UNIVERSITY OF HAWAIʻI SYSTEM ANNUAL REPORT

REPORT TO THE 2019 LEGISLATURE

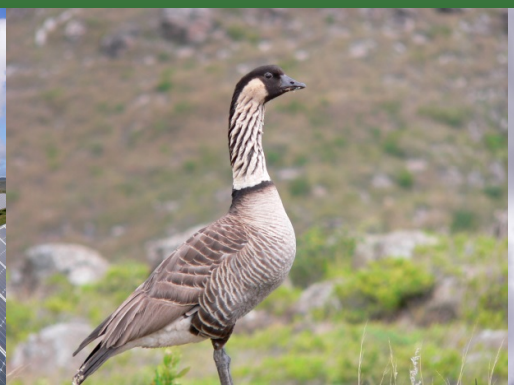
Annual Report from the Hawaiʻi
Natural Energy Institute

HRS 304A-1891

December 2018

Hawai‘i Natural Energy Institute

School of Ocean and Earth Science and Technology
University of Hawai‘i at Mānoa
Annual Report to the 2019 Legislature
HRS 304A-1891



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).

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

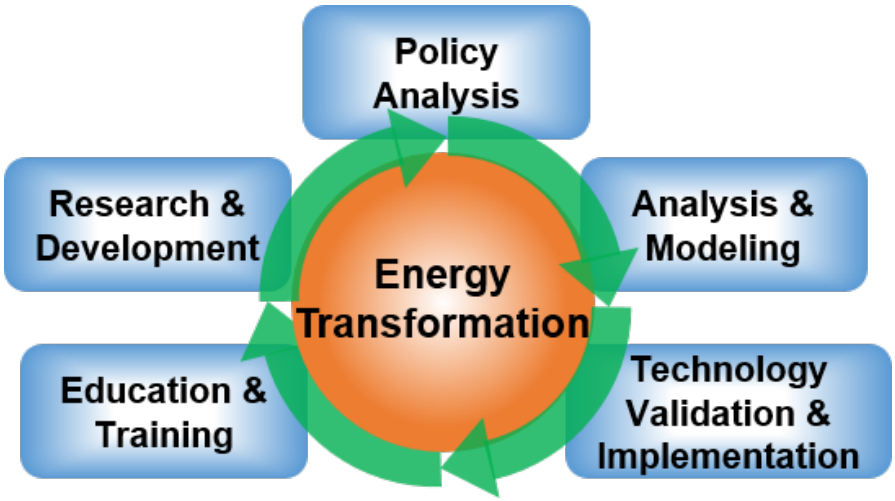


Figure 1. HNEI's inter-related functions used to maximize collaboration and leverage resources.

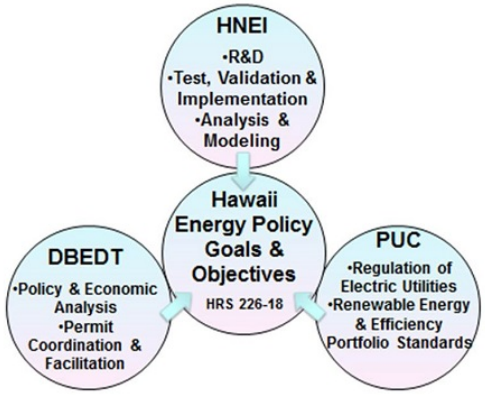
State Energy & Policy Support

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 as a State of Hawai‘i organization, HNEI is charged with contributing to Hawai‘i’s efforts to reduce dependence on fossil fuels by developing, deploying, demonstrating and evaluating renewable energy systems. Seeking commercially viable and scalable technological solutions for energy transitions, HNEI engages with industry, state and national organizations to create synergies and value through the energy business system. It leverages knowledge and resources towards specific projects and programs that will move the needle towards achieving Hawaii’s policy objectives in the energy sector. HNEI does this through its alliances with federal funding agencies, industry, the State Energy Office, State legislators, Public Utilities Commission and the Congressional delegation and other energy stakeholders.



