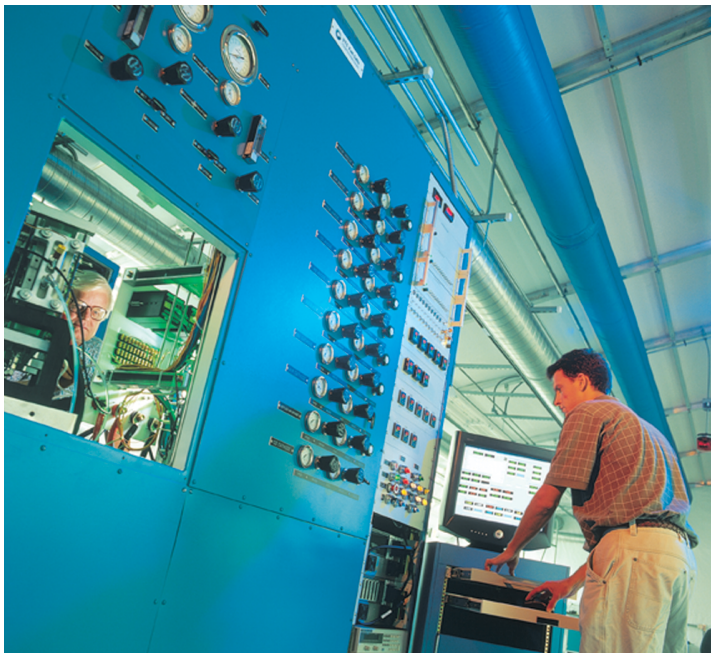
10 Hawai‘i Natural Energy Institute

10.1 Introduction



HNEI Mission (from ACT 273)

To coordinate and undertake the development of Hawaii's abundant natural energy sources, in order to:

- Diminish Hawaii's dependence on imported fossil fuels;
- Meet the state's increasing energy demands with little or no environmental degradation;
- Contribute to the technology base for finding solutions to the national and global energy shortage;
- Coordinate with state and federal agencies; and
- Demonstrate and deploy efficient end use technologies, including those that address peak electric demand issues.

The Hawaii Natural Energy Institute (HNEI) was established in 1974 to coordinate and undertake the development of natural energy sources for Hawaii. In 2005, HNEI faculty developed a strategic plan which called for HNEI to be the UH and State focal point for multidisciplinary research and education on the energy supply for Hawaii. In this plan, HNEI proposed to take a leadership role in the development of public-private partnerships on sustainable energy deployment and demonstration projects in Hawaii.

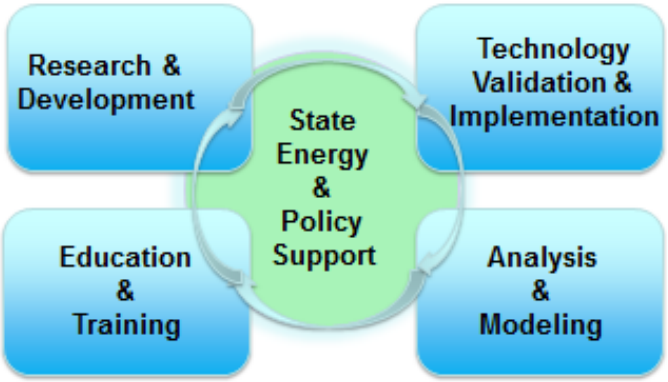
The significance of HNEI's contributions to the State was recognized by the Hawaii State Legislature which, in 2007, established HNEI in statute (ACT 273) and expanded its mandate to explicitly include coordination with state and federal agencies; and the demonstration and deployment of efficient end use technologies including those that address peak electric demand issues.

In executing this mandate, HNEI has assumed a pivotal role within the state to reduce Hawaii's dependence on fossil fuels, serving as the implementing organization for several large, high-visibility public-private partnerships to develop, deploy and demonstrate renewable energy systems. HNEI works closely with federal funding agencies, industry, the State Energy Office,

our State legislators, and our Congressional delegation; regularly participating in high level coordination meetings.

HNEI supports the State's "Hawai'i Clean Energy Initiative" (HCEI), to achieve the goal of 70 percent clean energy by 2030. HNEI also manages and implements the Energy Research Special Fund, funded through a tax on petroleum ("Barrel Tax") imported into the state. We also serve as a critical bridge between State and Federal initiatives. For example, HNEI serves as the implementing research partner for the Asia Pacific Technology and Education Program funded by the Office of Naval Research ("ONR"). The Director of HNEI also serves as co-chair of the energy subcommittee for the UH-PACOM (US Pacific Command) Partnership, formalized in 2010.

While HNEI's responsibilities go beyond traditional academic research, playing a significant role in public-private partnerships and supporting analysis for state energy policy, we have also maintained our strong core research effort. Today, HNEI conducts programs in the areas of Alternative Fuels; Renewable Power Generation Technologies; Energy Efficiency; Electrochemical Power Systems; and Systems Integration/Energy Security. As described in more detail below, HNEI faculty are predominantly non-tenure track, allowing greater flexibility in realigning research efforts. Along with the multidisciplinary education and extensive experience of HNEI's staff, HNEI can consistently align its efforts with the changing objectives of the State of Hawaii, the US DOE and DOD. For example, Systems Integration/Energy Security, the area with the most significant amounts of federal and state funding today were not part of HNEI's portfolio at the time our latest strategic plan was developed. HNEI's sustainability activities remain well aligned with the State's energy goals and with the University's Strategic Plan.



The energy needs of the state and the nation are both urgent and complex. Solutions are often capital intensive with long lead times and have the risk of unintended consequences. Development of technology, strategies and policies that will have significant positive impact on the state energy mix requires the integration of analysis, research, engineering, economics, and policy…. and more. It requires people from a wide range of disciplines and from different types of organizations to work together. HNEI operates in this manner.

HNEI's activities can be grouped into five core functions; Research & Development, Technical Validation & Implementation, Analysis & Modeling, Education & Training, and State Energy & Policy Support. As illustrated in the schematic, these functions are inter-related, and overlap by design, in order to maximize collaboration and leverage resources. These functions are described in more detail later in this document.

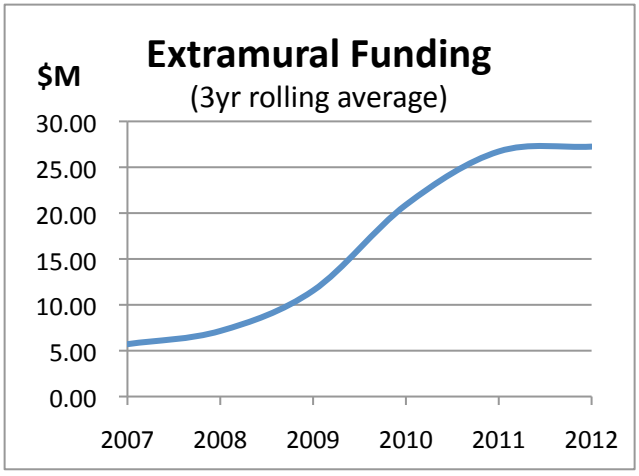
10.2 Strengths, Weaknesses, Opportunities and Threats

Strengths

The foundation of HNEI's strength lies in its people. The diversity of talents, education, experience, and the entrepreneurial spirit of this team create flexibility in performing the range of HNEI responsibilities, and consequently success in securing awards. In recent years, HNEI has forged strong partnerships with industry partners and state organizations creating a thriving synergy that expands resources and accomplishments for all involved. HNEI's ability to develop and to manage these partnerships provides stability to HNEI's portfolio and enhances the benefits afforded to residents of Hawaii. HNEI has a reputation for independent analysis, allowing us to work equally with the PUC, the State, and the state's utilities - groups that are frequently at odds with each other.

As described in more detail in subsequent sections and in the Appendices, HNEI is the leading partner in a growing number of federally funded multimillion dollar partnerships. Although HNEI has only 7 permanent faculty members, our success in garnering extramural funding provides us with the resources to support additional research and technical staff, to support undergraduate and graduate research, and actively engage post-doctoral fellows and visiting interns. As summarized in the figure below, HNEI has seen a dramatic increase in extramural funding from $5.7 million in 2007, to over $25 million for 2011 and 2012 (based on 3 year rolling averages).

