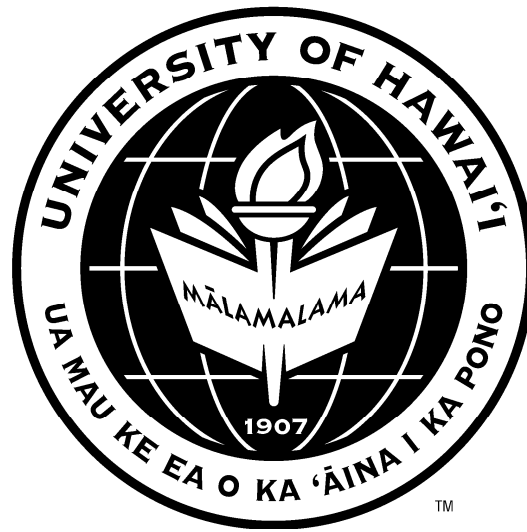


UNIVERSITY OF HAWAI‘I SYSTEM ANNUAL REPORT



REPORT TO THE 2017 LEGISLATURE

ANNUAL REPORT FROM THE HAWAI'I
NATURAL ENERGY INSTITUTE

HRS 304A-1891

December 2016

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).

HIGHLIGHTS:

The following key achievements were made possible in whole or part by contributions from the State’s barrel tax:

- **Wave Energy Test Site** –Support from the barrel tax was instrumental in allowing the buildout of the country’s first grid-connected wave energy test site offshore from the Marine Corps Base in Kāne‘ohe. Under a combination of Navy, ONR, and USDOE funding, HNEI is conducting power performance assessments on deployed devices, collecting environmental data, and providing logistics support. This unique facility provides developers the necessary infrastructure to test devices and gather data to advance their designs toward commercial readiness.
- **Grid Modeling – System Stability (RPS II Study)** – Independent electric utility system analyses continue to be conducted to determine the effects of large amounts of distributed photovoltaic systems on the O‘ahu grid. In addition to ongoing work to address curtailment, these studies identify likely challenges, and assess the cost-effectiveness of strategies to maintain system stability and

reliability with increasing amounts of renewable energy generation. These analyses provide valuable information to the Public Utilities Commission and other stakeholders as we move toward the State's RPS targets.

- **Hydrogen Fueling Station** – Support from the barrel tax was instrumental in development of the State's first unattended fast-fill hydrogen fueling station on the Marine Corps Base in Kāne'ohe allows drivers to self-fill their cars just like they would at a gas station, and serves to demonstrate the capability of the technology to be user friendly. Over 400 successful fills were achieved.
- **Hydrogen Fuel Cell Shuttle Bus for the County of Hawai'i Mass Transit Agency** – A hydrogen fuel cell electric bus to be operated by the County of Hawai'i Mass Transit Agency was completed and is ready for shipment to Hawai'i. It will be supported by a hydrogen fueling station being installed at the Natural Energy Laboratory Hawai'i Authority (NELHA) and will be used by the Hele-On bus service to demonstrate the benefits of hydrogen buses to the Kailua-Kona community. This is the first hydrogen vehicle in Hawai'i that will be available to the public.
- **Smart Inverter Deployment and Testing** – Support from the barrel tax was used to support development of smart inverters and communications protocols for better control of distributed PV. These smart inverters have been deployed in a Maui neighborhood to test and demonstrate their ability to manage rooftop PV generation and provide support to the distribution grid to enable higher penetrations of renewable energy on the system. Testing and data collection is ongoing using other funding sources.

These projects are described more fully later in this report.

SUMMARY:

The Hawai'i Natural Energy Institute (HNEI) conducts essential energy research relevant to Hawai'i and the world. Programs focus on identifying technically sound, cost effective solutions and practical strategies that can be implemented to deliver commercially viable renewable energy. The ultimate goal is to achieve a stable and cost-effective energy mix for Hawai'i, while reducing our 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