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)

Informed by consultation with its strategic partners, advisory board, and staff on issues of strategic importance and gaps in the rapidly changing energy marketplace, HNEI identifies technologies of interest and then validates and assesses their practicality and applicability for Hawai'i's infrastructure. These activities are often continuation of internal analysis and modeling efforts of HNEI's professional staff engaged in its programs, projects and ongoing R&D activities. HNEI's TV&I projects usually involve industrial partnerships and extramural funding that often includes 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.

HNEI faculty and staff have also 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 adoption of technologies that can be commercially replicated and integrated into the market to support Hawaii's energy goals and exported to locations throughout the world.

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. In 2018 HNEI completed the 3rd report to the Hawai'i PUC assessing the status of the various electrical utilities progress against the RPS mandates.

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, the College of Social Sciences, 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) and the Pacific Asia Center for Entrepreneurship (PACE) in the Shidler School of Business.

Summary of Activities, 2018
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	19
	Other temporary staff (APT, RCUH)	14
	Training (a)	19

(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, photovoltaics, batteries, biofuels, ocean resources, and electricity grid integration. Consistent with its conventional and applied research, HNEI has, in accordance with HRS 304A-1891, 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.

In 2018, the APRISES initiative, one of HNEI significant programs, funded by the Office of Naval Research (ONR), was awarded an additional $6.6 million. This program supports research 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 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 the island of Maui.

In 2018, a new task was added to the APRISES initiative intended to develop energy system assessments to enhance the reliability, stability, and resilience of the O'ahu

power grid. These efforts will build on and expand HNEI's previous integrated analysis and high fidelity power grid system modeling. This includes comprehensive resource characterization, cost analysis, integration of high penetrations of intermittent renewables, and the technology options and operating strategies to meet mitigation needs such as demand or dynamic response, energy storage, load and energy shifting, and other ancillary services.

In 2018, HNEI has continued 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.

HNEI's is replicating its work in Hawai‘i in other regions and nations with similar energy aspirations and challenges. In the Asia-Pacific region, for example, economic growth and the associated rising energy demand presents challenges to energy security and sustainable development. The U.S. Department of Defense has recognized that cost-effective, reliable, and secure supplies of energy and water are essential factors in assuring a stable, secure, prosperous, competitive, resilient and integrated economic region and has allocated resources to foster energy self-sufficiency programs (including the APRESA program described further below).

In 2018, HNEI coordinated and participated in a microgrid feasibility analysis of three Hawai‘i test sites with Korea businesses and research institutions entitled "Energy Independence in Island States: Deploying Resilient & Affordable Renewable Energy & Microgrid Systems." The project received financial support from the Korea Energy, Technology, Evaluation and Planning (KETEP) organization. Based on the positive results of the feasibility analysis, HNEI and its Korea partners collaborated on a July 2018 proposal, "Development and Field Verification of AI-based Microgrid (MG) Operation Platform and Business Model (BM) for Overseas Market," which was approved by KETEP in October of 2018 for follow-on funding. HNEI will support the project as the Hawai‘i-based principle investigator for microgrid and renewable energy/energy storage system design, analysis and installation at the Natural Energy Laboratory of Hawai‘i (NELHA). The 3.5-year project intends to showcase a viable integrated microgrid/smart grid and renewable generation technology platform by featuring power system reliability enhancement, real-time data, application and experimental verification of diverse algorithms, distributed energy resources (DER) cooperative operation and reduction of air pollution emissions.

In 2018, HNEI also teamed with the Renewable Energy Assistance Project (REAP) of Alaska and the Island Institute of Maine on a coordinated effort between Maine, Hawai'i and Alaska to develop and deploy islanded grid strategies and technological solutions for remote communities. The intent of the collaboration is for HNEI, REAP and the Island Institute to assist selected islanded communities and remote locations in understanding through efficient and effective design and analysis how to best carry out energy transition efforts to achieve a myriad of public policy objectives.