HNEI's programs are also unique among those at UH in their requirement for cost share with some as high as one-to-one non-federal to federal dollars. HNEI has used its strong partnerships with industry and the state to meet these cost share requirements. Since 2007, HNEI has raised more than $20 million in cost share commitments from our partners.



ACT 273 establishing HNEI in statute has brought greater recognition to the institute, both within and outside the state government. ACT 73 passed in 2010 and amended in 2012 also provided additional resources via the Barrel Tax. HNEI is working with DBEDT and the legislature to extend the sunset date of this fund, currently 2013, until the year 2030. This would provide increased stability to HNEI programs.

Weaknesses

HNEI is currently severely understaffed for the level of funding the organization now enjoys, which can be viewed as its main weakness. This also limits the number of opportunities for

further partnership development and funding pursuits. However, staffing levels are being addressed, and is an area within the control of the organization to remedy.

Opportunities

The need for technological advances in sustainable, cost effective energy is unlikely to diminish in the foreseeable future. This provides robust development opportunities in Hawaii and the US as a whole. HNEI is well positioned to continue to bring funding into Hawaii, and progressively develop solutions to Hawaii's many energy and sustainability challenges. Specific opportunities include: grid integration, energy security, alternative fuels, and energy efficiency.

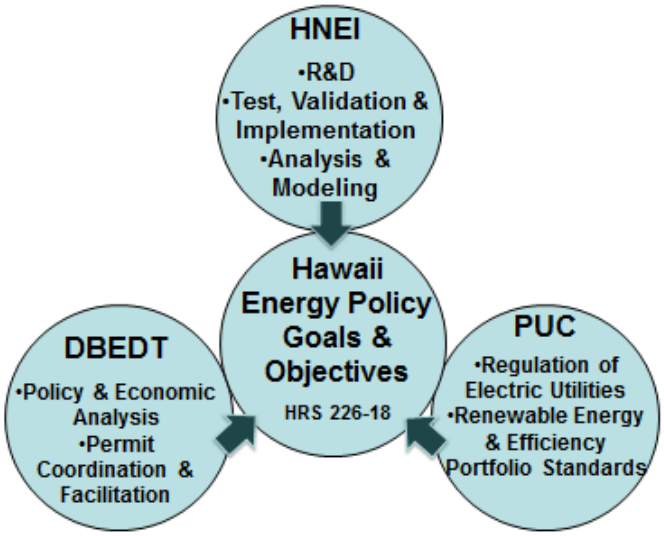
Hawaii's location and energy needs also serve as an opportunity for the institute. The critical energy needs, unique island grid systems, and rapid growth of renewable energy on the grid allows Hawaii to serve as a test bed for the nation for deployment of advanced energy systems. Through its partnerships, HNEI has taken advantage of this opportunity and is now well-established in this field of work. In addition, the Pacific region has been recognized for its near term strategic importance to the nation, and Hawaii is also home to the DOD's Pacific Command. Energy is one of three topical areas identified in the UH-PACOM MOU. HNEI has been able to take advantage of these opportunities. Several of HNEI's activities are co-funded by USDOE and ONR who have similar energy goals. HNEI is working to expand partnerships in the Pacific region. This is discussed in more detail in our Focus Areas Section of this document.

Threats

Changes in Federal funding always pose a potential threat to research institutions, particularly when the majority of faculty and researchers are dependent on contracts or soft money. However, HNEI's focus and successful track record are well-grounded in the needs –urgent and long-term – for a stable and cost-effective energy mix for Hawaii and the nation.

10.3 Governance and Faculty

The Hawaii Natural Energy Institute is an Organized Research Unit (ORU) of University of Hawaii at Manoa. The Institute Director is appointed by the President of the University. In addition to the Director, HNEI also has 7 permanent faculty positions, and 3 permanent administrative support staff. HNEI also supports a variety of full time faculty and staff with specialties required



to meet the program objectives. HNEI currently has 22 temporary faculty, 2 senior staff hired through RCUH, and 9 APT researchers funded by extramural awards. HNEI also currently supports 14 graduate students, 11 post-doctoral fellows, and is hosting 2 visiting scholars. Students are supervised by HNEI faculty who serve on the graduate faculty of various departments across campus and as chair of their thesis/dissertation committees. HNEI programs also support faculty and students in many other departments across campus.

HNEI has faculty meetings on an as needed basis with attendance based on the objectives of the meeting. HNEI has a Departmental Personnel Committee (DPC) that meets to decide on HNEI policy regarding personnel procedures and policies. Because of our small size, HNEI may also organize a Faculty Personnel Committee, including members from outside HNEI, for tenure and promotion action. The HNEI DPC conducts constructive annual evaluations of its entire non-tenured probationary faculty based on metrics defined in the HNEI Criteria for Tenure and Promotion.

As introduced above, Section 304A-1891 (ACT 273) passed by the Hawai‘i State Legislature in 2007 established the Hawai‘i Natural Energy Institute (HNEI) in statute, defined duties of the institute and its director, and requires an annual report to the legislature on its activities, expenditures, contracts developed, advances in technologies, coordination with State agencies and programs, and recommendations for proposed legislation. The relationship of HNEI with other state agencies engaged in the development of alternative energy for the state is depicted in the figure below.

Field	Highest Degree				
	PhD	**MS**	**BS**	**JD**	**MBA**
Engineering(1)	9	5	1		
Math/Applied Sciences(2)	11	1			
Other				2	2

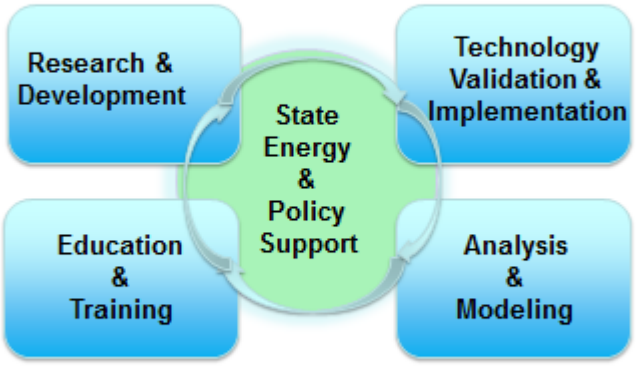
(1) Includes Chemical, Electrical, Mechanical, Ocean, Biological, and Materials Engineering
(2) Includes Applied Math, Chemistry, Electrochemistry, Energy Studies, Environmental Planning

HNEI’s senior staff, including both faculty and other staff (e.g RCUH hires) is truly multidisciplinary, with a wide diversity of backgrounds. For efforts requiring additional expertise, HNEI also works closely with other units on campus. In 2012 HNEI provided direct support to faculty and/or students in other departments within SOEST, in the College of Engineering, in the College of Tropical Agriculture and Human Resources, and in the College of Social Sciences. HNEI faculty serve on students thesis committees. This critical mass allows us to conduct increasingly comprehensive and complex research. The table to the left summarizes the academic diversity of HNEI’s faculty and two senior staff from RCUH that engage in business development for the institute.

10.4 Core Functions

HNEI's activities can be grouped into five core functions; Research & Development, Technical Validation & Implementation, Analysis & Modeling, Education & Training, and State Energy & Policy Support. These functions are driven by HNEI's mission, are inter-related, and overlap by design, in order to maximize collaboration and leverage resources.

10.4.1 Research & Development (R&D)



HNEI is recognized nationally and internationally as a research leader in areas such as hydrogen and fuel cells, biofuels and ocean resources. HNEI has won many highly competitive grants from several federal agencies include the USDOE, ONR, Air Force Office of Scientific Research, National Science Foundation (NSF), the Consortium on Plant Biotechnology Research, and the Directorate of Central Intelligence which have resulted in many publications and afforded high visibility for HNEI, UH and Hawaii. These R&D efforts support students and post-docs and have resulted in national and international patents including ones that have been licensed and are among the largest sources of revenue for UH/OTTED. Our faculty engage in collaborative research projects with many prestigious international agencies and universities in Asia and the European Union. Faculty chair sessions at the annual meetings of national and international conferences and workshops, and serve on the editorial boards of prestigious peer-reviewed scientific journals. Faculty have published more than 150 peer reviewed papers since 2007, and have made numerous invited presentations at national and international conferences. Specific projects are described in Section IV, Focus Areas.

