

EXECUTIVE SUMMARY

Hawai'i Distributed Energy Resource Technologies for Energy Security

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Hawai'i Distributed Energy Resource Technologies for Energy Security

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Executive Summary

This report summarizes work conducted under Cooperative Agreement Number DE-FC26-06NT42847, Hawai'i Distributed Energy Resource Technologies for Energy Security. This effort was funded by the U.S. Department of Energy (DOE), Office of Electricity Delivery and Energy Reliability (OE), and the Office of Energy Efficiency and Renewable Energy (EERE), with administration by the National Energy Technology Laboratory (NETL), to the Hawai'i Natural Energy Institute (HNEI), School of Ocean and Earth Science and Technology, University of Hawai'i.

HNEI has conducted research to address a number of issues important to move Hawai'i to greater use of intermittent renewable and distributed energy resource (DER) technologies in order to facilitate greater use of Hawai'i's indigenous renewable energy resources. Efforts have been concentrated on the Islands of Hawai'i, Maui, and O'ahu, focusing in three areas of endeavor: 1) Energy Modeling and Scenario Analysis (previously called Energy Road mapping); 2) Research, Development, and Validation of Renewable DER and Microgrid Technologies; and 3) Analysis and Policy. These efforts focused on analysis of the island energy systems and development of specific candidate technologies for future insertion into an integrated energy system, which would lead to a more robust transmission and distribution system in the state of Hawai'i and eventually elsewhere in the nation. The overall work was divided into twelve tasks, summarized in the following paragraphs.

Task 1: Hawai'i Analysis – Assessment of Electricity Infrastructure and Microgrid Applications

Under a previous award (DE-FC36-04GO14248), GE Global Research Center, under contract to HNEI, assessed the electric and transportation infrastructure for the Island of Hawai'i. Building on those results, additional analyses were conducted under this award to address target objectives of petroleum reduction, grid stability, and economic viability related to specific changes to grid operation and infrastructure. These analyses were performed so as to be consistent with the local utilities' Integrated Resources Plan, and were initially developed to modify the Island of Hawai'i's energy infrastructure to best meet the target objectives, while satisfying technical, social, and economic constraints identified by stakeholders.

Potential options were developed to address issues such as transmission congestion, management of high saturations of distributed energy resources, matching energy resources with grid loading dynamics, and the intermittency of renewables.

Task elements included:

- Development and validation of GE's electric grid models (MAPS™ and PSLF™) and transportation models.
- Stakeholder interviews and a follow-on stakeholder summit to work through the preferred metrics for addressing grid issues and for determining specific electricity scenarios to be modeled.

- Conceptual designs for the installation of new technology, such as energy storage including identification of site-specific barriers that could inhibit the successful deployment of the proposed energy solution were described.
- Development of scenarios of enhanced penetration of renewable resources on the utility grid.

Task 2: Research, Development and Testing of Distributed Energy Resource and Microgrid Technologies

Under this task, HNEI developed, tested, and validated emerging bulk energy storage and distributed energy technologies that afford opportunities for improved grid performance and facilitate more effective utilization of Hawai'i's indigenous resources. This task included the following subtasks:

2.1 Identify and Evaluate Emerging Distributed Energy Resource and Bulk Storage Technologies: Technologies considered included:

- Grid energy storage such as batteries and pumped hydroelectric storage systems.
- Hydrogen technologies as possible components of future DER and micro-grid systems. This effort leveraged investment in hydrogen infrastructure by the State of Hawai'i through the Department of Business, Economic Development and Tourism (DBEDT).
- Biomass technologies were identified and evaluated for potential contribution to Hawaii's energy mix including consideration of both crop production and conversion technologies.

2.2 Develop, Test, and Validate Distributed Energy Resource and Microgrid Technologies

This subtask examined a range of DER technologies for eventual use in operational utility grids and micro-grids including:

- Hydrogen - Work in this technology area focused on the off-peak production and storage of hydrogen. The efficacy of new systems for energy storage and peak demand utilization were tested and evaluated.
- Biomass - HNEI conducted R&D to advance biomass-to-energy distributed energy resource technologies. Specifically, HNEI examined use of biomass feedstock for fermentation, pyrolysis, gasification, biodiesel production, and related combined heat and power applications.
- Photovoltaics - HNEI conducted evaluations of the performance of various module designs, including total energy output and suitability for use in large-scale distributed energy systems.

Task 3: Develop Public Policy/Outreach to Accelerate Acceptance of Distributed Energy Resource and Micro-grid Applications

HNEI partnered with the University of Hawai'i's Hawai'i Energy Policy Forum (HEPF) to explore and develop protocols for linking technology demonstration and deployment activities with state and national policy and regulatory initiatives. By linking technology to policy, the potential for successful long-term commercialization will be enhanced. In order to implement effective program strategies for deploying successful technologies, HNEI

provided technical information, where possible, and explanations of its significance to policy decision makers. To this end, HNEI worked closely with state and federal stakeholders in ensuring that technology advances are adequately described in terms of their application and significance to the community and nation. HNEI provided information to decision makers on the results of these analyses, all of which have been completed.

