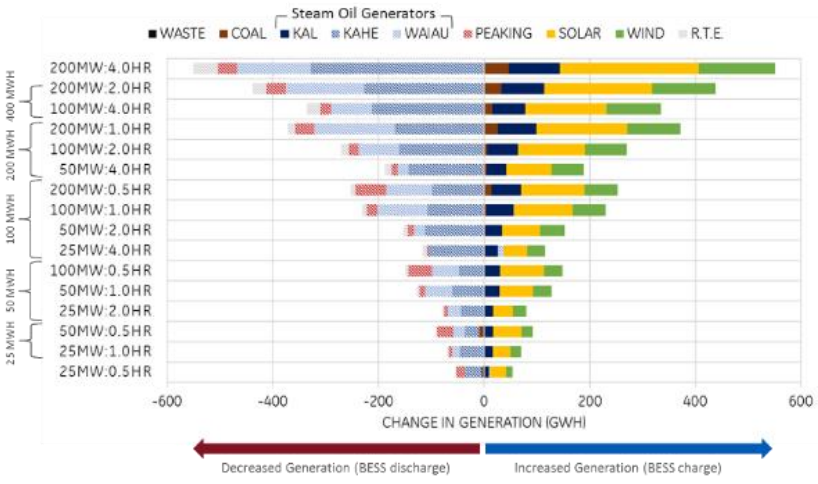
The Hawaiian electric power industry is at a critical nexus; intermittent renewable technologies such as wind and solar have gained an increasing share of the islands' overall energy mix, the Hawaii State Legislature instituted an energy policy requiring 100% of electricity be produced by renewable technologies by 2045, and the current utility planning calls for the installation of significant amounts of intermittent renewable generation. With the concomitant decrease in conventional generation, new solutions are required to provide essential reliability services required to maintain grid stability. Battery energy storage systems (BESS) are one of several emerging technologies under consideration to provide these grid services. However, to date, there has been little analysis that quantifies the functional/economic tradeoffs of BESS relative to other grid service technologies. In this project, HNEI and GE performed a benefit-cost analysis of BESS to provide several grid services including reserves and energy arbitrage. The analysis shows that BESS can be economically viable in the Oahu resource mix. BESS with higher power ratings were shown to be particularly valuable due to their availability for providing reserves.

Project Overview

With the growing penetration of intermittent renewable generation and concomitant decrease in conventional generation resources, battery energy storage systems (BESS) is one of several emerging technologies that are being considered to provide these grid services. BESS are highly configurable, modular and have the potential for different grid service applications. In this study, HNEI and GE quantified the benefits of BESS using high-fidelity models of Oahu's grid system. The objective of this analysis was to quantify the net benefits of various BESS configurations and determine what size, as well as power to energy ratio, may be best for the Oahu system. The production modeling and simulation software utilized in this project performs a least-cost, security-constrained unit commitment and economic dispatch for the simulation year as load, wind, and solar fluctuate over time. This analysis was performed for two grid scenarios on Oahu: (1) a renewable energy mix for a 2018 portfolio and (2) renewable resources equal to 50% available annual renewable energy penetration as a percent of load.



The analysis showed that BESS can cost effectively reduce production costs by helping to avoid curtailment of variable renewable energy, and providing regulating and contingency reserves that would have otherwise required traditional generation. A benefit-cost analysis was performed by comparing the production cost savings with the total capital cost of BESS for different combinations of power and energy ratings. The analysis showed that BESS can shift generation away from expensive oil-based units towards renewable energy and slower, cheaper traditional generation (e.g., coal) (see figure below). The savings increase with larger power rating of the BESS (due the ability to provide reserves) and to a lesser extent with its energy rating (due to the ability to shift energy). The benefit-cost analysis showed that BESS can be an economic addition to Oahu's resource mix (see right figure). However, it must be evaluated against other competing technology such as demand response and increased flexibility in traditional generators.



The report is undergoing final review and will be posted on HNEI's website.

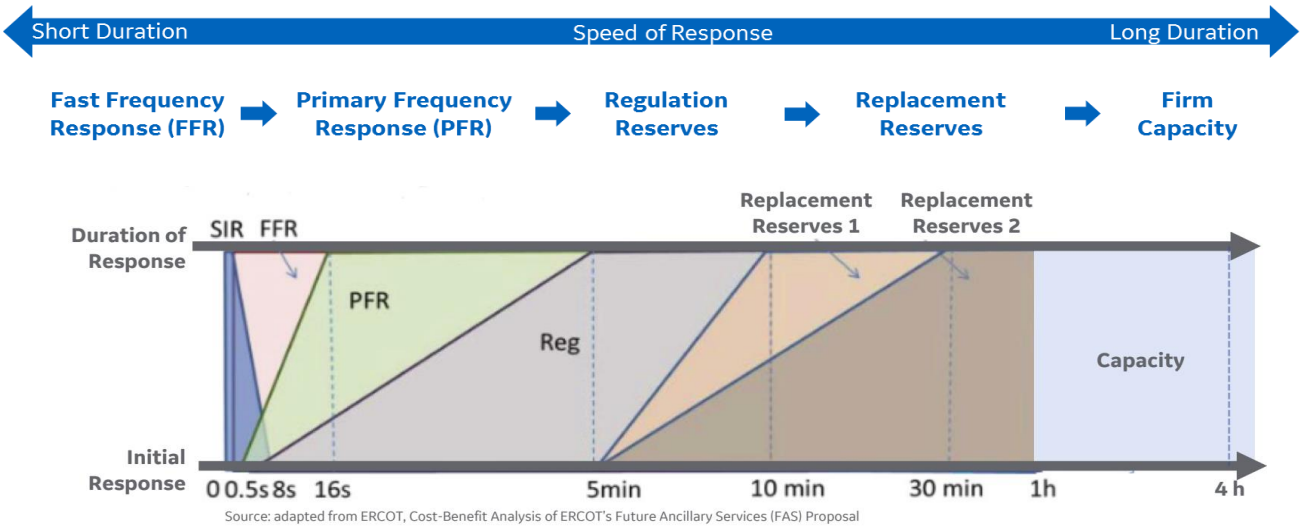
Grid Services for High Penetration Renewables