HNEI has been an Invited participant in international meetings that enhance research visibility and prominence of the University of Hawai'i at Mānoa and HNEI, such as the United Nations Global Solutions Summit 2018 (GSS 2018) convened at United Nations Headquarters in New York City on June 4, 2018. There, HNEI joined more than 450 participants ranging from impact investors, fund managers, scientists and inventors, social enterprise founders and entrepreneurs, students, NGOs, UN officials, and government officials from around the world. HNEI was also an invited participant in the 3rd annual United Nations Science, Technology and Innovation (STI) Forum 2018 on June 5-6, 2018, a multi-stakeholder, multi-nation forum to discuss solutions to Sustainable Development Goals with clean energy as one of the selected main topics.

Specific programs and projects are described in more detail below:

Asia Pacific Regional Energy System Assessment

The U.S. Department of Defense has recognized that cost-effective, reliable, and secure supplies of energy and water are essential factors in assuring a stable, secure, prosperous, competitive, resilient and integrated economic region and has allocated resources to foster energy self-sufficiency programs. In 2018, HNEI carried out the second year of a $13.1 million five-year extramural award by the Office of Naval Research to develop comprehensive energy system assessments that include technology options and operating strategies to enhance the reliability, stability, and resilience of the energy systems in select locations throughout the Asia-Pacific region and other geographic regions/countries of strategic US interest. Under the APRESA program, HNEI conducted preliminary energy systems evaluations for energy resources, power grids, energy efficiency and policy for a number of the Asia-Pacific countries such as Australia, New Zealand, Japan, Republic of Korea (ROK), Vietnam, Thailand, Malaysia, Singapore, the Philippines, and Indonesia.

From these preliminary evaluations, Vietnam has emerged as a featured APRESA opportunity stemming from multiple discussions and meetings with Vietnamese officials in Vietnam, Hawai'i and Washington, DC, during 2017 and early 2018.

In its support of key elements of Vietnam's proposed energy transition, HNEI had significant contact and discussions with the following entities throughout the Asia-Pacific region to evaluate and pursue as deemed appropriate strategic collaboration opportunities:

- Vietnam Academy of Science and Technology (VAST)
- Vietnam Ministry of Science and Technology, National Institute for Science and Technology Policy and Strategy Studies (MOST/NISTPASS)
- Vietnam Ministry of Industry and Trade, Electricity and Renewable Energy Authority (MOIT/EREA)
- Ho Chi Minh City University, Departments of Architecture and Urban Engineering
- Center of Regional and Urban Studies (CRUS), Ho Chi Minh City, Vietnam

In 2018 HNEI signed an MOU and formed a partnership with Ho Chi Minh City in Vietnam to develop a renewable energy demonstration site that will offer Ho Chi Minh City a visible and impactful means of increasing public awareness of energy efficient and renewable energy technologies. In collaboration with the NGO Center for Urban and Regional Studies (CRUS) and partner MKThink, HNEI planned and executed an energy efficiency summit in Ho Chi Minh City July 24-25. Attended by approximate 60 stakeholders, this summit identified numerous and diverse project opportunities. The summit team distilled all suggestions to a single course of action, a solar energy education pavilion and renewable energy site to be installed at a highly visible public park. CRUS and HNEI are currently developing conceptual plans and feasibility analysis in support of a project build-out in next two years.

During 2018, HNEI's GridStart team also conducted grid analysis and modeling for major electric utilities and government organizations in Vietnam under the USAID Vietnam Low Emission Energy Program (V-LEEP). HNEI's policy team is also supporting V-LEEP in the study and design of a suitable renewable portfolio standard (RPS) and RPS implementation roadmap in cooperation with the National Renewable Energy Laboratory (NREL).

