FINAL TECHNICAL REPORT

Executive Summary

Asia Pacific Research Initiative for Sustainable Energy Systems 2022

Office of Naval Research

Grant Award Number N00014-23-1-2720

July 1, 2023 through May 12, 2025

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

September 2025

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EXECUTIVE SUMMARY

This report summarizes work conducted under Grant Award Number N00014-23-1-2720, the Asia Pacific Research Initiative for Sustainable Energy Systems 2022 (APRISES22), funded by the Office of Naval Research (ONR) to the Hawaiʻi Natural Energy Institute (HNEI) of the University of Hawaiʻi at Mānoa (UH). The work conducted under APRISES22 was intended to comprise research, development, testing, and evaluation (RDT&E) over a range of technical areas. These included: Electrochemical Technologies with a focus on fuel cells, batteries, and flexible electronics; Alternative Fuels including carbonization of biomass, marine fuels, and hydrogen; and Resilient Energy Systems including development and demonstration of novel technologies for advanced smart microgrids and resource adequacy studies for the Hawaiʻi electrical grids. We also proposed that Makai Ocean Engineering, under subcontract to the University of Hawaiʻi, continue their efforts to develop high-performance, low-cost heat exchangers. However, due to a work stop order on May 12, 2025, funds were only expended in the areas of flexible electronics, hydrogen technology, and grid technology. A brief summary of results for these three activities follows.

Under the "Electrochemical Technologies" task, funding from APRISES22 allowed HNEI to complete a semi-monolithic integration method to mate electronic layers, originally developed for rigid substrates, was successfully adapted to mechanically compliant, flexible substrates using transparent conductive composites (TCCs) as the host. TCCs are polymer laminates embedded with conductive microspheres, combining high optical transparency with out-of-plane conductivity. This dual function enables them to serve as both mechanical supports and vertical electrical interconnects, which is particularly beneficial for multilayer device architectures and applications requiring mechanical flexibility.

The primary objective of this activity was to develop processes and demonstrate the ability to transfer fully fabricated thin films from rigid processing substrates to flexible hosts without compromising electrical or structural integrity. The first milestone was to demonstrate the transfer of a 1 cm^2, 100 nm silver thin film onto a TCC substrate using a room-temperature lamination and exfoliation process. The second milestone targeted mechanical durability, with a benchmark of retaining at least 80% of initial electrical conductivity after 20 bending cycles.

Electrical measurements confirmed that as-exfoliated Ag/TCC structures retained excellent conductivity, with in-plane resistance increasing modestly from 0.686 Ω/sq to 0.749 Ω/sq after 100 bending cycles—representing over 90% retention, far exceeding the target. Out-of-plane resistance also remained stable. Microscopic inspection revealed minimal wrinkling or voiding, with minor microcracks attributed to the exfoliation process. These can be mitigated through improved process control and surface treatments. Computational modeling supported optimization of lamination parameters and is being extended to address mechanical stress at microsphere contact points. Preliminary demonstrations with thin-film solar absorbers confirmed that the process can maintain device performance after transfer. This opens the door to flexible applications such as wearable photovoltaics, conformal sensors, and flexible displays, especially where low-temperature processing is essential. Future work will focus on integrating more complex active devices (e.g., chalcopyrite and perovskite solar cells), refining exfoliation techniques, and validating long-term system performance under dynamic mechanical stress.

Overall, the findings establish semi-monolithic integration using TCCs as a promising, robust, and scalable pathway for manufacturing high-performance flexible electronics. The method preserves functionality under repeated bending, overcomes limitations of conventional monolithic stacking on sensitive substrates, and holds strong potential for applications in wearable, aerospace, and marine environments.

Under the "Alternative Fuels" task, research on constant volume carbonization of biomass and fit for purpose characterization of marine fuels was not conducted. HNEI did continue research, development, demonstration, and assessment of hydrogen production, storage, and dispensing systems for heavy duty hydrogen vehicles, and evaluation of the operational performance of buses on the Big Island of Hawai'i. The team conducted power consumption analysis and optimization, updated and expanded operational and safety documentation, investigated corrosion and marine environmental effects, and developed dispenser software. Performance monitoring and the coordination of operations for the fuel cell electric buses also occurred. Various outreach, briefings, and engagements were supported by APRISES22 funds as well.

Under the "Resilient Energy Systems" task, HNEI advanced the development and demonstration of next-generation energy systems with a focus on distributed energy resources, microgrid applications, and electric vehicle (EV) grid integration. This research, conducted by HNEI's Grid System Technologies Advanced Research Team (Grid***START***), concentrated on targeted refinements to the Coconut Island DC microgrid to improve reliability and system monitoring; and furthering tool development through the bidirectional EV charging demonstration project.

The Coconut Island project previously established a research-ready DC microgrid in a harsh coastal setting, including rooftop PV, stationary batteries, advanced controls, and integration with an all-electric research vessel (E-boat). Building on this foundation, APRISES22 focused on improving the stability and functionality of the microgrid's monitoring system. Specific enhancements included streamlining data polling protocols and optimizing the dashboard interface design to resolve controller freezes and enhance long-term system reliability. This effort included the professional development of an electrical engineering graduate student, who gained hands-on microgrid experience and authored a peer-reviewed publication reviewing global DC microgrid deployments. Together, these efforts extended and strengthened the novel DC microgrid research platform and the program's contribution to training the next generation of microgrid engineers.

The bidirectional EV charging demonstration project at the University of Hawaiʻi at Mānoa includes two advanced bidirectional chargers with novel control algorithms developed to optimize EV charge/discharge cycles for cost savings, fleet management, and potential grid services. Under APRISES22, the project conducted analysis to examine the potential to extend this concept to residential applications by developing and refining a technoeconomic algorithm that determines the optimal sizing of rooftop PV, household batteries, and EVs with bidirectional power flow capability. The analysis highlighted the strong influence of time-of-use (TOU) pricing structures and driving schedules on the added value of bidirectional charging, with case studies demonstrating clear economic benefits across a robust range of operating scenarios. Graduate students contributed to this effort by building a user-friendly web tool that operationalizes the algorithm, combining technical training with the creation of a practical platform for homeowners, vehicle fleet managers and industry stakeholders.

This final report describes the research completed under each of these areas. Publications produced through these efforts are noted below and available on HNEI's website at https://www.hnei.hawaii.edu/publications/project-reports/aprises-22/.