Purpose and Scope

Hawaii's electric power grids are evolving quickly as the utilities plan and implement renewable resources to be compliant with the State's Renewable Portfolio Standards (requiring 100% of electricity to be produced by renewable technologies by 2045). As renewable energy continues to displace power produced by traditional power generation, it also displaces the essential reliability services provided by traditional generation. It is crucial to define and quantify reliability services so that they can be reallocated to alternative resources that can maintain grid stability. In previous studies, HNEI evaluated specific technologies, (e.g. battery energy storage systems) and specific services (e.g. operating reserves) within a limited research scope. With this study, HNEI is expanding the scope to review and evaluate a wide range of essential reliability and ancillary services for Hawaii, across a range of technologies. This study is supported by and directly supports the Hawaii Public Utilities Commission.

Project Overview

For this study, HNEI has provided technical support to evaluate HECO's Revised DR Portfolio Plan (HECO Plan) at the request of the Hawaii Public Utilities Commission (PUC), specifically regarding the definition of "grid services" and the avoided cost for services provided by alternative resources. The research categorized grid services along a temporal dimension (figure below), from fast frequency response (12-30 line cycles) to firm capacity (> 4 hrs). This involves both the speed and duration of a resource's response; generally, slower resources can sustain their load response longer than faster resources. It is anticipated that the provision of a required response will necessitate a sequential layering of a portfolio of grid services. The application of the individual grid services must be carefully coordinated in the future because renewable resources are generally applied to the grid via electronic inverters that have no physical inertia to intrinsically mitigate frequency and voltage deviations. This is a rapidly evolving area of policy, economics, technology and engineering that requires dedicated staff that can stay abreast of industry and policy changes. HNEI will continue to provide technical support to the PUC.



Source: adapted from ERCOT, Cost-Benefit Analysis of ERCOT's Future Ancillary Services (FAS) Proposal

Research Plan for Upcoming Work

This work has established a ongoing relationship for the PUC to utilize HNEI's technical expertise and resources to help inform policy decisions. HNEI will continue to provide technical support to the PUC. Future work is expected to include the evaluation of distributed energy resources (DER) and HECO's RFPs for capital investments.

Supporting HCEI's Environmental Review Process

Purpose and Scope

At the request of the Hawaii State Energy Office, the Hawaii Natural Energy Institute (HNEI) supported studies to broaden the scope of a Programmatic Environmental Impact Statement (PEIS) that had previously been narrowly focused on wind and undersea transmission technologies between Oahu County and the islands of Lanai and Molokai. The policy decision by the State Energy Office to broaden the scope reflected a reassessment renewable energy plans for Lanai and Molokai and public comments presented during scoping meetings of the Hawaii Interisland Renewable Energy Program (HIREP) (75 FR 77859) or "HIREP: Wind PEIS." HNEI provided funding and oversight to a statewide assessment of a wide range of clean energy activities and technologies with the potential for near-term development or application in Hawaii under a revised name, the Hawaii Clean Energy Programmatic Environmental Impact Statement (Hawaii PEIS).

The intent of the Hawai'i Clean Energy PEIS is for state, county, federal, and private project developers to use the PEIS as a reference document when preparing project-specific EISs. The U.S. DOE is also expected to use the Hawai'i Clean Energy PEIS in making decisions about future DOE funding and other actions to support Hawaii in achieving its HCEI objectives.

Project Overview

With leveraged funding by HNEI, the U.S. Department of Energy (DOE), and the Hawaii State Energy Office, the U.S. DOE issued an amended Notice of Intent in the Federal Register (77 FR 47828, August 10, 2012) to review the following five clean energy categories under the expanded range of energy efficiency activities and renewable energy technologies to be analyzed: (1) Energy Efficiency, (2) Distributed Renewables, (3) Utility-Scale Renewables, (4) Alternative Transportation Fuels and Modes, and (5) Electrical Transmission and Distribution.

The updated PEIS analyzed potential environmental impacts on an island-by-island basis for the islands of Kaua'i, O'ahu, Moloka'i, Lāna'i, Maui, and Hawai'i. The State Energy Office and the U.S. DOE conducted public scoping meetings in the communities of Honolulu, Lihue, Kailua-Kona, Hilo, Kahului, Lāna'i City, Kaunakakai, and Kāne'ohe. Federal, State, and local government agencies, Native Hawaiian and other organizations, and members of the public were invited to submit comments and participate in public meetings on the proposed scope of the PEIS.

The PEIS recognizes that clean energy development projects may have potential to cause environmental impacts, especially if not implemented properly. As such, the PEIS is a comprehensive source of the typical federal, state, and county laws, regulations, and permitting requirements of renewable energy projects. The final PEIS reflects technical reviews that are aligned with the 31 clean energy technologies and activities that could be used to meet the State's clean energy objectives. The final Hawaii Clean Energy Programmatic Environmental Impact Statement was published by the U.S. DOE as DOE/EIS-0459 in September of 2015.