In Thailand, another APRESA area of interest, HNEI executed a Memorandum of Understanding (MOU) with the following entities for collaboration: (1) Electricity

Generating Authority of Thailand (EGAT); and (2) Chulalongkorn University. Pursuant to the EGAT MOU, a joint HNEI-EGAT renewable energy grid integration analysis has been launched to assess the impact of high renewable energy penetrations on the Thai power grid and evaluate candidate mitigation measures to achieve effective integration. Under the Chulalongkorn MOU, Chulalongkorn has requested HNEI support on a project initiated by the Thai Energy Policy and Planning Office (EPPO) to define desired characteristics of firm RE resources, including dispatch control and ancillary services. The project deliverable is a proposed grid code revision applied to firm power RE interconnections to the Thai power system.

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 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 was 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 analyzes the impacts of the proposed development of high penetration levels of solar PV projects on Guam. The study provides the technical requirements for the PV projects as well as the system improvements required for the GPA power system to accommodate the high levels of PV integration being proposed. This work was completed in September of 2018.

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. The smart PV inverter testing and evaluation was completed in August of 2017. However, GridSTART continues to use the rich data set collected over the duration of the project to conduct follow-on research on the development data sets for distributed PV systems with limited data measurements

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. HNEI’s data collection period for this BESS ended in March of 2018.

A 2MW Moloka‘i BESS was installed and commissioned at the Palaau power station in June 2016 to help with the stability of the grid that has a high penetration level of distributed rooftop PV generation. Innovative control strategies are being tested to enable this system to provide fast response contingency reserves to manage transient disturbance such as the sudden loss of load or loss generation. As the testing progresses, the available power level of the BESS is being increased gradually and is expected to be at 1MW by January of 2019.

The 1MW CIP BESS completed installation and commissioning 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 enabling the testing of control algorithms and providing a wealth of data and experience 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 Kaneohe 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. GridSTART in collaboration with the Okinawa Institute of Science and Technology and the PUES Corporation of Okinawa have completed the development of an electric power boat, vehicle and associated swappable battery system on Coconut Island. The balance of the DC microgrid is under development.

Maui Virtual Power Plant Demonstration Project: Using Barrel Tax funds and leveraging BESS and PV 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 Haleakala Solar's business offices and operations center, and at Maui Electric Company's operations baseyard, 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. Following the resolution of several equipment and permitting issues in 2018, the project is expected to get underway in the first quarter of 2019.

Moloka'i Dynamic Load Bank: Moloka'i has reached the PV hosting capacity of the system. As a result, no additional Net Energy Metered PV systems have been allowed on the island since 2015 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 managed. 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 was installed to safely absorb the excess energy. Although acting a "safety valve" to sink or discard the excess energy, this low-cost solution (~$170,000) will allow a substantial amount of additional PV on the system and potentially help to maintain grid stability. The load bank's control system is currently managing potential the excess energy. HNEI is working with MECO to develop additional functionality to provide a frequency response as well.

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.

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. As illustrated in Figures 1 to 4, the site improvements have been completed. The hydrogen systems were installed and are currently being commissioned. It is expected to be fully operational by February 2019.

Figure 1: NELHA Hydrogen Station Rendering

Figure 2: NELHA Hydrogen Station Aerial View

Figure 3: NELHA Hydrogen Station Main Entrance

Figure 4: NELHA Hydrogen Station Dispenser

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

Figure 5: County of Hawaii Fuel Cell 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 and leverages technology developed by HCATT and the US Air Force. The bus will be operated by the County of Hawai'i Mass Transit Agency (MTA) and will be used to demonstrate hydrogen technologies to the public in Kailua-Kona. The MTA bus fuel cell power system was recently upgraded from 30 kW to 40 kW with a new technology US Hybrid fuel cell. The MTA bus was also retrofitted with a 10 kW power export unit that converts the stored energy on the bus to 110/120 VAC power for up to 30 hours of power. The bus can then be refueled with hydrogen for another 30 hours of supplying emergency power. This effectively converts the bus into a mobile power supply that supports civil defense during environmental emergencies such as hurricanes and flooding. 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 2019.