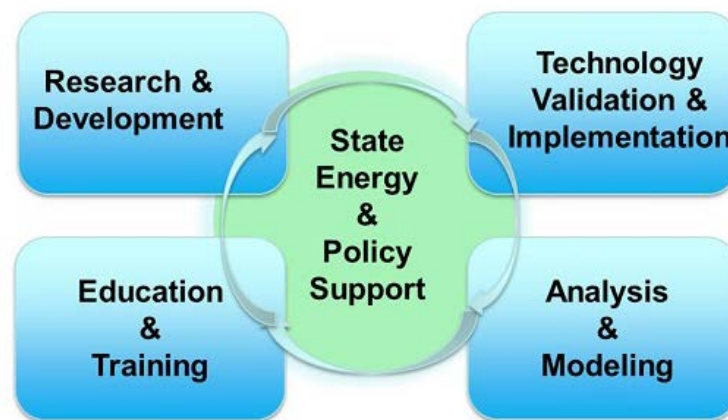


Figure 1. HNEI's inter-related functions used to maximize collaboration and leverage resources.

State Energy & Policy Support

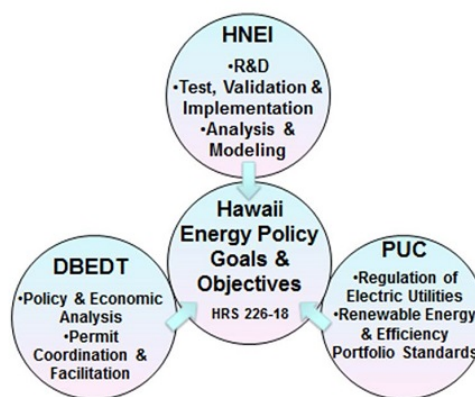
HNEI was established in 1974 to coordinate and undertake the development of natural energy sources for Hawai'i.

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 maximize 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, our State legislators, Public Utilities Commission and our 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 analysis for state energy policy.



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 critical mass allows HNEI to conduct increasingly comprehensive and complex research. With a strategic focus on remaining flexible to support the dynamic needs of renewable energy development, HNEI's direction continues to evolve.

Technology Validation & Implementation (TV&I)

Moving R&D discovery from labs to market is an important aspect of HNEI's TV&I mission and supports the adoption of innovative solutions in Hawai'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.

Additionally, there are many emerging technologies of potential significance to Hawai'i's energy needs developed elsewhere. Under our TV&I efforts, we identify and bring to Hawai'i technologies of interest, for validation and assessment for use in Hawai'i. These activities are frequently guided by our analysis and modeling efforts and supported by our R&D activities. HNEI's TV&I projects usually involve industrial partnerships and often include cost share. A good example is the ongoing effort to evaluate emerging grid scale and distributed battery energy storage technology as a solution to both transmission and distribution level issues associated with high penetration of intermittent renewable energy technologies.

Analysis & Modeling

HNEI conducts and supports analysis and modeling to analyze important forward looking scenarios for Hawai'i's energy mix. This analysis is critical to identifying optimal and realistic paths forward to meet Hawai'i's clean energy goals. Results from these studies are used as to guide state policy and help identify important 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).

The attached report summarizes HNEI's current research activities for the past fiscal year and provides a summary of the expenditure for the funds provided by the barrel tax to the ESDSF.

Summary of Activities, 2016
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) | 7 |
| | Other permanent staff (APT) | 3 |
| | Temporary Faculty | 28 |
| | Other temporary staff (APT, RCUH) | 16 |
| | Training (a) | 20 |

(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 basic 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 our project partners.

A brief synopsis of select HNEI activities follows:

Hawai'i Energy Sustainability Program (HESP): HESP, funded by the United States Department of Energy's (USDOE), ended in September of 2016. During the 7 year period it was in place, HESP significantly boosted HNEI's partnerships and capabilities in many areas including system modeling, renewable integration, and mitigation technology analyses.

Under this program, in partnership with GE Global Research and the HECO utilities, HNEI established a research and assessment program in integrated energy and systems analysis of electricity

technologies. This program provided essential research in areas of relevance to Hawai'i and abroad including analysis and modeling of isolated grid systems with high amounts of renewable energy resources, power distribution and microgrid systems, advanced power system monitoring, intelligent control, communications and enabling

technologies. The program focused on identifying technically-sound cost effective solutions and practical strategies that energy generators and grid operators can implement to deliver commercially viable renewable energy to achieve reduced dependence on oil and other fossil fuel resources. Major activities under this program included:

- *O'ahu Wind Integration Study (2008 – 2010)*
- *Hawai'i Solar Integration Study (2010 – 2012)*
- *O'ahu – Maui County Grid Interconnection (Stage 2) Study (2012 – 2013)*
- *O'ahu EV Charging Study (2012 – 2013)*
- *Renewable Portfolio Standards Study (2013 – 2015)*
- *Liquefied Natural Gas Study (2012)*
- *Evaluation of Alternative Ownership Options for Electric Utility Assets on the Islands of O'ahu and Hawai'i (2016)* – This assessment of municipal and cooperative ownership models included potential benefits and challenges associated with each and provided a roadmap of necessary steps and analyses necessary if these options are further pursued.
- *RPS II Study (2015 –)* HNEI's most recent and ongoing phase of system modeling and analyses, is looking at even higher penetrations of renewable

RENEWABLE ENERGY GRID INTEGRATION STUDIES

HNEI is developing ground-breaking analytic tools to allow higher penetration of renewables on island grid systems.

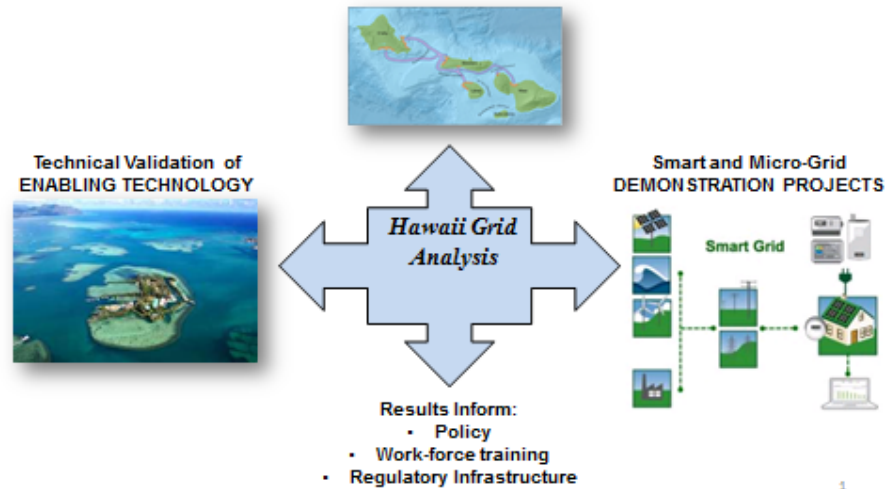


Figure 2. Renewable grid integration studies.

energy under the State's new 100% RPS law. It is evaluating likely system challenges, mitigations, and the costs and benefits associated with new equipment or modifications to operating practices including a more comprehensive review of energy storage.

* Descriptions and detailed reports of these studies can be found on the HNEI website.

This work has been closely coordinated with the State Energy Office and the USDOE, and HNEI has committed resources from the Energy Systems Development Special Fund to co-fund these efforts. Following the conclusion of the HESP program, additional work in these areas is being funded by the ESDSF and is described in more detail later in this report.

GridSTART: Building on its systems analysis experience and growing technical expertise in the area, HNEI established its Grid Systems Technologies Advanced Research Team (**GridSTART**) 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. **GridSTART** 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, Nissan, and the State of Hawai'i. The following five sections briefly describe a few of the projects **GridSTART** 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.

- Maui Smart Grid:**
 This very significant HNEI-led USDOE demonstration project was formally started on October 17, 2008, with partners that include General Electric, MECO, HECO, Sentech, and First Wind, among others. This \$15 million project was