10.4.2 Technical Validation & Implementation (TV&I)

Moving R&D discovery from UH labs to market is an important aspect of HNEI's TV&I mission. We have been successful in transferring patented HNEI technology in a variety of areas to demonstration scale, and even commercial implementation. HNEI has licensed technology in the areas of biocarbons, bioplastics from waste. Additionally, there are many emerging technologies of potential significance to Hawaii's energy needs developed elsewhere. Under our TV&I efforts, we identify and bring to Hawaii technologies of interest, for validation and assessment for use in Hawaii. These activities are frequently guided by our analysis and modeling efforts and supported by our Research and Development 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 battery energy storage technology as a solution to both transmission and distribution level issues associated with high penetration of intermittent renewable energy technologies.

10.4.3 Analysis & Modeling

HNEI conducts and supports analysis and modeling to analyze important forward looking scenarios for Hawaii's energy mix. This analysis is critical to identifying optimal and realistic paths forward to meet HCEI 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.

10.4.4 Education & Training

As an organized research unit, HNEI does not have its own academic program. However, HNEI has developed active partnerships throughout the university. Our faculty members develop and present courses for academic units in SOEST, the College of Engineering (COE), and the College of Tropical Agriculture and Human Resources (CTAHR); co-author grant proposals and/or publications with research collaborators in COE, CTAHR, Natural Science (NS), and Social Sciences (SS). Research collaborators from these colleges use our state-of-the-art research facilities.

More than one dozen of HNEI's alumni are now faculty members of universities around the world.

Many of HNEI's faculty also have appointments to the graduate faculty in departments across campus. HNEI faculty currently support and supervise 14 graduate students across departments within SOEST, CTAHR, and the COE. HNEI also currently provides funding to Maui Community College, Kauai Community College and the College of Engineering (UH Manoa) to support curricula and workforce development.

10.4.5 State Energy & Policy Support:

HNEI is directed by statute to help the state reduce its dependence on fossil fuels. Many of HNEI's programs, particularly in Analysis and Modeling, as well as the Technical Validation and Implementation areas support the State and its policy development. Examples include HNEI's leadership in developing the State's Bioenergy Masterplan and many of the recent grid analysis described below in the Integration/Energy Security focus area. In addition, HNEI has collected over $5 million from State Barrel Tax revenues into the Energy Systems Development Special Fund and continues to receive approximately $220,000 per month. HNEI works closely with the State Energy Coordinator to identify state needs and to develop a detailed expenditure plan to maximize value of these funds to meet near term needs and opportunities within the state.

Approximately 40 % of the Special Fund has been allocated for cost share to HNEI or other university projects meeting near term needs of the state. In addition, HNEI has funded independent projects to conduct research and/or assessments that directly support the HCEI goals. These include:

Geothermal Strategic Development Study: Assess the current level of industry interest, identify state and county agency needs, and prepare a geothermal strategic development plan that will serve as a guide to state agencies involved in geothermal development.

Hawaii Clean Energy Programmatic EIS: Analysis of the potential environmental impacts of clean energy activities and technologies, including an undersea cable, that may be necessary to comply with HCEI requirements to provide information and guidance to federal and local agencies and policymakers to help make decisions about actions to support achieving HCEI goals.

HCEI Metric Study: support the Hawaii Energy Policy Forum and the Social Science Research Institute at the UH in their development of a set of metrics to measure the State's progress toward meeting the Hawaii Clean Energy Initiative's requirements.

Grid Modernization Analysis: Follow-on studies after the conclusion of detailed analyses of the various island grids, and studies to quantify the operational benefits of interconnecting Oahu and Maui counties.

Smart Meter Education and Outreach: Work with local utilities and interest groups to develop a framework to guide utilities smart meter education efforts to effectively engage consumers, communities and advocates

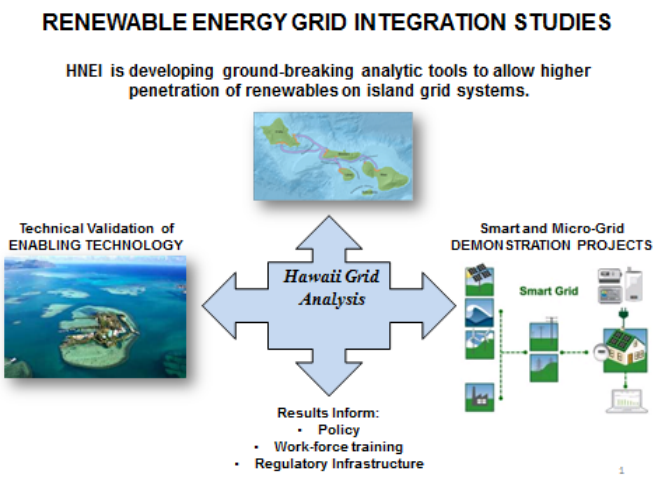
Pacific Asian Center for Entrepreneurship and E-Business (PACE): Support several fellowships at the UH College of Business to develop a workforce cross-trained in the business, legal and technical aspects of future energy systems.

10.5 Technical Focus

This section provides a brief summary of important HNEI activities organized into five focus areas; alternative fuels, renewable power generation, energy efficiency, electrochemical power systems and systems integration/energy security. Brief descriptions of representative projects are provided in each of these areas.

10.5.1 Systems Integration/Energy Security

HNEI has an established research and assessment program in integrated energy and systems analysis of electricity technologies. Through this program, HNEI conducts essential research in areas of relevance to Hawaii and abroad including analysis and modeling of isolated grid systems with high amounts of renewable energy resources, power distribution and microgrid systems, and advanced power system monitoring, intelligent control, communications and enabling technologies. HNEI's program is 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.

This is currently HNEI's largest program area encompassing an array of different projects and research initiatives. In 2006, HNEI established a partnership with GE Global Research and Hawaiian Electric Company (HECO) to develop high fidelity models of the various island electrical grid systems. Over the years this partnership has grown and evolved with new partners joining. As a result, the following activities have either been completed or are now underway:

Oahu Wind Integration Study (2008 – 2010): Utilizing a variety of modeling and grid simulation tools, this study evaluated the technical feasibility and economic viability of operational strategies, improvements to existing infrastructure, and new technologies to enable high penetrations of renewable energy in Hawaii. More specifically, through the implementation of key mitigation measures including wind power forecasting, refined reserve requirements, reduced minimum power of baseload units, seasonal cycling of select baseload units, and modified generator and wind turbine controls, a viable strategy was developed to integrate up to 500 MW of wind and 100 MW of solar energy on the isolated Oahu power grid.

Hawaii Solar Integration Study (2010 – 2012): The Hawaii Solar Integration Study (HSIS) builds upon the knowledge gained in the Oahu Wind Integration Study (OWIS). The study examines very high penetration scenarios of solar and wind energy – up to 760 MW of distributed and utility scale solar PV and 300 MW of wind resources for Oahu, and up to 45 MW of distributed and utility scale solar PV and 72 MW of wind on Maui. Focusing on the operational impact on the Oahu and Maui bulk power systems, the HSIS evaluates reserve strategies, impacts on thermal unit commitment and dispatch, utilization of energy storage, renewable energy curtailment, and other aspects of grid reliability, operations and costs. Key to the study, high-resolution (2-second) solar power profiles were generated using a new combined Numerical Weather Prediction model / stochastic-kinematic cloud model approach, which represents the "sharp-edge" effects of clouds passing over solar facilities. Study final reports are targeted for publication in December of 2012.

Oahu – Maui County Grid Interconnection Study (2012 – 2013): HNEI continues to drive, in partnership with Hawaiian Electric Company, a study that builds upon the work of both the OWIS and HSIS to examine the value proposition of prospective grid interconnection of the power systems on Oahu to those in Maui county (Maui, Lanai and Molokai) via submarine power cables, advanced control systems and operational strategies. This study is of critical importance to the State of Hawaii as high-cost investment decisions regarding the desirability and benefits of grid interconnections via submarine power cable systems progress. Study completion and report publication is targeted for February 2013.