Assessment of Resource Variability

Purpose and Scope

The State of Hawaii, US DOE, and Hawaiian Electric launched the Hawai'i Clean Energy Initiative (HCEI) in 2008 to transform Hawaii to a 70% clean energy economy by 2030. Since that time, numerous modeling efforts have evaluated the impacts of intermittent renewables on grid operations, confirming the ability to integrate large amounts of solar and wind into the island grid systems. While various assessments confirm resource potential to meet these goals current models of wind and solar resource data are limited as they are based on data from only one or two years. This project assessment, by the UH Department of Meteorology, is analyzing the variability of the solar and wind energy resource on the Island of Oahu over periods of seconds, minutes, hours, days, months, years, and decades with higher spatial fidelity than available in many of the current data sets. The overarching objective of this project is to develop high-fidelity long-term gridded data sets of solar and wind energy resources for Oahu and then other islands to inform grid modeling and development planning to meet Hawaii's goal for affordable and reliable clean energy. (Figure to the right illustrates the three pillars of utility planning).

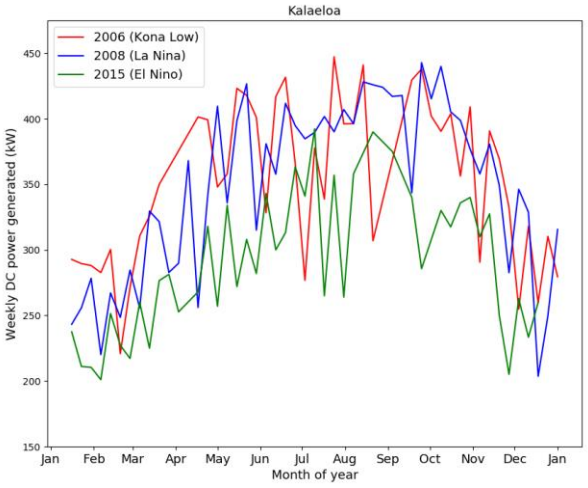
Project Overview

For Hawai'i, a clearer understanding of the actual variability of wind and solar resources over multiple timescales is critical for both accurate forecasting and planning of energy output from renewable generation resources. Current models of wind and solar resource data are limited as they are based on data from only one or two years. This project assessment, by the UH Department of Meteorology, is analyzing the variability of the solar and wind energy resource on the Island of Oahu over periods of seconds, minutes, hours, days, months, years, and decades. HNEI and the UH Department of Meteorology has applied the Heliosat model to satellite data over the Island of Oahu over a 10-year period (2006-2016) to construct a gridded dataset of solar energy (W m-2) with 1-km spatial resolution and 15-min temporal resolution. To assess wind power variability, HNEI and the UH Department of Meteorology has applied the Weather Research and Forecast (WRF) model over the Island of Oahu at 1-km resolution to produce a gridded dataset of wind power density (W m^{-2}), with 1-km spatial resolution and 15-min temporal resolution at turbine height level (80 and 150 m) over the same 10-year period.

Results from the Heliostat and WRF model utilized in this project were validated against National Solar Radiation Database and pyronometer data and turbine tower wind data.

Application of Study Results

The results of this analysis determined the inter-annual variability in total power generated each week over the last decade. Weekly inter-annual variability from 2006, 2008, and 2015 are shown in the figure to the right. These results allow for the identification of magnitude and frequency of 'outlier' events.



Production cost modeling is underway to assess impacts of inter-annual variability.

Pathways to an Open Grid: Oahu

Purpose and Scope

Current utility planning (PSIP 2017) to meet the State's aggressive clean energy goals includes the addition of substantial amounts of distributed resources (DER) including rooftop photovoltaics (PV). While hosting capacity of circuits were included in the utility's PSIP, critical questions remain about current grid constraints and how the grid's capabilities can change as DER is developed. A thorough understanding of the grid's capabilities is necessary for evaluating possible scenarios for the integration, mix, and feasibility of the distributed energy resources (DERs) under consideration in Hawai'i. HNEI is partnering with Kevala Analytics (an Elemental Excelerator funded startup) to create web-accessible tools that allow users to explore a map of Oahu's current grid infrastructure and determine where distributed energy projects could be beneficial to the grid and how to maximize those benefits by combining types of DERs under various resource adoption scenarios.

Project Overview

With Hawaii's high penetration of distributed PV, the capacity to host additional PV systems is becoming limited on many distribution circuits. Identifying the limiting factors (constraints), and the value to the system of avoiding them, (for example, by using storage or otherwise controlling distributed resources to support grid function), will allow for continuing adoption and interconnection of distributed PV and other DERs.

Kevala Analytics has developed a tool that aggregates public and private sources of electric grid data and performs geospatial and time-series analyses. Under this project, Kevala will evolve its tool to perform hosting capacity analysis and locational benefit analysis of DERs on Oahu.

Through the engagement of a broad group of market participants and stakeholders via a series of workshops, the POG project objective is to support improved, data-driven decision making by developing tools, techniques, and shared data that facilitates a better understanding of the local impacts and potential value of cumulative distributed solar generation and other DERs.

Project Plan for Upcoming Work

- Stakeholder workshops will continue through May, 2018
- Oahu Map Buildout in April, 2018
- Functional Review of the Network Assessor tool in May, 2018
- Launch of Network Assessor tool in June, 2018

ALTERNATE FUELS

Hydrogen Energy Systems for Grid Services: Fuel Cell Electric Bus

Purpose and Scope

In Hawaii, extensive penetration levels of variable renewable energy resources are causing challenges to grid operations. As penetration increases further and use of conventional fossil units decreases, new sources of grid services will be needed. Under this project, HNEI is evaluating the ability to use hydrogen production/fueling infrastructure (e.g. electrolyzer and associated hardware) as a variable load to help regulate grid frequency. By providing electric grid services, an electrolyzer can be assigned a monetary value, which in turn can be used to offset the cost of H_2 production. The H_2 in turn can be used in high value applications such as a transportation fuel as a replacement for imported fossil fuel. This jointly funded USDOE-ONR-SOH project is intended to test the dynamic response of an electrolyzer system and its impact on the performance and lifetime of the electrolyzer while also providing fuel for two transportation demonstration projects. The system was delivered to the NELHA facility in Kona in November 2016 and is expected to be fully operational by May 2018. Funding from the ESDSF was used to partially support the purchase one of the fuel cell electric buses for use by the County of Hawai'i Hele-On bus system.