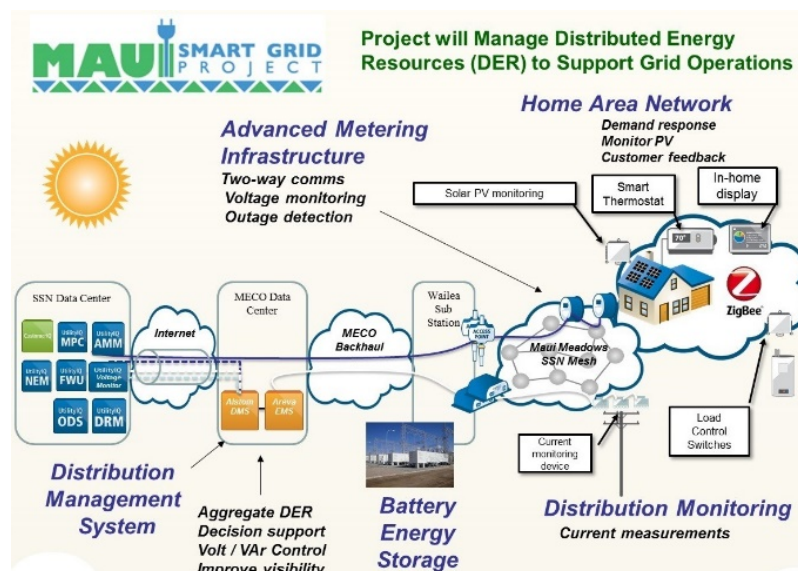


Figure 3. Maui Smart Grid Demonstration Project.

intended to demonstrate reduction of peak electricity demand by at least 15% through the use of advanced smart grid and demand-side-management technologies, and to assist MECO in providing reliable and stable electricity with increasing percentages of as-available renewable resources. The equipment was installed, and the demonstration was conducted through 2014. A final report on this work was completed in December 2014. As a result of the collaborations established under this program, HNEI continues to serve as one of the Hawai'i implementing organizations for the NEDO Smart Grid Initiative, also located on the south side of Maui.

- 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. Continued testing of this hardware on the Maui grid is now supported by the Office of Naval Research.

- **Grid-Scale Battery Energy Storage System (BESS) Projects:** New projects on Moloka'i and at the Campbell Industrial Park (CIP) generating station on O'ahu are joining 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 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 our island grids, while maintaining reliable service.

- **Micro-grid Projects:** HNEI's GridSTART team are participating in microgrid projects on Coconut Island in Kāne'ohe Bay, and the University of Hawai'i at Mānoa campus 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.



The UH Mānoa project will be a 25MW microgrid to help support and demonstrate the value of using on-site renewable energy generation. The objectives of the project include managing the high cost of electricity, improving the campus' grid reliability, quality of service and operations, and supporting the development and demonstration of advanced grid modernization.



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-grid applications. This program has provided substantial support for various smart and microgrid research activities with ongoing efforts on Moloka'i, Coconut Island, at the UH Mānoa campus, and various projects on Maui.

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). 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 2017. The total budget is approximately \$5 million.

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 2017. 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.



Marine Corps Base Hawai'i (MCBH) Hydrogen Fueling Station at Kāne'ōhe 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.

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. A second WEC device, the Fred.Olsen "Lifesaver," was deployed in March 2016 by Sound and Sea Technology.



Figure 5. Azura and Lifesaver wave energy converters deployed off of Marine Corps Base Hawai'i.

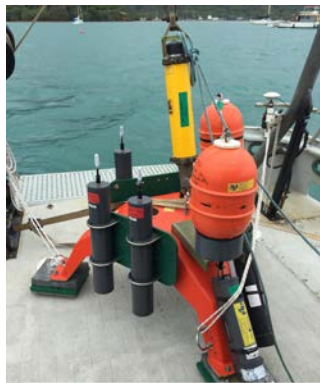


Figure 6. Acoustic device deployed at wave energy test site.

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 marine services support for the vendors which also serves to document system maintenance and reliability.

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 phase 2 of this project HNEI will implement a pilot demonstration project selecting the most appropriate of desiccant technologies in conjunction with a small scale, free standing application such as a Project Frog site or Department of Education site.

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.

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 will use these working classrooms as research platforms to develop and test energy technologies

including integrated PV-battery systems. These buildings are monitored for energy flows as well as environmental conditions, helping test design concepts that may be applied to other state facilities such as classrooms.

EXPENDITURES: **General Funds \$ 1,314,183**
 Tuition and Fees S Funds \$ 41,885
 Research and Training Revolving \$ 514,739
 Extramural Awards \$ 7,096,945

Due to new or expanded programs in ocean energy, hydrogen, and grid integration, including interest by 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 \$7 million for FY 2016 based on a 3 year rolling average).

All of these funds support the research and training activities described above. We anticipate 2017 extramural funding levels to be comparable to those from 2016. The rate of expenditure is expected to be similar to that of 2016.