Oahu EV Charging Study (2012 – 2013): Leveraging the validated models of the Oahu power grid refined in the OWIS and HSIS, the study's primary objectives are to quantify the impact of

electric vehicle charging on Oahu grid operations and to explore how different control techniques to manage EV charging profiles could further enhance the integration of wind and solar resources (e.g., by reducing curtailment and/or providing a new source of reserves). Study completion and report publication is targeted for March 2013.

Managing Distribution System Resources for Improved Service Quality and Reliability, Transmission Congestion Relief, and Grid Support Functions (2008 – 2014): A U.S. DOE funded multi-year research grant was awarded to HNEI to develop and validate the use of smart grid technology to reduce peak demand and facilitate the integration of intermittent renewable technologies. The project includes the recruitment of residential utility customer volunteers in south Maui and the development and integration of advanced utility infrastructure with intelligent hardware and software systems. Total expenditure for the project is around $13M with about half of it coming from our key industry partners, including HECO and Maui Electric Company (MECO), Silver Spring Networks, and Alstom.

Development and Demonstration of Smart Grid Inverters for High-Penetration PV Applications (2011 – 2015): This U.S. DOE funded, HNEI led multi-year research project with expenditures of around $12M will integrate grid management functionality software and standards-based communications hardware and software into a Fronius inverter to create a "smart grid inverter." Through modeling, development, testing, and deployment of this advanced technology in both a residential south Maui community and distribution and network service territories of PEPCO Holdings, Inc. (PHI) on the U.S. east coast, the project aims to demonstrate the ability of the smart grid inverters to mitigate grid reliability impacts resulting from high-penetrations of distributed PV systems. Key partners in this project include utilities HECO, MECO and PHI, technology providers Fronius, Silver Spring Networks and Hitachi, and community volunteers and stakeholders.

Japan-U.S. Island Grid Project (2011 – 2016): This large-scale smart grid project valued at over $40M is funded by the New Energy and Industrial Technology Development Organization (NEDO), a Japan government agency, and is led by technology provider Hitachi. The project seeks to integrate high levels of PV, wind energy, and electric vehicles into an island based smart grid environment on Maui. Along with the two HNEI led smart grid projects identified above, this NEDO sponsored project is co-located in south Maui, shares partners in common, will integrate hardware, firmware and software across project boundaries, and will compare and correlate results and lessons learned. HNEI serves a key technical advisory role and is guiding the close coordination of project development and execution across all three Maui sited smart grid projects.

Battery Energy Storage System (BESS) Testing and Evaluation: Funding in the amount of $8M from the Office of Naval Research (ONR) and U.S. DOE has been placed to deploy, operate, and validate the performance of four grid-scale BESS for various ancillary service applications on the grid. The first, a 1MW Li-ion titanate battery was installed in 2012 at the Hawi Wind plant on the Island of Hawaii. Algorithms to manage frequency variability, a major consequence of the uncontrolled ramping of intermittent sources, have been developed and will

be tested live on the HELCO grid. The second is the Waiawa Battery Energy Storage Project on Oahu, with testing and evaluation of a 1MW Li-ion titanate battery system and control algorithms for power quality control in a distribution line with a high penetration of photovoltaics.

10.5.2 Energy Efficiency

Energy efficiency is a cornerstone of Hawaii's commitment to reducing its reliance on fossil fuels. In 2008 The Hawaii Clean Energy Initiative established a goal of 70% clean energy in Hawaii by 2030, with 30% from energy efficiency and 40% from renewable energy. As a key voice in the development of state energy policy, HNEI began to engage in energy efficiency research in 2010 and by 2012 hired full time staff dedicated to energy efficiency activities. HNEI's objectives are to support the development and deployment of energy efficiency through research, testing and validation of technologies, education and training, and project collaboration with private and public sector partners that include:

- United States National Park Service (NPS)
- Golden Gate Park Conservancy
- Forest City Military Communities
- State of Hawaii Department of Business, Economic Development and Tourism (DBEDT)
- State of Hawaii Department of Education (DOE)
- University of Hawaii School of Architecture's Energy Research and Design Laboratory (ERDL)
- County of Kauai
- Project FROG
- MK Think
- Anderson Anderson Architecture
- Loisos + Ubbelohde Architecture * Energy (L+U)

Ongoing projects that illustrate HNEI's activities include:

Energy Neutral Buildings Performance Comparison Study: In collaboration with PROJECT Frog and MKThink, HNEI is deploying and instrumenting several high performance, energy neutral or Net Zero Energy (NZE) buildings on Oahu and Kauai to evaluate their performance in differing environments and different usages. The performance (energy and comfort metrics) of these structures will be compared to standard buildings in Hawaii and used to validate predictive models.

Off-Grid Net Zero Energy Visitor Center: In collaboration with Anderson Anderson, a San Francisco based architecture firm, HNEI is deploying a turn-key, off-grid Net Zero Energy Visitors Center for the NPS in Volcano National Park on the Big Island. This structure will

demonstrate performance of advance building design and state-of-the art energy technologies including photovoltaic solar energy, advanced lighting, and energy storage for off-grid applications.

Advanced Deep Retrofit Programming for Local Governments: HNEI is collaborating with the County of Kauai to develop a performance contracting model (Energy Savings Performance Contract or ESPC) with aggressive goals to achieve 30% beyond a conventional energy savings retrofit. HNEI is working with L+U and other consultants to ensure a successful outcome, and to help establish the template for future ESPC projects in the State.

Education and Training: Building Simulation and Energy Modeling Skills: In collaboration with the School of Architecture's Environmental Research and Design Laboratory (ERDL), HNEI is supporting development of core competencies on the UH Manoa campus in building simulation, modeling and monitoring to provide students and design professionals a new professional skillset required to meet Hawaii's increasingly stringent International Energy Conservation Codes.

Monitoring and Field Performance Validation: ERDL and HNEI staff have partnered with Forest City to develop building monitoring and instrumentation skills and to assess performance of energy efficiency measures in a residential setting.

State of Hawaii Department of Education Facilities Energy Audit and Inventory Study: At the request of the SOH DOE HNEI is facilitating a project that will develop an analytic tool to evaluate, assess and rank all school facilities within the state based on a range of DOE-defined criteria that includes environmental conditions, energy use, comfort and other human factors related to healthy learning environments. HNEI will participate as the administrative lead utilizing the expertise of MK Think as prime contractor. The key deliverable to the DOE will be an analytic tool they can use to objectively prioritize building and campus improvement projects using their own sustainability criteria.

The scope includes using UH Environmental Research and Design Lab personnel (staff and students) to conduct a portion of the field work as well as build computer models to simulate energy utilization and prioritize energy design options for future building improvements.

10.5.3 Alternative Fuels

An essential step in reducing our dependence on imported fossil fuels is the development of alternate fuels for transportation and power generation. HNEI has active programs with multiple projects in three areas; biofuels and high value products derived from renewable resources, hydrogen from renewable resources, and methane hydrates. In

addition, HNEI has several R&D and TV&I projects directed to the treatment of waste streams to reduce energy consumption or to produce high value products.

Biofuels: HNEI's primary focus in this area is on Research and Development, with accompanying Technical Validation to substantiate research results. Analysis and technical assessments across the entire value chain also plays an important role in guiding direction of research as well as supporting industry and the State.

Alternative fuels and energy products based on biomass resources often require development of a value chain stretching from an initial biomass resource to a refined end product as shown. With its partners, HNEI undertakes projects to inform and enable the value chain process. These activities support energy and food security for Hawaii and the US.

Waste streams: Bioprocessing offers the opportunity for low value waste streams to become a resource for bioenergy and high-value product development. HNEI is investigating processes, including high rate anaerobic digestion of dilute waste to develop integrated platforms that efficiently treat wastewater, with the concomitant recovery of energy, nutrient rich irrigation water, and soil amendments. With its partners, HNEI personnel collaboratively conceptualize and evaluate early stage translational research on (i) immobilization media that improve yield and reaction rates, (ii) system designs that integrate HRAD with pre-existing aerobic digestion technology, and (iii) biochar addition to soils as a means to improve their productivity and long-term resiliency to long-term irrigation with anaerobically treated wastewater.