Project Overview

HNEI utilized Barrel Tax funding to fund the purchase and conversion of one hydrogen fuel cell electric bus. US Hybrid has completed the conversion. It is anticipate that the bus will be shipped to the Big island of Hawai'i when the hydrogen fueling infrastructure has been installed and commissioned at NELHA in early 2018. The bus will be operated by the County of Hawai'i Hele-On bus system and will be used to demonstrate hydrogen technologies to the public in Kailua-Kona. The bus conversion leverages non-recurring engineering technology (valued at $750,000) developed US Air Force by the Hawai'i Center for Advanced Transportation Technology (HCATT). This bus will be the first fuel cell electric bus operated in Hawai'i that will be used by the public and will provide the following value propositions:

- Evaluate the potential of integrating hydrogen production to help regulate the grid while supplying hydrogen for transportation applications.
- Introduce the public to the advantages of hydrogen buses as an alternative to diesel buses;
- Provide applied operational and maintenance experience to the County of Hawaii Mass Transit Agency on operating hydrogen buses. This experience can be transferred to other neighbor island county bus operators.

Research Plan for Upcoming Work

1. Support the operation of the bus by providing hydrogen refueling at NELHA.
2. Collecting and analyzing operational and economic data.
3. Support public education and outreach.

Hydrogen Energy Systems for Grid Services: Hydrogen Transport Trailers

Purpose and Scope

In Hawaii, extensive penetration levels of variable renewable energy resources are causing challenges to grid operations. As penetration increases further and use of conventional fossil units decreases, new sources of grid services will be needed. Under this project, HNEI is evaluating the ability to use hydrogen production/fueling infrastructure (e.g. electrolyzer and associated hardware) as a variable load to help regulate grid frequency. By providing electric grid services, an electrolyzer can be assigned a monetary value, which in turn can be used to offset the cost of H2 production. The H2 in turn can be used in high value applications such as a transportation fuel as a replacement for imported fossil fuel. This jointly funded USDOE-ONR-SOH project is intended to test the dynamic response of an electrolyzer system and its impact on the performance and lifetime of the electrolyzer while also providing fuel for two transportation demonstration projects. The system was delivered to the NELHA facility in Kona in November 2016 and is expected to be fully operational by May 2018. Funding from the ESDSF was used to purchase two hydrogen transport trailers in support of this project.

Project Overview

HNEI used funding from the ESDSF to purchase two 450 bar Hydrogen Transport Trailers (HTT) that will be used to transport hydrogen from the NELHA hydrogen production site to a hydrogen dispensing system located at Hawaii Volcanoes National Park (HAVO) to support the operation of two fuel cell electric buses. The buses will be used to transport some of the over 2 million park visitors on a variety of routes in the park designed to fully test their capabilities on a different grades and elevations to evaluate the suitability of hydrogen buses to replace diesel buses in the park. The HAVO buses have been modified with an HNEI patent pending air filtration system. The trailers have been customized to allow over 90% of the hydrogen to be extracted from them thus reducing the transportation cost by almost 45%. The trailers will provide the following value propositions:

- Evaluate the operational issues and economics of central hydrogen production and distributed hydrogen dispensing;
- Demonstration of the electrolyzer as a controllable, rapidly variable load that can potentially provide grid ancillary services
- Introduce the Hawaii transport industry to the requirements for transporting hydrogen;
- Support workforce development opportunities for drivers and maintenance professionals;
- Support the operation of the HAVO buses and outreach to visitors from all over the world;
- Demonstrate to private industry the potential opportunities of entering the hydrogen market.

Research Plan for Upcoming Work

1. Support the operation of the hydrogen transport trailers.
2. Collect and analyze operational and economic data.
3. Support public education and outreach

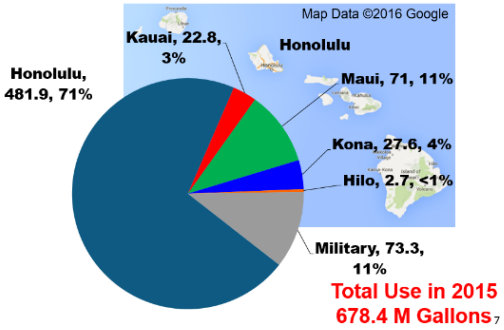
Aviation Sustainability Center
Federal Aviation Administration

Purpose and Scope

Hawaii currently uses over 700 million gallons of jet fuel per year, all of it is derived from petroleum. The University of Hawaii has joined the Federal Aviation Administration (FAA) Aviation Sustainability Center (ASCENT) team of U.S. universities conducting research on production of alternative jet fuels (AJF). The University of Hawaii's specific objective is to conduct research that supports development of supply chains for alternative, renewable, sustainable, jet fuel production in Hawaii. Results may inform similar efforts in other tropical regions.