Task 4: The Hawai‘i Energy Road-mapping Study - Project Implementation Plan

The Hawai‘i Energy Road-mapping project goals included the development of a strategic energy roadmap for the Island of Hawai‘i (discussed in Task 1). By analyzing and quantifying numerous technical, regulatory, and policy issues associated with the electricity and transportation infrastructures on the Island of Hawai‘i, this study provided a significant contribution to meeting the Nation's energy objectives, where the tools, procedures, and conclusions developed and technologies deployed will address similar energy issues throughout the rest of the country.

As part of activities described in Task 1, models of electricity and transportation infrastructures were developed, calibrated, and validated against the conditions on the Island of Hawai‘i, and stakeholders were engaged to establish target goals, key metrics, and potential technology responses to meet the State's energy goals. As a result of model development efforts, additional interaction between the local utility and system modelers became necessary to ensure that the correct information had been captured for this system. Based on this stakeholder input and the exhaustive information from the electricity utility, various integrated energy scenarios were developed and analyzed using electricity and transportation models that were developed and refined in earlier parts of the project. Each scenario was evaluated against the stakeholders' target objectives, while satisfying technical, social and economic constraints.

Due to the unique nature of the early findings (and their direct implications to larger mainland systems) obtained in these programmatic activities, this task ensured that the true nature and explicit aspects of the Island of Hawai‘i's energy infrastructure were properly characterized. This was a key overall project requirement, since the grid issues being evaluated and analyzed on a relatively small grid on the Island of Hawai‘i have direct and considerable implications on the future of mainland grid systems. These issues have been discussed with DOE program managers in Washington and at NETL. This task follows on from earlier results to properly capture all aspects of these important issues. The "lessons learned" report resulting from this task will be used to set the stage for future demonstrations of technologies that will enhance the performance and ameliorate current problems with the grid system on the Island of Hawai‘i.

Task 5: Development of information, Models, and Analyses for Characterizing the Future Electricity Grid on Maui

The Maui Electric Company (MECO), a wholly owned subsidiary of the Hawaiian Electric Company (HECO), generates and distributes electrical power on the island of Maui. The generation mix currently includes some renewable energy resources, primarily associated with a 51 megawatt (MW) wind farm in Kaheawa. High cost of electricity, coupled with aggressive renewable energy targets for the state of Hawai‘i, make expansion of renewable

energy resources likely. Examples of this potential expansion include Shell's desire to add 40 MW of wind power with pumped hydro firming at the remote corner of 'Ulupalakua Ranch on Haleakala. Additionally, significant solar power generation projects have been discussed among the larger end-use customers on Maui. Under this task HNEI developed and validated MAPSTM and PSLFTM models of the MECO grid system.

Subtasks completed for this task include: 1) data consolidation and preliminary model feasibility analysis for the Island of Maui, 2) data evaluation, completion and manipulation, and 3) system model development and baseline model validation. Following completion of the model validation effort, a negotiated agreement by the State of Hawai'i Public Utilities Commission required that the model be utilized in conjunction with independent power producers as part of a complaint resolution. Thus, no scenarios were run using federal funding following the completion of the subtask.

Task 6: Coordination and Support of DOE/OE R&D Initiatives

HNEI supported the DOE's OE in developing new and appropriate systems for evaluating new research, development and deployment initiatives. Existing approaches that focus on the exclusive use of the NEMS model, while required, need to be supported by additional planning tools that can address the unique nature of the DOE/OE technology portfolio and goals. To this end, HNEI staff participated with other organizations selected by DOE/OE to address this issue and recommend other planning tools to incorporate into the decision-making process.

HNEI also worked closely with DOE management to help implement new technology deployment programs for Hawai'i. This new initiative requires close coordination between energy end-users, the state utilities, state agencies, DOE consultants, members of the national laboratory system, and DOE management.

HNEI also worked with NMT to coordinate overall programmatic activities. These efforts included the sharing of significant results and breakthroughs, as well as coordinating interactions with key utility partners, prime subcontractors and DOE program management.

Task 7: Energy Modeling and Scenario Analysis

Task 7 continued the efforts initiated under tasks 1, 4 and 5, for which detailed assessments of the grid systems of the Island of Hawai'i and Maui were developed as well as a transportation model for the Island of Hawai'i and Maui. In addition, various scenarios for evolution of the electricity system of the Island of Hawai'i have been evaluated and reported.

Under Task 7, HNEI specifically conducted additional scenario studies for the islands of O'ahu and Maui grid systems with emphasis on the detailed evaluations needed to plan for implementation of projects. In addition, plans were made for evaluation of the impact of electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) on the Maui grid.

Task 8: Continued Research, Development and Validation of Critical Renewable Distributed Energy Resource, Microgrid and End-Use Energy-Efficient Technologies

This task, following on the efforts completed under Task 2, was structured to address both original plans as well as lessons learned during the earlier parts of the project. Work under Task 8 is structured around several potential renewable, DER, and micro-grid technology initiatives. Specific technologies examined included: 1) PHEVs, 2) use of hydrogen for energy storage, 3) photovoltaic system demonstration, and 4) technologies for energy-efficient buildings.