Demonstration reactors, Hawaii Kai wastewater treatment facility.

Other areas of focus include biofuels and bioplastics from renewable feedstocks, involving microbial metabolism and biocatalysis, bioreactor and bioprocess design, thermal catalysis, artificial photosynthetic system for capture and conversion of solar energy and CO_2.

Hydrogen: HNEI has a long history, beginning in 1986, of conducting research to develop cost effective processes for the production of hydrogen from renewable resources. An experimental research effort to develop new materials and new device structures for the photo-electrochemical production of hydrogen continues today. Recently, 2012, this effort was expanded to include other solar fuels. In 2003, HNEI received an award from the USDOE to implement the Hawaii Hydrogen Power Park project, and Technology Validation effort to demonstrate various elements of the value chain for a practical renewable hydrogen system. This project has evolved since 2003, and now includes infrastructure deployment on Oahu and the Big Island; over $ 8M in funding form sources including USDOE, ONR, NRL, and the State of Hawaii supporting both DOD and civilian transportation projects; and new partners including Marine Corps Base Hawaii, the Hawaii Volcano National Park, the Hawaii Mass Transit authority, Hawaii Center for Advanced Transportation Technology, and Puna Geothermal Ventures, among others.

Methane Hydrates: Since 2002, HNEI has conducted Research to understand the formation and decomposition of methane hydrates for use as a fuel; and to explore their use for engineering applications such as gas separations and water desalination.

Brief descriptions of Alternate Fuels projects for each of the sub-areas are presented below.

"Hawaii State Bioenergy Master Plan Project": The Bioenergy Master Plan was developed in accordance with Act 253, Session Laws of Hawaii (SLH) 2007, which called for a bioenergy master plan to "set the course for the coordination and implementation of policies and procedures to develop a bioenergy industry in Hawaii."

"Center for BioEnergy Research and Development": NSF funded Industry/University Cooperative Research Center program to undertake industry identified projects including carbon storage in soils under biofuel feedstock production and net energy analysis and greenhouse gas emissions from *Eucalyptus* plantations activities, etc.

"Directed Bioenergy Analyses": Stakeholder-driven analyses identified during development of the Hawaii State Bioenergy Master Plan Project were subsequently performed including assessments of invasive species, lease instruments for State lands, and life cycle assessments for bioenergy value chain components, etc.

"Assessment of Algae Production Potential in Hawaii": A statewide GIS analysis of phototrophic open pond algae production potential using suitability criteria for solar insolation, rainfall, slope, land use classification (zoning), etc.

"Experimental Characterization of Emerging Biofuel Feedstocks' Gasification Potential": Collaboration with the College of Tropical Agriculture and Human Resources to develop higher yielding plant systems suitable for biofuel production using gasification.

"Contaminant Control in Thermochemical Gasification of Biomass": Development of effective control strategies for removal or conversion of contaminants present in product gas from biomass gasification.

"Hydrogen Production from Glycerin Reforming": An experimental investigation of thermochemical reforming of crude glycerin, a byproduct of biodiesel production.

"Control of Inorganic Constituents of Biomass in Thermochemical Gasification": Development of modeling tools to predict gas-phase inorganic species formation and support control system design.

"Control of Sulfur Species in Gas-Phase Fuel Streams": Development of modified activated carbon materials to remove a range of sulfur species from low temperature fuel gas streams in residential fuel cell applications.

"Deep Ocean Reforming of Methane from Seeps and Hydrates": Experimental investigation of high-pressure reforming of methane using hydrogen peroxide simulating deep-ocean conditions.

"Fuel Reforming Using Non-thermal Plasmas": Assessment of non-thermal plasma reforming stabilized in a reverse vortex flow reactor using methane, bio-gas, tactical fuels, and biofuels.

"Production of Biofuels from Syngas": Experimental investigation of thermocatalytic formation of fuels and co-products from biomass derived syngas.

"Assessment of Second Generation Biofuels": Assessment of fit-for-purpose testing of biofuel candidates including microbial and corrosion vulnerabilities and storage stability. A second focus is the development of green additives to improve fuel characteristics.

"Hydrogen Production from Waste Resources": Investigation of thermochemical hydrogen production strategies from waste resources.

"Technology Assessment for Tropical, Island-Scale Biorefineries": Conducted assessment of biochemical and thermochemical biomass conversion systems for applicability in scale-limited, tropical biorefineries.

"Pyrolysis of Tropical Biomass Resources": Experimental laboratory-scale investigation of pyrolysis for use in evaluating products and product distributions from tropical biomass resources.

"Gas Separations": Experimental investigation of bench-scale pressure swing adsorption unit to evaluate separation strategies for hydrogen from pipelined synthetic natural gas and from product gas from the HNEI fluidized bed gasification system.

"Analysis of LPG Reforming Options": Evaluation of LPG reforming as a potential source of hydrogen for distributed fuel cell power applications in Hawaii.

"Assessment for Ethanol Production Potential for Hawaii": Statewide assessment of ethanol production potential from sugarcane, banagrass, *Eucalyptus*, and *Leucaena*, based on GIS analysis of production resources and conversion technologies.

"Assessment and Analysis of Food Waste Generation in Hawaii": Characterization of food waste resources provides data necessary to inform policy and decision making and business interests.

"Biorefining of biodiesel waste to make polyesters": Experimental investigation of the conversion of crude glycerol to polyester using *Ralstonia eutropha* cells under nutrient-limited conditions to elucidate the metabolic pathways.

"Artificial photosynthetic conversion of CO_2 into polyester and bio-oil": Experimental investigation of the photosynthetic fixation of CO_2 fixation using a decoupled artificial photosynthetic.

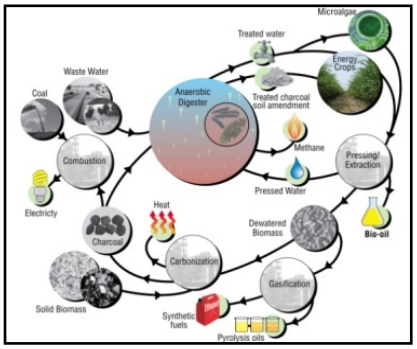
Demonstration reactors under construction, Pacific Biodiesel waste trap grease processing facility.

"*Bioprocessing of sugar waste into bioplastics":* Experimental investigation into the cost effective production of biodegradable plastics from sugar industry residues by using high cell density culture and efficient polymer recovery. This technology has been scaled up to a pilot plant and now to a commercial plant

"High Rate Anearobic Digestion": Collaborative research with Pacific Biodiesel and RealGreen Power to develop and integrate high rate anaerobic digestion of liquid wastewater into commercial process streams.

"Ionic liquid based co-solvents": Experimental investigation to develop produce multi-component ionic-liquid solvents that possess unique chemical (e.g., charge or hydrophobic/hydrophilic) and physical (e.g. structure) distribution patterns at micro-scale that result in advantageous extraction and separation features at macroscale

"Enzyme/Microbial Fuel Cell": Long standing project to develop conductive macroporous electrodes for application in enzyme and microbial fuels cells.



"Water, Energy, and Soil Sustainability (WESS)": The WESS program was created in 2011 to promote integrated efforts of UH Manoa faculty, Hawai`i's industry, State government, venture capital, legal/regulatory authorities, and the private sector with an interest in providing for the water, energy, and soil sustainability in Hawai`i. The WESS program champions a systems approach and assumes that all -- but especially small -- businesses producing liquid and solid waste streams will increasingly need to mitigate the cost of their disposal.

"Conceptual Design of Hydrate Desalination Laboratory Scale-up Facilities": Development of a conceptual design of experimental facilities necessary to provide proof-of-concept at a pilot-scale level of a process to desalinate seawater using methane or CO_2 hydrates.