Project Overview

This project initiated in October 2015 and now continuing into its 3rd year. Activities undertaken in support of AJF supply chain analysis include:



- conduct literature review of tropical biomass feedstocks and data relevant to their behavior in conversion systems for AJF production
- engage stakeholders to identify and prioritize general AJF supply chain barriers (e.g. access to capital, land availability, etc.)
- develop geographic information system (GIS) based technical production estimates of AJF in Hawaii
- develop fundamental property data on biomass resources
- develop and evaluate regional supply chain scenarios for AFJ production in Hawaii

Key Accomplishments to Date

Literature reviews of both biomass feedstocks and their behavior in AJF conversion processes have been completed; companion reports have been issued. Based on stakeholder input, barriers to AJF value chain development in Hawaii have been identified and reported. GIS analysis underlying technical AJF production estimates have been completed. Pongamia (*Milletia pinnata*) samples have been collected and are being subjected to physicochemical property analyses.

Project Plan for Upcoming Work

Analyses needed to evaluate AJF production system scenarios in Hawaii will be conducted. These are summarized as:

- Analysis of feedstock-conversion pathway efficiency, product slate (including co-products), maturation
- Scoping of techno-economic analysis(TEA) issues
- Screening level greenhouse gas (GHG) life cycle assessment (LCA)
- Identification of supply chain participants/partners
- Identifying and engaging stakeholders
- Acquiring transportation networks and other regional data
- Evaluating infrastructure availability
- Evaluating feedstock availability

GRID DEMONSTRATION

Smart Grid Inverters for High- Penetration PV

Purpose and Scope

Hawai'i has seen rapid growth in rooftop distributed PV deployments that has resulted in circuit level penetrations up to 250% of daytime minimum load on numerous circuits in Hawai'i. This project, funded by the US Department of Energy, focused on developing enhanced capability smart inverters and demonstrating improved operational performance, control and visibility to manage distributed PV deployments. The project was conducted in partnership with PEPCO, a utility in Washington DC. The objective of this project was to demonstrate that smart grid-enabled inverters can address critical distribution-level barrier issues to help enable utilities to approve more residential rooftop PV systems, thereby increasing their potential contribution to Hawai'i's collective renewable energy portfolio.

Project Overview

To date, research on advanced inverter functions has mostly focused on large utility scale PV systems, theoretical models or lab testing of residential PV inverters operating in isolation. In contrast, this project considered advanced residential inverters in a real-world environment and also included a demonstration project with deployment and evaluation of smart inverters on operating utility distribution feeders in two locations with very high penetration of rooftop photovoltaics.

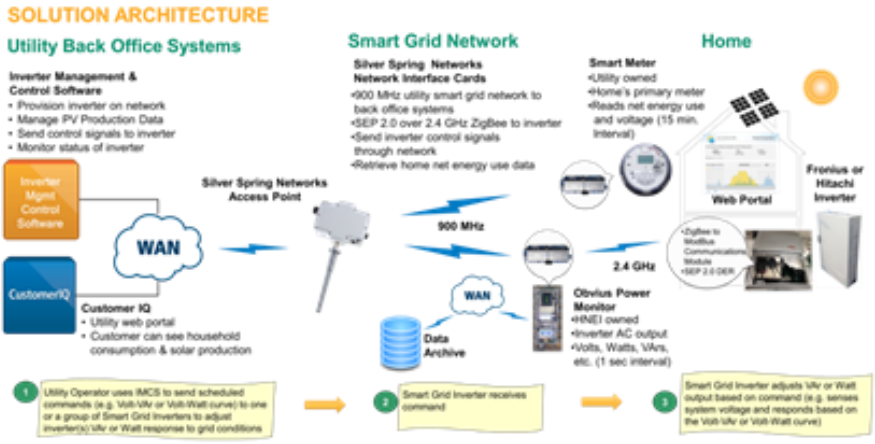


Figure 1. Project technology and solution architecture.

In this demonstration, HNEI installed 20 new and retrofit smart inverters at Maui residences to test the feasibility of using inverters to mitigate voltage fluctuations caused by the intermittency of PV systems and to control PV system power output with the curtailment capability. The project utilized inverter management and control software and a smart grid network to test the inverters actual response and impact on improved grid performance. The project completed full end-to-end testing of the control system, field communications systems, and inverters using an installation at Maui Electric.

Key Results

HNEI deployed advanced function inverters and integrated them with inverter control software via standards-based communications to enable remote access and control in 20 homes. A network of data collection devices were deployed on the target distribution feeder to capture high resolution (1 sec.) synchronized inverter and feeder performance data. The data collected from the devices and invertors were used to adjust the control algorithms. The study determined that voltage can be effectively controlled using reactive power (Var) capability as opposed to control of real power production (Watts). During the demonstration, HNEI was able to provide a localized supply of reactive power for the feeder while maintaining a level voltage profile across the feeder length (i.e., reducing feeder VAr being supplied through the substation transformer from the transmission system). If the feeder voltage was still too high after utilizing smart inverter VAr capabilities, the invertor controls used the Volt/Watt capability to avoid exceeding utility voltage limits.

Renewable Molokaʻi Initiative: Dynamic Load Bank Technology for Grid Resiliency

Purpose and Scope

Molokaʻi is currently closed to additional rooftop photovoltaics due to concerns regarding the stability of the grid. HNEI is supporting the implementation of a Dynamic Load Bank on Molokai, effectively a large resistor, which will provide a cost-effective means of removing energy from the grid when there is excess production. The project is specifically targeted to demonstrate the ability to remove excess energy intermittently generated from the rooftop photovoltaics. Models show that, if successful, this technology should allow higher penetration of distributed PV enabling customers in the utility queue to implement their installations. The Load Bank is also expected to provide grid operators with greater flexibility to conduct generator testing and maintenance during daytime working hours, whereas current maintenance is challenging due to high PV output. This project supports the utilities Renewable Molokaʻi Initiative, to achieve 100% renewable energy on Molokai by 2020.