HNEI 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 (HAVO) and NELHA. In May 2018 Mother Nature struck a major blow to the project with the eruption of the Kilauea volcano at HAVO, causing significant damage to HAVO's infrastructure. After 3 months, the eruption finally stopped in August, however volcanologists have stated there is no guarantee that the eruption will not start again. The eruption has not been officially declared over by the Governor. The HAVO segment of the project is currently on hold until the situation has been clarified.

Marine Corps Base Hawai'i (MCBH) Hydrogen Fueling Station at Kaneohe Bay:

HNEI developed a "Fast Fill" dual pressure (350/700 bar) hydrogen fueling station for MCBH in support of five General Motors (GM) Equinox Fuel Cell Electric Vehicles (FCEVs) leased by ONR (Figure 6). The station successfully completed over 400

fueling operations between November 2014 and August 2015 when GM recalled the vehicles. 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):

HNEI continues to work 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.

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

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 continues to conduct testing to better predict the lifetime of grid-scale battery energy storage 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 through September 2018.

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.

FEATURED PROGRAMMATIC INFORMATION - 2018

Expenditures: **General Funds $ 1,303,572**
Tuition and Fees S Funds $ 16,359
Research and Training Revolving $ 529,028
Extramural Awards $ 10,104,851

Contracts Developed

Due to new or expanded programs directed to Asia-Pacific partnerships and secure microgrids HNEI has consistently been able to capture extramural funding of over $10 million per year.

These funds support the research and training activities described above. We anticipate 2019 extramural funding levels to be comparable to those from 2018. HNEI has developed many subcontracts under its existing extramural federal funding including use of the Energy Systems Development Special Fund for cost share. HNEI coordinated and planned for ESDSF expenditures with the State Energy Resources Coordinator. Specific projects funded by ESDSF are described below.

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. Specific activities include:

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 maintains its impartiality by abstaining from proposing legislation on matters in for which it conducts research. However, HNEI informs policies at all levels through its analysis, findings, reports and outreach.

At the state level, HNEI is a member of the Hawai‘i Energy Policy Forum and provides feedback on the Forum’s review of 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.

At the federal level, HNEI is an Affiliate Member of the National Association of State Energy Officials (NASEO), the only national non-profit association for the governor-designated energy officials from each of the 56 states and territories. HNEI supports NASEO’s efforts to facilitate peer learning among state energy officials and for advocating the interests of the Hawai‘i and other state energy offices to Congress and federal agencies.

ENERGY SYSTEMS DEVELOPMENT SPECIAL FUND

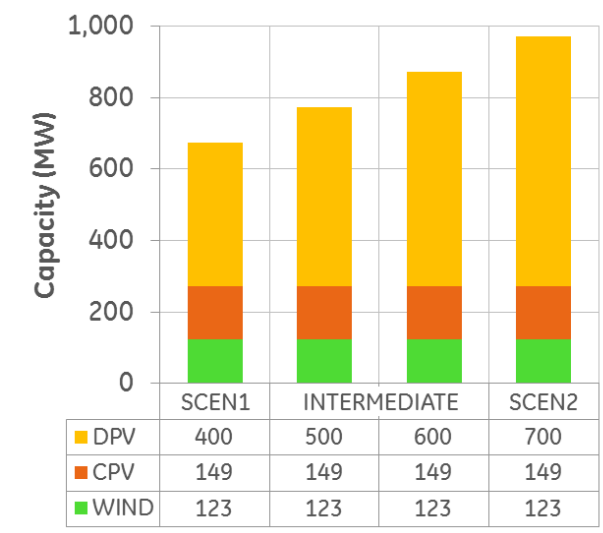
The Energy Systems Development Special Fund (ESDSF) was established in 2007, but went unfunded until 2010, when the Hawai'i Legislature established a barrel tax and authorized that 10 cents of the $1.05 tax on each barrel of petroleum product imported into Hawai'i be deposited into the Fund. This has amounted to approximately $2,300,000 per year of barrel tax funding for the ESDSF. HNEI works in collaboration with the State Energy Resource 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.