"Enhanced Tactical Fuel Design: Fundamental Combustion Studies of Boron Nanoparticle Multi-Component Fuel": Experimental study of the combustion of multi-component fuels comprising aviation fuels (military grade JP-5) and boron nanoparticles to determine fundamental flame structure characteristics. This includes the design and fabrication of a benchtop burner system and instrumentation.

"Engineering Analysis of Seafloor Methane Hydrates": Laboratory and field investigations of methanogenic and methanotrophic processes in the ocean sediment and water column impacting formation and decomposition of methane hydrates.

"Subsea Application of Chemical Dispersants in Deep Oil Spills": Laboratory studies of the effect of chemical dispersants on the break-up of oil jets and the dissolution and fractionation of the resulting oil droplets rising through the ocean.

"Environmental Impacts of Deep Oil Spills": Conduct laboratory experiments and modeling to support a field experiment to investigate the behavior of deep oil spills like the 2010 Deepwater Horizon incident and develop appropriate response strategies.

"Hydrogen Energy System as a Grid Management Tool": A joint USDOE-DOD Technical Validation project to demonstrate the dynamic use an electrolyzer as a demand response tool for grid management. The hydrogen produced at the geothermal plant will be used to fuel fuel-cell-powered shuttle buses operated by the County of Hawai'i Mass Transit Agency and support of fuel cell buses at Hawai'i Volcanoes National Park.

"Marine Corps Base (MCB) Hawai'i Hydrogen Fueling Station": Technical Validation project supporting the development of 5000 bar hydrogen fueling infrastructure in support of the operation of General Motors (GM) Equinox Fuel Cell Electric Vehicles (FCEVs) at MCBH to enable the US Navy/Marine Corps to conduct technical evaluations and gain experience in the operation of FCEVs utilizing direct hydrogen fuel.

10.5.4 Electrochemical Power Systems

Under this focus area, HNEI researchers conduct testing and modeling of battery and fuel cell technology to further the understanding of their performance and durability for use in electric vehicles, for renewable energy storage applications, and for use in unmanned vehicles for the Department of Defense. This Research and Development Effort is conducted in two laboratories, the Electrochemical Power Systems Laboratory focused on the testing of emerging battery technology and the Hawaii Sustainable Energy Research Facility (HiSERF), a partnership with Hawaiian Electric Company for testing of fuel cells and other enabling technologies for grid application.

Researchers in the Electrochemical Power Systems Laboratory conduct testing and modeling to develop advanced battery system diagnostic and prognostic technology seeking to develop better protocols for management of batteries and battery charging. Funding sources include the USDOE's Office of Energy Efficiency and Renewable Energy (EERE) through the Idaho National Laboratory, the Air Force Research Laboratory through the Hawai'i Center for Advanced Transportation Technologies, the Hawai'i Renewable Energy Development Venture funds through Better Place, and the Office of Naval Research. This Research and Development Effort has resulted in several patents and a significant number of peer reviewed publications and conference presentations.

At HiSERF (formerly known as the Hawaii Fuel Cell Test Facility), researchers conduct testing on PEM fuel cells, fuel cell stacks, and small FC systems for commercial and DOD applications, including unmanned aerial and undersea vehicles. Initiated under a grant from ONR in 2001, this effort has garnered over $12M in funding from ONR, USDOE, and industry. Current Research and Development effort is focused on understanding the impacts of fuel and airborne contaminants on fuel cell performance and lifetime; and the impact of operations on the performance and lifetime of small battery-FC hybrid power systems. HNEI was part of the team (including Naval Research Laboratory and Protonex) that developed and flew an unmanned plane for over 24 hours on 500g of H2. Researchers in this laboratory have developed many innovative chemical and electrochemical characterization techniques to elucidate mechanisms controlling fuel cell degradation. These techniques are now being applied to testing of battery packs to gain additional insights into the operation of real battery energy storage systems.

Representative projects from these laboratories are described below. (A more complete listing of projects is shown in the Appendices.)

"Path Dependence Degradation Study of Li Ion Battery for PHEV Applications": Develop a realistic battery diagnostic and prognostic methodology to study battery degradation that is path dependent.

"Cell Testing": Conduct laboratory testing of advanced Li-ion battery cells that are targeted for large-scale grid energy storage applications under HNEI's integration focus area.

"Biofuel cells-Electrochemistry": Conduct advanced in situ characterizations of catalytic behavior of redox reactions at the electrode-electrolyte interfaces that are designed for bio-fuel cell applications.

"HCATT Vehicle Demonstration Program"*:* Ongoing projects to collect and analyze data related to the operation of hybrid electric vehicle powertrain and battery, fuel cell in field demonstrations with the vehicle fleet operated by the Hawaii Center for Advanced Transportation Technologies in collaboration with Air Force Research Laboratory and Hickam Air Force Base.

"*Better Place HREDV Project*"*:* Collaborate with Better Place, Hawaiian Electric Company (HECO), Kyoya/Sheraton hotels, General Motor to collect vehicle operation data from seven Chevy-Volts used in the Hawaii Renewable Energy Development Venture project and the meter data from HECO to study the charging habit of the vehicle operators and demand on charging from the fleet operation.

"*High Fidelity Electrochemical System Models*": Work with Southwest Research Institute to develop common battery system models for hybrid powertrain applications for vehicle platform simulation.

"*Nano- and Micro-Enzymatic Power Sources*": Develop and study several prominent nano- and micro-power sources using enzymatic bio-fuel cell concepts, using common fuels such as alcohols, urea, carbohydrates, and other exotic biofuels.

"Prognostic Battery Remaining Life": Work with Expert Microsystems in an STTR phase one project to develop a novel prognostic tool to predict battery service life for Joint Striker Fighter program under a Navy contract.

"Impact of System Contaminants in Proton Exchange Membrane Fuel Cells": An experimental investigation of the impact of gas phase contaminants released from system components on the performance durability of PEM Fuel Cells using accelerated testing durability protocols.

"Use of a Segmented Cell to Identify MEA Defects": An experimental investigation to assess the use of high resolution segmented cell analysis to characterize MEA defects in PEM fuel cells and facilitate their detection for manufacturing quality control.

"The Effect of Airborne Contaminants on Fuel Cell Performance and Durability": Identification, selection, and characterization of impacts of airborne contaminants including ppm levels of SO_2 to identify degradation mechanisms and devise mitigation strategies .

"Use of PEM Fuel Cells for Helium Recovery": Engineering design, modeling, and testing of a PEM fuel cell based separation system for the recovery of high purity He from mixed H2/He streams. Project scope includes the design, build, and testing of full scale hydrogen separation reactors for system integration.

"Characterization of Fuel Cell Performance with sub-ppm CO Contamination": Experimental program to measure the impact of CO in hydrogen at practically low concentrations using high resolution gas sampling and innovative analysis techniques on PEM fuel cell performance.

"*Development of Passive Noise Wavelet Filtering Technique for Identification of PEMFC faults"* Experimental program to evaluate the applicability of electrochemical noise monitoring and real-time analysis of voltage signals for fuel cell fault identification.

"Development of Spatial Gas Analysis Add-On for the Segmented Cell System": Engineering design and hardware implementation for integration of high resolution gas sampling at multiple points along the flow path of the segmented cell system.

"Testing of GM Subscale Fuel Cells for UUV Application": Experimental program to evaluate the performance impact of non-standard operating modes of automotive fuel cells, which are designed for intake of ambient air, being operated inside pressure vessels of large diameter UUVs.

"Testing of Protonex Stacks for UUV operation using H2/O2": Experimental program to evaluate the operational and safety aspects of utilizing fuel cells originally designed for H2/Air alternatively using pure oxygen as an oxidant source for small scale UUVs.

"*Evaluation of Contaminant Removal Systems for Fuel Cell Operation in Volcanic Environments":* Experimental program evaluating contaminant removal systems for fuel cell powered plug-in-hybrid vehicles for use at Volcano National Park, where the vehicle route includes exposure to elevated levels of SO2 and other volcanic emissions.

"Impact of Fuel and Oxidant recirculation in PEM Fuel Cells for UUV Application": Design, construction and testing of a flexible fuel cell reactant gas recirculation test bed to analyze accumulation behaviors of gas phase impurities in closed loop systems and evaluate mitigation strategies.