Project Overview

The 5 MW system load of the Molokaʻi grid provides a challenge to integrating high penetration levels of VRE on the system because the system frequency and voltages are significantly dynamic and change more quickly than conventional generating units. The current capacity of PV on the island can push the system load down to the minimum thermal generation when the load is low and PV generation is high. As a result, no more rooftop PV is being allowed on the island. This project will evaluate the extent to which the Load Bank can increase the hosting capacity for PV systems. The Load Bank will also be evaluated as a potential solution for providing ancillary services (e.g., active down reserve) from a non-traditional alternative and possibly allow lower cost dispatch of conventional generation. HNEI is providing technical, financial, and strategic support for MECO's Renewable Molokaʻi Initiative.

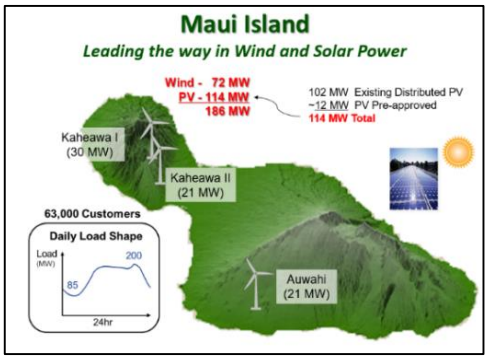
Research Plan for Upcoming Work

The Dynamic Load Bank is expected to be installed on Molokaʻi during the 1st quarter of 2018. HNEI will then work with HECO, MECO, and Molokaʻi stakeholders and load bank Manufacturer to optimize dispatch parameters and control algorithms.

Maui Virtual Power Plant Demonstration

Purpose and Scope

HNEI is implementing the Maui Virtual Power Plant Demonstration Project to evaluate the technical attributes, requirements, and efficacy of distributed battery energy storage systems (BESS) in providing grid services on circuits under duress from high penetrations of PV. Previous renewable integration studies completed by the utility and HNEI have shown that using BESS to provide generation reserves is an effective way to increase system's renewable energy hosting capacity and reduce generation costs. While such services have been demonstrated in the field using utility scale BESS, there have been no conclusive studies to demonstrate how customer sited systems can be used effectively to provide grid services. In addition to demonstrating effective distributed control systems and algorithms, this study will estimate the value proposition of combined PV and BESS for ratepayers and the utility.



Project Overview

One of the biggest grid-services issues in Hawai'i is the amount of generation reserves that are needed to backup the VRE resources should they suddenly ramp up or down due to changes in cloud cover or wind speed. Because of its very high penetration levels of variable renewable generation (VRE), Maui is driving the need for innovative battery energy storage solutions and has hosted several "smart grid" demonstration projects including the Maui Smart Grid and Smart Grid Inverter project funded by the US Department of Energy and the Office of Naval Research and the JUMPSmart Maui project funded by Japan's NEDO. This project, initiated in fall 2017, is intended to demonstrate how battery energy storage can be used effectively to address system level issues. Leveraging the previous investments on Maui, this project will evaluate:

- the technology applications, including PV + BESS systems, invertors, & controllers,
- the prioritization of various technical use cases, including demand response grid services,
- functional/economic trade-offs in VPP dispatch (e.g., customer versus utility grid benefits), and
- the value proposition of deployment of combined BESS+PV resources.

Research Plan for Upcoming Work

1. Obtain service request and SIA
2. Interconnect systems to the grid and commission service
3. Work with HECO, MECO and Sunverge to optimize dispatch parameters and control algorithms
4. Final report and decommissioning of VPP sites.

Electric Vehicle Transportation Center

Purpose and Scope

To achieve the State's aggressive Renewable Portfolio Standards for renewable electricity generation, Electric Vehicles (EVs) are being targeted by the utility as having the potential to help integrate higher penetrations of wind and solar energy while reducing curtailment. For Hawaii, the nation's most petroleum dependent state, these changes to both ground transportation and electricity generation could have a significant impact on reducing net petroleum imports, emissions and enhancing energy security and economic stability. In order to assess the benefits and limitations of EV integration into Hawaii's power grids, the Hawaii Natural Energy Institute (HNEI) leveraged Hawaii's Environmental Response, Energy, and Food Security Tax to secure double the amount in US Department of Transportation funding, under the Electric Vehicle Transportation Center (EVTC).

Project Overview

EV petroleum usage and emissions were quantified under a variety of controlled charging profiles and compared with gasoline-powered vehicles on Oahu. This work leveraged HNEI's power grid modeling and provided a transportation perspective on the impact of reducing curtailed energy under various near future scenarios with exceptionally high wind and solar penetrations on the Oahu power grid. The utilities are piloting Time of Use (TOU) rates to control EV charging profiles, as well as considering EV batteries as a potential source of energy storage for the future. However, since this has the potential to degrade EV batteries, the EVTC study included analysis and battery testing at the cell level to assess battery performance and durability under everyday charging conditions as well as was Vehicle to Grid (V2G). Additionally, a synopsis was provided on the dynamic landscape between electrified transportation and renewable energy integration in Hawaii (*The State of Electric Vehicles in Hawaii* reports).

Key Findings

The completed study results indicate some benefits as well as some limitations with EV power grid integration in Hawaii. EVs contribute to the demand for electricity and reduce curtailment. However even with very high penetrations of EVs, curtailed wind and solar energy was reduced less than expected. When approximately one-fifth of the gasoline-powered passenger vehicles on Oahu were replaced with fully battery-powered EVs, and all followed a perfect charging profile, curtailment was reduced by half. With scenarios looking ahead to over 40% wind and solar energy on Oahu's grid, EVs will start to reduce petroleum usage compared with similar gasoline-powered vehicles. On the other hand, vehicle emissions are essentially cut in half by fully battery-powered passenger vehicles. Additionally, battery testing revealed charging schedules that could slightly improve battery performance. Unfortunately EV battery capacity loss was considerable when substantial energy was discharged to the grid in V2G applications. Building on this project and other HNEI battery studies, researchers have applied for a provisional patent to accurately estimate remaining capacity as batteries begin to age. In summary, with controlled charging profiles such as the piloted TOU rates, increasing EV adoption can be used to improve and increase wind and solar energy integration on the power grid. Controlled battery charging can potentially be used to extend battery life, while further study is needed to ascertain if the extent of V2G use can be limited to avoid any significant loss of battery life.

