

# **FINAL TECHNICAL REPORT**

## **Executive Summary**

### **Asia Pacific Research Initiative for Sustainable Energy Systems**

**Office of Naval Research**

**Grant Award Number N00014-15-1-0028**

**January 1, 2015 through June 30, 2019**



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**Final Technical Report**  
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## **EXECUTIVE SUMMARY**

This report summarizes work conducted under Grant Award Number N00014-15-1-0028 the Asia Pacific Research Initiative for Sustainable Energy Systems 2014 (APRISES14), 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 APRISES14 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. APRISES14 encompassed 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 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 Testing, HNEI continued to develop and apply fuel cell diagnostics, contributed to the development of fuel cell contamination mechanisms and mitigation strategies and applied this knowledge to design novel water purification technologies, and also to synthesize lower cost fuel cell catalysts. Contaminant Mitigation focused on development of syntheses and characterization techniques of advanced metallo ionic liquids and molten salts air purification materials to enable efficient use of fuel cells in harsh environmental conditions. Hydrogen Refueling Support involved the commissioning of hydrogen production and compression equipment, recertification of Hydrogen Transport Trailers (HTT), and the installation of improved design Thermal Pressure Relief Devices on hydrogen cylinders. Low-Cost Material for Solar Fuels Production continued to develop novel thin film materials for low-cost photovoltaic applications using scalable “printing” processing.

Efforts under Task 3, Biofuels, focused on the development, testing and evaluation of alternative fuels and technologies, and included activities in the areas of Bioenergy Systems, High-Rate Anaerobic Digestion, Liquid Fuels from Syngas, Bio-contamination of Fuels, and Oxygen-enhanced Flash-Carbonization. For Bioenergy Systems, yields and fatty acid profiles of oils derived from the *Milletia pinnata* seed were determined to support development of alternative fuels and higher value products. A final system design was completed for demonstration scale High-Rate Anaerobic Digestion reactors, with an initial mixing tank followed by an up-flow packed-bed anaerobic digester filled with biochar-based biofilm supports, with optional follow-on reactors. Liquid Fuels from Synthesis Gas research revealed the reaction routes of catalytic reforming a polymer into hydrocarbon oil and demonstrated bio-oil formation from residual microbial biomass. To control biofuel contamination, a eukaryotic metabolic pathway for biofuel degradation has been proposed based on proteome and genome data, and biological inhibition has also been examined. The effects of Constant-volume carbonization processing conditions on product yields and properties were determined to support the development of novel materials.

Methane Hydrates Task 4 primary accomplishments were: 1) using 3D seismic profiles and borehole data was used to calculate volumetric gas-in-place estimates for hydrate reservoirs in the Kumano Basin offshore of the Kii Peninsula, Japan; 2) laboratory experiments were completed to evaluate the effectiveness of environmentally-benign glycerol solutions to destabilize methane hydrate; and 3) continued the investigation of microbial degradation of methane and heavier hydrocarbons in marine environments through benchtop experiments and metagenomics techniques.

Secure Microgrids, Task 5 included a range of projects to develop, test and integrate secure microgrid technology including distributed energy resources. The Molokai Load Bank project analyzed performance and of a controllable load bank as an energy safety valve to provide a near-term solution for interconnection and a longer-term grid management asset for this small island grid and other microgrid applications. The Coconut Island DC Microgrid project progressed efforts to demonstrate the performance and resilience of a DC microgrid designed to serve loads within two buildings on the island, including reliable power to critical loads during interruptions of grid supplied power, and to provide the island with clean electrified transportation options powered primarily by the sun. The Load and PV Synthesis project focused on validating synthesized load and PV data by injecting it along with field measurements into a simulated electrical model of the Maui Meadows feeder, with the overall objective to synthesize PV and load data from a limited number of field measurements in order to enable realistic distribution feeder modeling with high distributed PV penetration. Under the Power Grid Monitoring and Controls project, a low-cost, fully integrated and highly flexible device and system were developed for distributed electrical measurement, real-time analysis, and controls to help solve grid operational issues with high penetrations of distributed energy resources.

Under the Conservation Voltage Reduction (CVR) Demonstration project, a distribution circuit was selected for the demonstration. This circuit supplies the Plaza Housing complex at USMC Camp Foster in Okinawa, Japan. Hardware-in-the-loop testing was performed to validate the proposed CVR control algorithm and the associated communications between the field meters and the CVR controller. A user-interface was also developed to provide USMC Okinawa personnel with information regarding the status of the voltage and HNEI-controller. Under the Solar Forecasting project HNEI significantly expanded the long-term database to study regional irradiance patterns and variability, and utilized the observations within the database to calibrate and validate several components of the solar forecasting system, generate a new regional turbidity product for clear sky irradiance modeling, and evaluate the effects of the new turbidity product on the accuracy of satellite image derived irradiance. Under the Advanced Power Systems Laboratory project, a conceptual design was developed and HNEI collaborated with a local electrical engineering firm to produce design drawings necessary for laboratory build-out, based on a highly flexible architecture incorporating state-of-the-art grid test and simulation equipment.

Task 6, Ocean Energy focused on development of advanced heat exchangers for Ocean Thermal Energy Conversion (OTEC) through a subaward to Makai Ocean Engineering. Makai's work continued development, fabrication, and testing Thin-Foil Heat Exchangers (TFHX), in addition to corrosion testing and biofouling prevention. In order to compare the TFHXs to the previously tested heat exchangers, twelve 1.2-m long TFHX plates were fabricated, and each configuration was tested as both a condenser and an evaporator. When evaluated in terms of heat exchanger operating pressure, at 2MW duty, the TFHXs have both a better operating pressure at the same seawater pumping power and a higher energy density compared to the previously tested heat exchangers. Funding for the Wave Energy Testing planned for Task 6 was reallocated to other areas of the program as approved by ONR.

Under Energy Efficiency Task 7, HNEI resumed monitoring the three first generation Project Frog buildings, (constructed and instrumented under previous ONR funding), to compare performance to second generation FROGs constructed at UH Manoa. Secondly, HNEI contracted with a manufacturer, HEWS Technology, Inc., to install, test, and report on performance of their novel "High Wind Energy Generator".

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 a patent application. **Publications produced through these efforts are listed and available, or linked, on HNEI's website at <https://www.hnei.hawaii.edu/publications/project-reports#APRISES14>.**