"Residence Time Distribution Analysis for PEM Fuel Cells": Experimental investigation to characterize the presence and effects of liquid and solid water within PEMFCs utilizing a volume sensitive tracer based system for the measurement of residence time distributions incorporating tracer gas injection profiles with high speed FTIR detection techniques to analyze dispersion phenomena occurring within the cell.

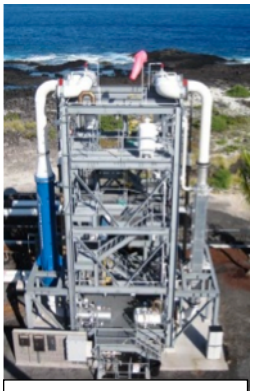
"Development of Novel Controls for Battery/Fuel Cell Power System for UAV Applications": Simulation and experimental evaluations of a novel hybrid designs and control strategies for UAV application using high speed Hardware-in-the-Loop to optimize performance and mission duration.

"Separation of reactant mass transfer coefficients using different gas diluents": Development of a novel method to separate reactant mass transfer coefficients in gas and solid ionomer phases using gas diluents of different molecular masses for the optimization of membrane/electrode assemblies.

10.5.5 Renewable Power Generation

Renewable power generation technologies have advanced significantly nationally and internationally in recent years. As a result of these advances, the high cost of electricity in Hawaii, and generous federal and state subsidies, deployment is growing rapidly across Hawaii. Within the renewable power generation umbrella HNEI has active programs in the areas of wind, photovoltaics and marine energy.

Given the advanced state of wind development, HNEI's primary focus is addressing issues associate with high penetration of intermittent wind on the electrical grid. These efforts are described in detail under the Integration/Energy Security Focus area. In collaboration with the Golden Gate Park Conservancy, and of specific interest to HNEI funding sponsors, the Office of Naval Research, HNEI has deployed five small scale (1kW) vertical axis wind turbines that are being monitored to evaluate performance for distributed applications. This work, conducted at Crissy Field Center, an environmental education center for youth located in San Francisco includes development of a web-based dashboard that monitors all of the sustainable features of the building: energy flow in and out by end-use, water, comfort and weather.



Makai Heat Exchanger Test Facility, NELHA

HNEI researchers associate with the Thin Films Laboratory conduct a modest Research and Development efforts for development of advanced photovoltaic materials. However, the primary focus of this effort is the solar generation of alternate fuels, including hydrogen. In addition, HNEI, under funding from the USDOE and ONR is conducting high-fidelity resource assessments and testing of emerging solar technologies. The objectives are to characterize real-world performance of emerging photovoltaic (PV) technologies in differing environments. These data will be publically available to inform consumers and will also support ongoing grid stability studies. HNEI has partnered with industry, the local utility, and other UH campuses in the conduct of this work.

Marine energy technologies, while less developed also have the potential to contribute significantly to Hawaii's and the nation's future energy mix. In 2008, HNEI won a highly competitive award as one of only two National Ocean Energy Test Centers funded by US DOE (a third was named in 2010). The objectives of the Center are to facilitate the deployment of wave energy technologies and to reduce the technical risk of Ocean Thermal Energy Conversion (OTEC) technology. To date, this center has received over $7M in DOE funding with an equal amount of in-kind cost share from the industrial partners. With this funding from USDOE, HNEI has forged a close working partnership collaboration with Navy to develop the nation's first grid connected wave energy test site (WETS). Navy is funding infrastructure development, HNEI is conducting independent analysis and modeling of systems performance; and developing monitoring program to characterize the physical, chemical, and biological environment.

Specific project activities in the renewable generation focus area include:

"Testing Protocol for Wave Energy Conversion (WEC) Devices": Developing procedures and data acquisition system for the independent evaluation of device output as a function of environmental input to estimate the relationship between electricity generation and wave parameters.

"*Wave Energy Test Site (WETS) at Kaneohe Bay*": Collaboration with the US Navy (NAVFAC), in the design and Environmental Assessment (EA) of a multiple-berth site for the in-water testing. When completed in 2013, this test site will have multiple berths between 30 and 70 m in depth, to accommodate wave energy devices for grid connected testing.

"Acoustic and EMF Signature of Wave Energy Conversion Devices": Field investigation of the acoustic and electromagnetic field (EMF) signature of devices tested at WETS. This should yield a unique an unprecedented database and methodology to be used by the nascent marine renewable energy community.

"Calibration of Shallow Water Wave Hindcast and Forecast Models": Wave records to be obtained with newly deployed HNEI Directional Waverider buoys will be used to calibrate the UH wave models for shallow waters conditions corresponding to depths envisioned for WEC

devices (e.g., 30 m to 80 m) and to provide developers with information about the site specific extreme waves that devices must survive during their life cycle.

"Wave Energy Converters Performance Models": (i) Develop a computer model to allow for the virtual testing, modification and optimization of single devices prior to in-water testing; and, (ii) Develop a computer model to evaluate the performance of arbitrary arrays of wave energy converters.

"Ocean Thermal Resource and Sustainable OTEC Power Assessment": Implement a numerical model with a 1° x 1° (Lat./Long.) horizontal resolution to simulate the large-scale deployment of OTEC plants across tropical oceans to estimate the world-wide power output without modifying the deep ocean circulation of the cold water resource.

"Interactive OTEC Power Atlas": Combine ocean thermal data available through the NODC's World Ocean Atlas with the HNEI OTEC thermodynamic model to provide the user an estimate of OTEC power production at any location defined by latitude and longitude.

"Aluminum Corrosion and Biocorrosion Testing": In search of cost effective materials for use in marine renewable energy systems, HNEI will continue long-term testing of aluminum alloys exposed to flowing seawater from different depths at the NELHA laboratory. Aluminum was chosen because of the relatively low cost of the material; multiple options for fabrication; and, relatively good corrosion resistance based on prior research.

"*Photoelectrochemical H_2 Production*": Study hydrogen production efficiency and stability of several promising materials used in the tandem photovoltaic-photoelectrochemical cells for hydrogen production.

Other projects focused on related solar applications and high value products include:

Photoelectrochemical hydrogen production (2007-2012, DoE via MVSystems): the goal of this research program is to develop efficient and durable photocatalytic materials to produce hydrogen fuel via solar-assisted ("wireless") water splitting process.

Solar fuels production (2012-2014, ONR): this program aims to produce hydrocarbon fuels at low cost via photo-electro-reduction of carbon dioxide by combining efficient catalysts with cheap thin-film solar cells.

Rapidly Deployable Solar Electricity and Fuel Sources (2008-2010, Air Force via Toledo): the goal of this research project is to adapt existing deposition processes in order to manufacture solar cells on flexible substrates (such as titanium foils).

Acoustic enhanced electrolyzer (2009-2010, ONR via H2 Technologies): this research project aims to establish if the water splitting efficiency of an electrolyzer can be improved by the use of acoustic cavitation.

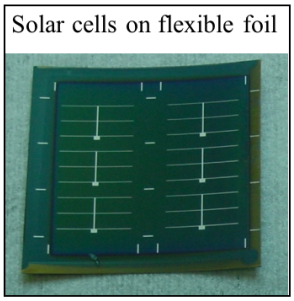
10.6 Notable Facilities

HNEI maintains a number of core laboratories which have all been equipped with the preponderance of funding from extramural sources. In addition, other than salary of our eight permanent faculties, all operating costs of these facilities are borne by extramural awards.

10.6.1 Hawaii Sustainable Energy Research Facility (HiSERF)

HiSERF (formally known as the Hawaii Fuel Cell Test Facility) was established to accelerate acceptance and deployment of fuel cells for commercial and military applications. The mission has been expanded to include battery energy storage and other grid enabling technologies. The facility currently houses eleven test stands for testing of single cells from 50 to 600 cm2 single cells and small stacks (up to 5 kW) including one high-speed hardware-in-the-loop for dynamic testing. Supporting equipment includes on-site hydrogen generation and storage, extensive safety systems, and on-line high-resolution gas analysis, and in-house innovative electrochemical test equipment. The facility houses 11 test stands most designed for long-term life testing and cell performance.