Full reports and publications available here: https://www.hnei.hawaii.edu/projects/electric-vehicle-transportation-center

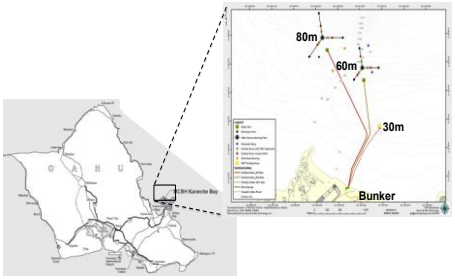
Support to the U.S. Navy Wave Energy Test Site

Purpose and Scope

In 2009, USDOE executed a five-year agreement with UH - HNEI to establish the Hawaii National Marine Renewable Energy Center (HINMREC) to facilitate the development and implementation of commercial wave energy converter (WEC) systems, and to advance Ocean Thermal Energy Conversion (OTEC) technology. HINMREC coordinates engineering and science to address industry needs and leverage U.S. Department of Defense (DOD) interest in Hawai'i energy projects. The USDOE awarded multi-year funding (2008-2015) to HINMREC of approximately $8 million. Cost share of $500K from ESDSF was critical to receipt of this multimillion dollar award. The ESDSF funds were used to support critical surveys and engineering support to assist the Navy with planning for the addition of two deeper water test berths at the Navy's Wave Energy Test Site (WETS), located off Marine Corps Base Hawaii (MCBH) resulting in a total of three grid-connected berths, the first grid-connected wave energy test site in the U.S. This resulted in an additional $12.8 million from the Naval Facilities Engineering Command (NAVFAC) in 2014 and 2016, through the University of Hawai'i's Applied Research Laboratory, to support testing and infrastructure monitoring at WETS. To date, two devices have been tested – the Northwest Energy Innovations Azura beginning in June 2015 for 18 months, and the Fred. Olsen Lifesaver, deployed in March 2016 for just over one year at-sea testing.

Project Overview

Wave energy has enormous potential to address global renewable energy goals, yet it poses daunting challenges related to commercializing technologies that must produce cost-competitive electricity while surviving the energetic and corrosive marine environment. The nascent commercial wave energy sector is thus critically dependent on available test infrastructure. WETS provides this with a test site consisting of test berths at 30m, 60m, and 80m water depths, and can host point absorber and oscillating water column devices to a peak power of 1 MW. HNEI conducts independent WEC device power and durability assessments, environmental measurements, and key logistical support to commercial developers who deploy at WETS.



Key Accomplishments to Date

- Navy EA for deep berths completed February 2014 – key support provided by HNEI.
- Navy deployed 60m and 80m berths in June 2015.
- HNEI environmental monitoring program commenced October 2014, now collecting acoustic and ecological data in presence of WECs.
- Outfitting of site-dedicated vessel nearing completion – subcontract to Sea Engineering, Inc. of Hawaii
- Northwest Energy Innovations (NWEI) deployed Azura device at 30m berth June 2015 to Dec 2016.
- Sound and Sea Technology deployed Fred. Olsen Lifesaver at 60m berth March 2016 to April 2017.

Project Plan for Upcoming Work

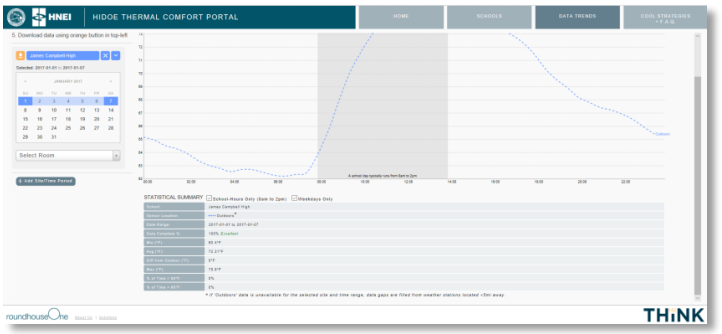
- Redeployment of modified Azura at 30m berth - Dec 2017
- Redeployment of Fred. Olsen Lifesaver, at 30m berth, including demonstration of the provision of wave-generated power to sensing, charging, and data transfer functions – Apr to Oct 2018
- Ocean Energy to deploy 500kW oscillating water column device at 60m berth in mid-2018 for 1 year
- Columbia Power Technologies, Oscilla Power, NWEI, Calwave Power, and Aquaharmonics to deploy devices 2019 through 2022.

ENERGY EFFICIENCY

Hawaii Department of Education
Heat Abatement Program Data Hosting

Purpose and Scope

Many of the public schools in Hawaii do not have space conditioning nor do they have access to weather data that could inform decisions about activities impacted by weather in school facilities. Under this project, the Hawaii Natural Energy Institute (HNEI) is providing the State of Hawaii Department of Education (HIDOE) with the technical resources and expertise to support the delivery of energy and weather data that enables researchers, the community and design professionals to make data-driven decisions for designs and resource allocation. The DOE Thermal Comfort Portal (http://hnei.hidoe-thermal-comfort.4dapt.com) is a research tool developed for HIDOE to implement their heat abatement program. In addition to providing date for current users, the intent is to broaden the program participants to include the sustainable design community, who can contribute to solutions but who are currently outside of the specific scope of HIDOE heat abatement program.