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 Study II (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 2016, and newly initiated and planned projects.

Continuing/Completed Projects

Smart Inverter Deployment: (\$400,000) This US DOE funded project led by the University of Hawai'i, was intended to develop and commercialize smart grid-enabled PV inverters to mitigate grid reliability impacts of high penetrations of PV systems. This project was part of the ongoing smart grid demonstration projects on Maui. HNEI obligated \$400,000 from the Fund to match partner cost share. This cost share from the Fund resulted in an initial federal award of \$1.5 million with an additional \$4.5 million that was awarded upon successful demonstration of the go/no-go deliverables in early 2013. Due to changes to the DOE program, continued testing of this hardware on the Maui grid is now supported by the Office of Naval Research.

Hydrogen for Grid Management: (\$500,000) In 2011 HNEI was awarded \$ 1.7 million by the Naval Research Laboratory (funds provided to NRL by US DOE) to demonstrate the use of electrolyzer technology to simultaneously produce hydrogen for fuel and for grid management. This program leveraged other investment from the US Department of Energy, the Hawai'i Hydrogen Capital investment Fund, and in-kind cost share from Puna Geothermal Venture and County of Hawai'i Mass Transit Agency. The hydrogen system, originally intended to be located near PGV, has been delayed due to continuing delays in executing a Memorandum of Agreement with PGV, and most recently the lava flow threatening Pahoehoe and the main access road. Due to the continuing delays the project is conducting initial system dynamic testing at the Powertech Labs facilities in Vancouver, Canada, after which the system will be delivered to Hawai'i and installed at the NELHA facility in Kona. It is expected to be fully operational by early 2017. HNEI also contracted with the Hawai'i Center for Advanced

Transportation Technologies (HCATT) to procure a bus and convert it to operate on advanced fuel cells to for use in the county. Approximately \$500,000 from the ESDSF was committed for this work.

Hydrogen Fueling Transport Trailers (\$555,000) 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 at Hawai'i Volcanoes National Park and the Island of Hawai'i Mass Transportation Agency. 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 are projected to be delivered in 2017 with the hydrogen energy system equipment.

Hawai'i Energy Policy Forum Support, HCEI Metrics (\$350,000). 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.

Wave Energy Test Site (\$500,000). UH/HNEI through the Hawai'i National Marine Renewable Energy Center was awarded a total of \$8 million by USDOE to support wave energy testing at the recently completed Wave Energy Test Site (WETS) at MCBH. This \$500,000 cost-share from the fund was critical to receipt of this award. These funds will support environmental and resource studies supporting the Navy sponsored plug-and-play facility. The Navy has committed approximately \$11 million for infrastructure at the WETS. Combined resources of the Navy, USDOE and the Fund have resulted the country's first grid-connected site where developers can test their wave energy conversion technology for proof of seaworthiness, functionality, system integrity, and technology viability.

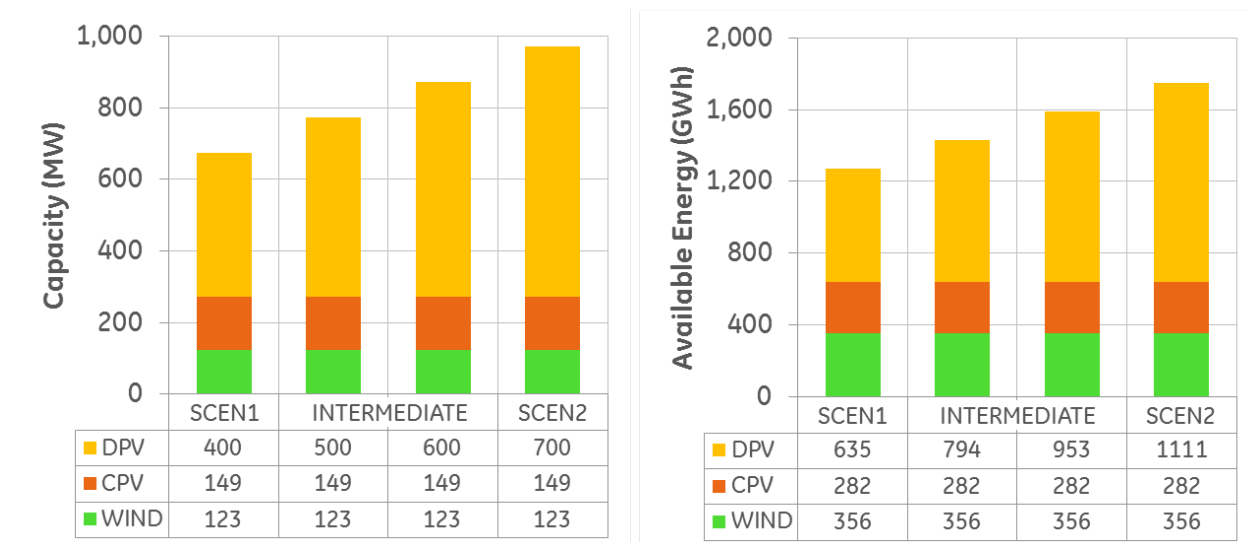
Hawai'i State Energy Office Support (\$1,095,000) HNEI continues working with the Hawai'i State Energy Office in DBEDT to support programs for:

- 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.

New Projects

Renewable Portfolio Standards Study II (\$750,000) HNEI is continuing its modeling efforts with GE to provide independent assessments of issues critical to policy development and infrastructure investment. The analyses further evaluate impacts of increasing renewables, system challenges, mitigations and the costs and benefits of various solutions.



This study has been 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 help 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 March and May of 2016, two 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. A third report on grid strength will be released soon. The study is also evaluating distribution level challenges and mitigations including further distributed PV growth, frequency response, ride through capabilities and the ability of distributed resources (e.g. smart inverters, battery systems) to address these challenges on O'ahu and other island grids.

Economic Study of Hawai'i's Renewable Portfolio Standard (\$121,000)

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.

Assessment of the Variability of the Energy Resource for Solar and Wind Power on O'ahu (\$103,000)

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.

Electric Vehicle Transportation Center Partnership (\$150,000) 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 conducting research targeting the integration of electric vehicles into power grids characterized by high penetration of intermittent renewable energy.



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

Energy Efficiency Education and Training

Develop and deliver educational content on building performance and net-zero topics to the design community. Provide in-person and web-based training opportunities to educate building professionals and students to design for Hawai'i's climate.

Project will result in a series of half-day workshops, evening courses and webinars for students and design professionals, covering topics such as net-zero design, energy efficient HVAC, passive cooling, comfort, lighting & daylighting design, relevant energy codes and design standards, building-integrated PV, designing buildings as grid assets.

Department of Education Support

Based on needs expressed by Department of Education, HNEI will work with DoEd to collect and utilize monitored school building data to develop high performance/ net-zero design recommendations for DoEd facilities that are not in existing heat-abatement contracts. HNEI and partners will also train staff of Maui non-profit, Ma Ka Hana Ka 'Ike, that collaborates with DoEd with at-risk youths, in building systems monitoring and data management in order to develop professional skill sets in energy monitoring and energy simulation and to provide design recommendations for high-performance / net-zero DoEd facilities. This initiative will provide STEM technology transfer from ERDL to DoEd initially through the Maui Ma Ka Hana Ka 'Ike, by training students and staff in building science and monitoring.

HNEI will also host a statewide database housing the data DoEd has collected from schools statewide.

Department of Hawaiian Homelands Support

HNEI and partners will provide the Department of Hawaiian Home Lands with guidelines and recommendations to improve comfort and reduce energy use, decrease electricity costs for occupants. This initiative will train UH System students and design professionals in energy monitoring and energy simulation; will result in recommendations for design and operation of high-performance and net-zero site-built and packaged housing units; will quantify energy efficient and net zero options for 1,000 site built and packaged homes.

In-House Energy System Modeling

Leveraging its staff expertise, the GE grid-modeling projects, and other partnerships, HNEI is expanding its in-house modeling capabilities. Recently acquired PLEXOS modeling software will provide HNEI with a robust tool to supplement and expand on current modeling efforts. The model is being populated by utility data gathered for the GE modeling studies, and is capable of simulating detailed system operations and costs. It will provide HNEI with the capacity and flexibility to analyze additional renewable energy scenarios and sensitivities either to supplement existing projects, or do independent analyses.