10.6.2 Thin Films Laboratory



The Thin Films Laboratory (TFL) has been a leader in innovative material research and development for solar energy conversion systems and the discovery of new photo-catalytic materials capable of direct conversion of sun light into usable chemical energy, also known as “Solar Fuels”, with focus on solar-driven water splitting for hydrogen production. The TFL is houses sophisticated state-of-the-art tools for the fabrication of thin film materials and devices, including co-evaporation chambers and sputtering systems and analysis tools for film characterization.

10.6.3 Renewable Resources Research Laboratory

The Renewable Resources Research Laboratory (R3Lab) is a test-bed for the development of innovative technologies and processes for the conversion of biomass into fuels, high-value chemicals, and other products. A consistent theme of the lab's research throughout its history has been the search for new uses for Hawaii's abundant agricultural crops and by-product. Recently, the R3Lab research has focused on the efficient carbonization of biomass. The R3Lab houses the Lab-scale Flash Carbonization reactor, as well as a moderate-temperature, aqueous-alkaline/carbonate biocarbon fuel cell assembly, a Quantachrome Autosorb 1 gas sorption analyzer, a Hewlett-Packard (HP) model 6890 GC, a HP model 5890 GC with a HP model 7673 autosampler, a Nicolet Avatar 360 FTIR with a long path cell, and

other instruments. Across campus R3Lab personnel operate the Demonstration-scale Flash Carbonization Reactor with its associated catalytic afterburner (see photo). The licensing of UH patents on the R3Lab's Flash CarbonizationTM process has been among the largest sources of licensing income to UH.

10.6.4 Ocean Resources and Applications Laboratory

Raman calorimetry system

The Ocean Resources and Applications Laboratory investigates a wide range of topics including marine methane hydrates, desalination, biofuels from macroalgae (seaweed), carbon sequestration, and deep ocean oil spills. The laboratory is equipped with a number of custom-designed ocean simulator chambers and tanks that can replicate conditions from the surface down to about 1,000 m depth. Key instrumentation include a unique facility that combines calorimetry and Raman spectroscopy, micro- and bomb calorimeters, GC, HPLC, and PDPA (phase Doppler particle analyzer) and laser Fraunhofer diffraction particle sizers. The particle sizers also have been employed in studies of boron nanoparticle combustion and medical nebulizer performance.

10.6.5 Electrochemical Power Systems Laboratory

The EPSL is an advanced R&D and testing facility with cutting edge instrumentation and computer modeling and simulation capability to assist government, industry, and private organizations to conduct battery and other electrochemical power systems R&D and evaluations. We have expertise and sophisticated test capabilities to effectively utilize instrumentation and computer simulation and modeling to evaluate electrochemical systems for energy storage and power source applications. Our testers range from high precision to high power (60 kW) systems with a variety of environmental chambers to conduct thermal and cycle aging tests with high throughput data analysis capability.

10.6.6 Biomass and Fuels Processing Laboratory

A wide variety of research is underway in the Biomass and Fuels Processing Laboratory, including activities in biomass resource assessment, thermochemical conversion of biomass, evaluation of energy conversion and utilization processes, and reforming of transition fuels for the hydrogen economy.

10.6.7 Bioprocessing Laboratory

HNEI has research facilities dedicated to anaerobic and aerobic bioprocessing. Facilities include 2, 5 and 10 liter fermentation reactors complete with full process controls as well as a 10 liter three-phase anaerobic digester. The laboratories are equipped with autoclaves, biosafety

cabinets, incubators, thermal reactor, micro and centrifuges, cell disrupters, membrane filtration systems, and freeze-dryers. Advanced instruments used for chemical and physical analysis include UV/VIS spectrophotometer, FTIR-ATR spectrophotometers, GCs with TCD/FID detectors, HPLCs with UV and IR detectors, UHPLC with RID/PDA, PC1 photon counting spectrofluorimeter, size exclusion chromatography (SEC), differential scanning calorimeter (DSC), tensile tester, Keyence 3D laser scanning microscope, and various optical microscopes with heating plates, cameras., and fluorescent lenses. Wet chemistry instruments used for measurement of liquid phase metabolites include HACH reactor systems for wastewater analysis, parametic and infrared gas analyzers for gas phase O2 and CO2, Process design, simulation and economic analysis are conducted with computer software (SuperPro Designer).

10.7 Measures of Success

10.7.1 Funding

As stated in the narrative, HNEI enjoyed substantial growth in extramural funding from just over $5M in 2007 to over $25M in each of the past two years. Many of our programs are multi-year in nature and annual funding can vary significantly due to small changes in award dates, so a rolling three-year average has been used to give a more accurate representation of our funding situation. A detailed listing of awards can be found in the supporting documents for this chapter. The current level of activity, however, is stressing our facilities and placing substantial burden on our already productive staff. Availability of space, both laboratory and office, will limit further growth.

10.7.2 Patents & Licensing/Intellectual Property

HNEI faculty are encouraged to develop intellectual property and routinely file and receive patents for their work. HNEI faculty have received 15 patents for work conducted at HNEI. An additional 7 preliminary patent applications have been filed with the patent office, and 4 disclosures have been filed with UH OTTED awaiting action. A detailed listing of patents received by HNEI personnel can be found in Appendix 10.2.

10.7.3 Publications/Reports

HNEI currently has 7 permanent faculty and 22 temporary faculty. Of the latter group, 8 are non-PhD faculty in specialist positions whose main responsibilities is providing support services within the Institute. While this latter group does support the research and authorship of papers they do no routinely initiate publications. Since 2007, HNEI has published over 150 papers in a wide range of peer reviewed journals, consistent with the diversity of our faculty. A complete listing of publications is found in Appendix 10.1.

HNEI have also contributed 17 chapters to books since 2007 predominantly in the areas of electrochemical power systems and biochemical processing. A listing of these contributions can be found in Appendix 10.3. HNEI faculty and staff have presented more than 180 papers at

national and international conferences, many of them invited talks. A partial listing can be found in Appendix 10.6.

Due to the applied nature of HNEI's programs, much of the outcome of HNEI's endeavors are initially submitted in written reports to funding agencies. Since 2007, HNEI faculty have produced more than 50 reports documenting their research and analysis efforts. Some are routine annual reports describing work effort. Others, such as the Hawaii Bioenergy Masterplan are very substantial. A summary of major reports can be found in Appendix 10.4.

10.7.4 Citations

The total citation count for HNEI is approximately 11,993. (Please refer to Appendix 10.10 for a further breakdown.)

10.7.5 Service

HNEI faculty and staff routinely provide service to various federal agencies and journals including serving as reviewers for journal submissions and book chapters; serving on local, national and international panels review panels, and organizing conference sessions and special workshops. Energy is a very important community issue in Hawaii. HNEI staff make presentations at local meetings and participate in local gatherings of the energy community. A summary of major service in these areas can be found in Appendix 10.5.

10.7.6 Strategic Plans

HNEI faculty last developed a strategic plan in 2005. In this plan HNEI stated "HNEI seeks to be the UH and State focal point for multidisciplinary research and education on the energy supply for Hawaii, coordinating and leading the effort to diversify Hawaii's energy supply with special emphasis on renewable and sustainable energy technology, energy analysis, and technology-based policy. The environmental implications of energy supply and utilization is an important component of these activities. HNEI should also take the lead coordinating organization for the development of public-private partnerships focusing on sustainable energy deployment and demonstration projects in Hawaii." Since that time, HNEI faculty and staff have made great strides in meeting this goal including development of major new partnerships, development of major new programs in integration and energy security, and new recognition from the State of Hawaii affirming our role in reducing the State's dependence on fossil fuels. HNEI has attracted and is continuing to hire new faculty.

HNEI's current programs will extend into 2016 and beyond. The legislature this year will consider legislation to extend the sunset date of the barrel tax beyond 2020, possibly to 2030. HNEI will remain an important and viable state resource for the foreseeable future. During this period of stability, HNEI faculty need to come together to lay out a new vision, based on the new realities of the state and national energy needs to assure that our value continues into the future.