FINAL TECHNICAL REPORT

Executive Summary

Asia Pacific Research Initiative for Sustainable Energy Systems

Office of Naval Research

Grant Award Number N00014-16-1-2116

March 1, 2016 through December 31, 2020

March 2021

Final Technical Report
Asia Pacific Research Initiative for Sustainable Energy Systems
Grant Award Number N00014-16-1-2116
March 1, 2016 through December 31, 2020

EXECUTIVE SUMMARY

This report summarizes work conducted under Grant Award Number N00014-16-1-2116 the Asia Pacific Research Initiative for Sustainable Energy Systems 2015 (APRISES15), funded by the Office of Naval Research (ONR) to the Hawai‘i Natural Energy Institute (HNEI) of the University of Hawai‘i at Mānoa (UH). The work conducted under APRISES15 was intended to research, develop, test, and evaluate (RTD&E) distributed energy systems, novel energy technologies, and power grid integration using Hawai‘i as a model for applicability throughout the Pacific Region. APRISES15 comprised fuel cell research, contaminant mitigation and evaluation; seafloor methane hydrates destabilization; microbial degradation and reservoir mapping; 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), development of several microgrid test projects, and wind energy generation.

Under Task 1, Program Management and Outreach, HNEI senior faculty provided overall program management and coordination, developed and monitored partner and subcontract agreements, and developed outreach materials for both technical and non-technical audiences.

Task 2 technologies included for RDT&E included fuel cells and associated air purification technology, Li-ion batteries, hydrogen refueling infrastructure, and the development of new techniques for printed photovoltaic materials. HNEI continued to develop and apply fuel cell diagnostics to advance the understanding of fuel cell contamination mechanisms and to develop mitigation strategies for critical air contaminants. These efforts also included the development of ex-situ regenerable filtration materials. Testing and analysis included the development of new tools to better understand the performance of battery packs and analysis was extended to different grid connected battery systems, as well as Hydrogen Refueling Support, including ongoing support for the commissioning of hydrogen production and compression equipment and Hydrogen Transport Trailers (HTT) at the Natural Energy Laboratory of Hawai‘i Authority (NELHA) fueling station site. Finally, Task 2 also included a modest effort to continue the development of a novel low-cost printing process for the fabrication of electronic materials for photovoltaics.

Efforts under Task 3, Biofuels, includes several subtasks focused on the development, testing, and evaluation of alternative fuels and technologies. These included work to assess the feasibility of Pongamia (*Millettia pinnata*); completion of the laboratory development of a process for high rate anaerobic digestion and initiation of efforts to identify a suitable commercial partner; efforts to develop new technology to produce high-grade liquid fuels from syngas (H_2, CO, and CO_2) via the formation of polyhydroxybutyrate (PHB) from the gas substrates by using a chemoautotrophic microorganism and subsequent conversion of the PHB into hydrocarbon oil; and continuation of the work to characterize the storage and oxidation stabilities of catalytic hydrothermal produced diesel (CHCD-76), synthesized isoparaffin (SIP-76), and hydroprocessed renewable diesel (HRD-76) and their blends with F-76.

The three objectives of Task 4, Methane Hydrates, included advancing our understanding of the environmental impacts of natural seeps and accidental releases of methane and other hydrocarbons in the deep ocean; exploring the feasibility of sequestering CO_2 in natural methane hydrate reservoirs; and continue to promote international research collaborations on methane hydrates. Specific technical initiatives that were pursued to attain the above goals included the initiation of a laboratory study of hydrate formation on natural gas bubbles and bubble dissolution in seawater using the new HNEI high pressure water tunnel; continuation of laboratory experiments to identify microbial metabolic pathways that break down methane and other hydrocarbons in the ocean; calorimetric experiments to investigate the energetics and rates of CO_2-CH_4 hydrate exchange; and support to organize the 10th International Workshop on Methane Hydrate R&D.

Secure Microgrids, Task 5, included a broad range of projects to develop, test, and integrate secure microgrid technologies. Projects conducted under Task 5 included the Moloka‘i Dynamic Load Bank; Conservation Voltage Reduction Demonstration; the Coconut Island DC Microgrid; a Bi-Directional EV Charging Demonstration Project; continued development of a Hawai‘i BESS + PV Virtual Power Plant Demonstration; development of advanced Power Grid Monitoring and Controls; new tools for Real-Time Health Assessment of Distribution Transformers; analysis of Automated Distribution Circuit PV Hosting Capacity Estimation; Load and PV Synthesis; continued progress and demonstration of a cost-effective Solar Forecasting methodology; and initiation of effort to develop a Marine Corps Base Hawai‘i Installation Energy Security Plan. Each of these are described in detail in the report below.

Task 6, Ocean Energy, supported two subawards: one to Makai Ocean Engineering to continue develop of thin foil heat exchangers (TFHX) and a second to the University of Alaska Fairbanks (UAF) to identify and evaluate techno-economic benefits or issues associated with integrating wave energy along with other variable renewable energy sources into small, isolated grid systems. Under APRISES15, Makai conducted performance testing of the TFHXs, expanding testing fluids to include air in the external channels and installed air-water testing apparatuses. Seawater-ammonia and seawater-seawater performance testing was also conducted at the 100 kW test station and the first commercial TFHX unit was installed at Cyanotech. In their small grid analysis, UAF

used a mix of tools including the Hybrid Optimization of Multiple Energy Resources (HOMER) model, the UAF-developed Micro Grid Renewable Integration Dispatch and Sizing (MiGRIDS) package, and a Mathworks Simulink-based model to explore the integration of wave energy into a small grid.

Under Energy Efficiency Task 7, HNEI completed its ongoing effort to characterize the performance/comfort of the second generation FROGs constructed at UH Mānoa. In the first subtask, HNEI conducted a study to measure energy performance and CO_2 concentrations in two Hawai‘i classrooms to determine the impact of user decision-making on adequacy of fresh air and on CO_2 concentration. In the second subtask, both subjective and objective data were collected over a period of two years to comprehensively describe fan performance, fan control preferences, and occupant responses to thermal conditions, with the objective to compare user perceptions with comfort model predictions using measured conditions.

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/aprises-15**.