FINAL TECHNICAL REPORT

Executive Summary

Asia Pacific Research Initiative for Sustainable Energy Systems

Office of Naval Research

Grant Award Number N00014-13-1-0463

For the period March 1, 2013 to September 30, 2018

HNEI
Hawai'i Natural Energy Institute
University of Hawai'i at Mānoa

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EXECUTIVE SUMMARY

This report summarizes work conducted under Grant Award Number N00014-13-1-0463 the Asia Pacific Research Initiative for Sustainable Energy Systems 2012 (APRISES12), funded by the Office of Naval Research (ONR) to the Hawaii Natural Energy Institute (HNEI) of the University of Hawaii at Manoa (UH). The overall objective of APRISES12 was to develop, test, and evaluate distributed energy systems, emerging technologies and power grid integration using Hawaii as a model for applicability throughout the Pacific Region. APRISES12 encompassed fuel cell research, contaminant mitigation and evaluation; battery testing; seafloor methane hydrates extraction and stability; synthetic fuels processing and production to accelerate the use of biofuels for Navy needs; alternative energy systems for electric power generation and integration into smart microgrids, and energy efficient building platforms. Testing and evaluation of alternative energy systems included Ocean Thermal Energy Conversion (OTEC), grid-scale battery energy storage, and development of several microgrid test projects.

Under Task 1, Program Management and Outreach, HNEI provided overall program management and coordination, developed and monitored partner and subcontract agreements, and developed outreach materials for both technical and non-technical audiences. Additionally, HNEI continued to collaborate closely with ONR and NRL to identify high-priority areas requiring further detailed evaluation and analysis.

Under Task 2, Fuel Cell Systems, HNEI conducted testing and evaluation of single cells, stacks and balance of plant components to support NRL efforts to develop fuel cells for unmanned aerial vehicles (UAVs), identified contaminant mechanisms and developed mitigation techniques for organic contaminants present in air and hydrogen, validated a method to measure and separate mass transfer coefficients suitable for the design of low cost and high power density fuel cells, and evaluated the potential of anion exchange membrane fuel cells. Development and laboratory testing continued on fuel cell air purification materials and novel sensor devices. HNEI also developed and advanced battery diagnosis techniques and investigated key performance aspects of battery modules.

Efforts under Task 3, Alternative Fuels, focused on the development, testing and evaluation of alternative fuels and technologies, and included activities in the areas of Methane Hydrates,

Technology for Synthetic Fuels Production, Low-cost Material for Solar Fuels Production, and Hydrogen Fueling Support. Methane hydrate destabilization was examined using ionic salt compounds found in seawater, and calorimetric investigation focused on hydrate formation and dissociation in sand matrices. Hydrate desalinization and removal of biological contaminants was also examined. Synthetic fuels processing focused on hydrogen production for fuel cell applications, second generation biofuel properties impacted by petroleum aromatics, solvent based extraction of fermentable sugars from biomass, development of a novel bioreactor for liquid fuels from synthesis gas, bio-contamination of blended fuels and biodiesel degradation, biofuel corrosion in diesel/renewable diesel/seawater mixtures, constant volume carbonization processing variables to convert waste biomass, and enhanced performance of hybrid biochar supports for high rate anaerobic digestion. For solar fuels production an environmentally friendly potentially low-cost thin film printing process was refined to fabricate copper-zinc-tin-sulfo-selenide solar cells with double the efficiency achieved during APRISES11. Hydrogen refueling support involved commissioning hydrogen production and compression equipment, procurement of a Power Export Unit for emergency backup power from a fuel cell electric bus, and the design of a hydrogen dispensing system.

Task 4, Ocean Energy included development of advanced heat exchangers for Ocean Thermal Energy Conversion (OTEC), Wave Energy Testing, and baseline water monitoring for Seawater Air Conditioning. To advance OTEC heat exchanger development, a subaward was made to Makai Ocean Engineering. Makai designed, built, and tested six configurations of Epoxy-Bonded Heat Exchangers. A new 100-kW test station was designed and constructed to support this testing. Results were promising and led to the design and fabrication of the Foil Fin Heat Exchanger. An autonomous control system for the OTEC test facility was also developed, and long term corrosion testing was continued. In support of the Navy's Wave Energy Test Site (WETS) off Marine Corps Base Hawaii, and in collaboration with NAVFAC, HNEI subcontracted with Sea Engineering, Inc. to conduct a selection process, deploy and commission a remotely operated vehicle (ROV). This adds a critically important capability to support wave energy conversion device and mooring inspections, particularly for the deep-water sites at WETS. Seawater Air Conditioning (SWAC) pre-impact conditions were characterized with further deployments of long-term oceanographic mooring, water column profiling and sampling to assess the environmental impact of this new system on the ocean ecosystem near Honolulu.

Funding for the Geothermal Resource Assessment planned for task 5 was reallocated to other areas of the program as approved by ONR.

Task 6, Microgrids/Grid Integration included a range of projects to develop, test and integrate secure microgrid technology including distributed energy resources. An empirical model to characterize the DC performance of PV modules was expanded to evaluate AC performance of PV systems and power conditioning units, as well as the impact of shading. Development of a

low-cost, real-time power monitor with wireless communications for distribution system operations was continued. Advanced, real-time data analysis and controls were added to the power monitor system hardware and software, leading to a second provisional patent being filed, "Enabling Ubiquitous Distribution Grid Modeling for Enhanced Visibility and Controls". Hardware-in-the-loop equipment was purchased and initial setup completed in order to test distributed energy resources and devices in real-world grid operation scenarios. Additionally, the Conservation Voltage Reduction prototype was advanced towards being more cost effective by utilizing a small DC power supply to emulate a solar module and power an inverter. Initial tests were successfully conducted at the UH Marine Center. The Battery Energy Storage System (BESS) on Molokai was modified for faster response, enabling the BESS to respond to contingency events on the grid. Work continued on the Coconut Island DC microgrid including procurement of an electric boat (E-boat) and electric utility vehicle, along with a swappable battery system. HNEI completed the conversion of the E-boat to an all-electric vehicle, and installed the battery charging station for the swappable battery system in the Boat House on Coconut Island. To increase the amount of distributed PV that can be connected and utilized by the microgrid on the Island of Molokai, the impact of a Load Bank was analyzed and found to be an effective solution. Development was continued on solar forecasting methods and systems, including testing and evaluation in an operational framework, and validating the predictions generated using ground observations. Work continued on the Coconut Island DC microgrid including procurement of an electric boat (E-boat) and electric utility vehicle, along with a swappable battery system. HNEI completed the conversion of the E-boat to an all-electric vehicle, and installed the battery charging station for the swappable battery system in the Boat House on Coconut Island. The Maui College project integrated an additional 500 kW of PV and a 500 kW/500 kWh battery, and performance was assessed on the campus microgrid, along with charging of electric vehicles from renewable energy. Additionally, agreements executed with the utility for Power Purchase, Energy Performance, and Fast Demand Response. The Kauai College project assessed, procured, deployed and analyzed the performance and impact of Demand Side Management Load Controller technologies and protocols on the campus microgrid.

Under Task 7, Energy Efficiency, areas of focus included modeling air flows in naturally ventilated spaces, monitoring and performance comparison of building research platforms, the installation and analysis of small, vertical axis wind turbines, and support of the utility's demand response demonstration projects.

This report describes the work that has been accomplished under each of these tasks, along with summaries of task efforts that are detailed in journal and other publications, including reports, conference proceedings, presentations and patent applications. Publications produced through these efforts are listed and available, or linked, on HNEI's website at https://www.hnei.hawaii.edu/publications/project-reports#APRISES12.