Task 9: Public Policy Analysis and Assessment

This particular task followed on the work of Task 3. It continued the effort to link technology with policy and economics. Specific subtasks are described below.

Subtask 9.1: Hawai'i Bioenergy Master Plan

As part of this task, HNEI (in consultation with relevant stakeholders), worked with the State's Department of Business, Economic Development, and Tourism in developing a state biomass energy strategic plan. The primary objective of the master plan was to develop a Hawai'i renewable biofuels program to manage the State's transition to energy self-sufficiency based in part on biofuels for power generation and transportation. The bioenergy master plan addressed outcomes such as: strategic partnerships, evaluation of biofuel potential, biofuels demonstration projects, promotion of biofuels to potential partners and investors, and a plan to implement commercial biofuels development.

The bioenergy master plan also addressed: objectives and timelines; water resources; land resources; marine and land distribution infrastructure; labor resources/issues; technology to develop bioenergy feedstock and biofuels; permitting; financial incentives/barriers and other funding; business partnering; policy requirements for implementing the master plan; and identification/analysis of the impacts of transitioning to a bioenergy economy while considering applicable environmental concerns.

Subtask 9.2: Economic and Environmental Modeling of Island Energy Systems

HNEI worked with the University of Hawai'i Economic Research Organization to develop these models, which were used to better determine the impacts of potential legislation related to greenhouse gases on the economy of Hawai'i. As the need arises, these analyses can be related to other activities in the United States, Europe, and Asia in evaluating the consequences of climate change, new regulatory requirements and the attendant economic impacts associated with these activities. As part of this effort, HNEI has developed a flexible, spreadsheet-based model to analyze the different scenarios for the Hawai'i utilities meeting the State's Renewable Portfolio Standards requirements (see the Subtask 9.2 Deliverable report referenced under Subtask 9.2 in the main body text of this report). By implementing the model within a spreadsheet, the various stakeholders can assign their own assumptions about the future and assess the outcomes. HNEI anticipates following a similar approach in developing future models for policy analysis.

Subtask 9.3: Analysis of Integrated Tropical Biorefineries

HNEI has been involved in biomass energy research and development for many years. As a result of new interest in tropical agricultural and aquacultural feedstocks, HNEI worked with private sector entities to evaluate and plan for potential development of future commercial biorefineries in Hawai'i based on these feedstocks. Analysis included (1)

establishing baseline material and energy balances for well-defined feedstock production and/or conversion modules, (2) integrating the modules to investigate their use as components of tropical biorefineries, and (3) preliminary estimation of production costs for the primary product of each module.

Task 10: Energy Modeling and Scenario Analysis

Subtasks completed under this task have included: 1) O'ahu Scenario Analysis -- the O'ahu Wind Integration Study report, and 2) System Simulation using High-Performance Computing -- reports that: a) describe numerical tools for simulating/analyzing the state of the grid and estimating stability indices for the grid, and b) describe model abstraction techniques for power systems with a large penetration of renewable energy.

Task 11: Research and Development on Distributed Energy Resource and Renewable Energy Systems

This task continued to focus on the utilization of DER and renewable energy systems in Hawai'i. All efforts were predicated on the concomitant focus of utilizing what is developed in the State for related purposes on the mainland. This task builds from the related Task 8 subtasks.

Subtasks for this task addressed the issues of: 1) photovoltaic systems, 2) energy storage systems, and 3) end-use energy efficiency and demand response.

Task 12: Policy Analyses and Assessments

This activity continued efforts commenced under Task 9 in a previous amendment to this cooperative agreement. The new and expanded subtasks include the following elements: 1) bioenergy analyses covering a variety of issues, 2) energy and economic model development, 3) use of geographic information system (GIS) resources to aid in the State of Hawai'i biomass/bioenergy/biofuel future, and 4) life cycle analyses of bioenergy production systems.

Information on Obtaining Special Status Reports (Deliverables) Submitted during the Course of This Cooperative Agreement

In the main body of this report, each of the award tasks will be discussed in separate sections. For each task, an overview of accomplishments is presented and summaries are provided for the large number of deliverable reports that were submitted over the six years of this Cooperative Agreement. The last section of each task is one entitled Topical Report(s) Submitted Under This Task. The reports are presented there in chronological order for the date the report was submitted. Each report has reference to the deliverable number for that report and the title for the report.

For readers who are interested in examining any of those reports, it is possible to download any of them from the HNEI website (<http://www.hnei.hawaii.edu/>). In the green navigation band at the top of our homepage is an item entitled PUBLICATIONS. Clicking on that item will reveal a list of publication sections, the top one of which is entitled DOE PROJECT REPORTS. By clicking on that item you will be led to a page showing several HNEI DOE projects. Clicking on the item entitled Hawai'i Distributed Energy Resource

Technologies for Energy Security: DE-FC26-06NT42847 will lead to a listing of the deliverables submitted for all tasks of this report. They are arranged in chronological order, showing the dates submitted for all of the reports plus references to the deliverable numbers and title for each report. Clicking on any of these items will bring up the PDF document for the deliverable report of interest.