Project Overview and Results

In December 2013, HNEI and HIDOE executed a Memorandum of Agreement whereby HNEI and its contractor MKThink initiated monitoring activities that resulted in the HIDOE heat abatement program. HIDOE subsequently worked directly with MKThink and partner Roundhouse One to continue assessment of HIDOE facilities, install weather stations on HIDOE campuses throughout the state and to develop the HNEI hosted web based portal as a mechanism to distribute data collected at the schools.

HIDOE uses this information in several ways:

- To provide access to local weather data to help schools with short-term decisions related to weather.
- To provide community members access to data on local micro-climates at school campuses allowing for further study.
- Helping HIDOE identify areas that have consistent heat issues for targeted thermal comfort improvements by providing relevant outdoor and indoor temperature readings.
- Providing detailed information from classrooms to help architects and planners design heat abatement solutions to address the specific issues for particular buildings.

Publicly released in November of 2017, the HNEI website features the Thermal Comfort Portal as a research resource for microclimatic data across Hawaii as well as specific building performance of the public schools. HNEI will commence public outreach through workshops and webinars to promote the use of the portal. HNEI continues to work as a strategic advisor to HIDOE, MKTHink and Roundhouse One on the completion of the Thermal Comfort Portal.

Energy Efficient Home Design: Department of Hawaiian Homelands

Purpose and Scope

Over the past 20 years, the State of Hawaii Department of Hawaiian Home Lands (DHHL) has built over 2,000 homes for low-income Hawaiian families. It currently owns over 200,000 acres of land on which it plans to construct another 875 homes over the next 5 years. This forthcoming residential construction presents an opportunity to ensure efficient measures are incorporated into building plans that can further advance Hawaii's energy initiatives.

To align with long term state energy goals, DHHL and University of Hawaii collaborated to determine the potential energy savings in housing and future communities that would result from improved energy efficient design and renewable energy utilization. HNEI and primary partner, UH School of Architecture's Environmental Research and Design Lab (ERDL), are in the middle of an 18-month initiative to develop guidelines and provide recommendations for the DHHL to improve comfort and reduce energy use and electricity costs for occupants. This initiative will: (1) train UH system students in energy monitoring and building simulation, (2) result in quantified recommendations for design and operation of high-performance and net-zero site-built and packaged housing units, and (3) quantify the savings from energy efficient and net zero options for 1,000 site-built and packaged homes.

Project Overview

The program is partially a field effort, monitoring the energy consumption of nine DHHL homes in Kapolei to gain an understanding of energy usage patterns. This data will be used to validate building simulation models that can be extrapolated to predict energy consumption of future DHHL communities. The energy improvement recommendations of existing housing stock will be shared with DHHL and its related professional partners such as Honsador (providers of manufactured housing), Habitat for Humanity (community-built homes), and Gentry Homes, (general contractor and builder), with the intent of informing design and construction with the ultimate goal of achieving net zero energy communities.

Key Accomplishments to Date

To date, key accomplishments:

1. Identified and recruited DHHL participants for the study
2. Installed energy monitoring equipment in the homes to understand how energy is being used
3. Maintaining communications with homeowners to keep them engaged

Project Plan for Upcoming Work

This project will be complete by June 2018. Future tasks include energy simulation of the homes with parametric analysis of design features that will reduce the energy footprint of the homes. Results from the simulations will be utilized in recommendations and guidelines for a community-wide approach to efficient design and to determine the energy impact of a net-zero energy community.

Advanced Energy Efficient & Renewable Technologies Training and Workshops

Purpose and Scope

To achieve State energy goals and reduce Hawaii's dependence on imported fossil fuel sources, Hawaii's professional design community must be afforded opportunities to expand skill sets, be exposed to new energy technologies, and remain apprised of initiatives and developments in the state and energy industry. With this training initiative, HNEI and the School of Architecture's Environmental Research and Design Lab (ERDL) have teamed up to provide technical training to professionals, advanced university students, state entities and community organizations on advanced energy efficient and renewable energy technologies. In support of this objective, ERDL will develop and deliver a series of workshops, seminars, and webinars on building science and energy performance topics. ERDL will provide instructor and web-based training opportunities for contractors, professionals, and students to inform sustainable design for Hawaii's climate.

Project Overview

HNEI is working with the UH School of Architecture's Environmental Research and Design Laboratory to leverage its in-house expertise and subject matter experts to create workshops, seminars, and webinars to be offered to the public, but targeting the design and sustainability community. HNEI and ERDL will collaborate and leverage HNEI, State, and private entity resources to utilize existing networks to reach professionals in the design and construction industry to expand local knowledge base to expedite achievement of long-term energy goals.

Topics include:

- Daylighting and energy simulation
- Lighting & daylighting design
- Net-zero energy building design
- Innovations in energy efficient HVAC
- Thermal comfort in tropical environments
- Energy codes and design standards
- Building design as grid assets

Expected Outcomes

Expected outcomes of this effort include:

- Build local professional capacity in area of high performance, energy efficient, and net-zero design
- Develop a collaborative between state energy training stakeholders (HNEI, DBEDT, Hawaii Energy, ERDL) to leverage outreach and delivery of energy related industry training programs.
- Develop professional sustainability skills with architecture, engineering, and other academic disciplines resulting in energy savings by design in future building construction and community development.

Project Plan for Upcoming Work

A two-day lighting design workshop co-sponsored by HNEI, Hawaii Energy, and DBEDT is scheduled for March of 2018. A series of webinars and workshops on net-zero energy design and building energy simulation are in development, to be presented spring of 2018. In parallel to the live workshops, webinars on these topics will be developed for public release Q2-Q3 of 2018.