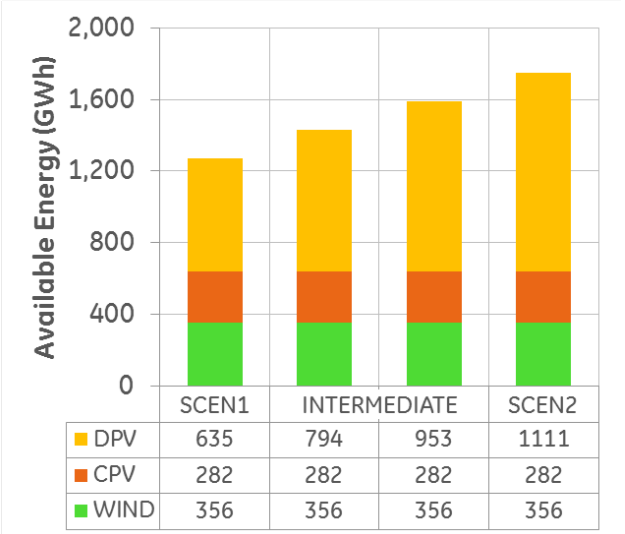
Below is a description of projects that were supported by money committed from the ESDSF and were ongoing or completed in FY 2018, and newly initiated and planned projects.

GRID MODELING/ANALYSIS

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

Supported by GE Power, HNEI conducts electricity grid modeling and independent assessments of issues critical to policy development and infrastructure investment in Hawai'i. Because of Hawaii's isolation, analyses of its six independent electrical grids represent evaluated impacts of increasing renewables, system challenges, mitigations and the costs and benefits of various solutions that are not only important to Hawai'i, but are relevant on the world stage.





The Charting the Path to a Renewable Future RPS Study II is a multi-year analysis 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

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.

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.

Pathways to an Open Grid: O‘ahu

HNEI is partnered 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 was 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 hopes 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 contributed $125,000 to HNEI for its support of the effort.

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 Haleakala Solar’s business offices and operations center, and at Maui Electric Company’s operations baseyard, 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.

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.

ALTERNATIVE FUELS AND ENERGY TECHNOLOGIES

Hydrogen Fueling Transport Trailers

ESDSF money was used to purchase two hydrogen transport trailers (HTT) 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, however this plan is on hold due to the Kilauea eruption. 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.

It was decided to recertify the HHTs that were approaching their five-year certification expiration date before they were shipped by Powertech to Hawai‘i in order to save the very high expense of shipping them back to the mainland. There is no cylinder certification capability in Hawai‘i able to certify composite cylinders of the size used in these trailers. The hydrogen storage cylinders were successfully certified by Luxfer, the cylinder manufacturer. During the inspection of the trailer frames, a defect was discovered caused by water freezing inside one of the structural steel tubing components. This required the frame to be repaired and recertified. The frame repair has been completed by Powertech (Figure 7). The trailers are being shipped to Hawai‘i with the first trailer scheduled to arrive at NELHA in December 2018.

Figure 7: Hydrogen Transport Trailer undergoing certification at Powertech

Figure 8: New hydrogen compression post

HNEI contracted Powertech to design and build a hydrogen boost compressor system that will be used to extract residual hydrogen from the hydrogen transport trailers. This will significantly reduce the number and cost of delivery trips by approximately 50%. Figure 8 is a photo of the new compression post that contains the boost pump.

ENERGY EFFICIENCY

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

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 Hawaii’s energy initiatives.

Advanced Energy Efficient & Renewable Technologies Training and Workshops
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, HNEI and ERDL provided instructors for a two-day seminar on lighting technologies, a six day seminar in lighting design and four webinars on building energy simulation, all intended for contractors, professionals, and students to inform sustainable design for Hawaii’s climate.

Technical Support Services to the Hawai'i Public Utilities Commission

In 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 Hawaii'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 has provided $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 was been committed to additional GE grid modeling work to support this agreement.