Hawaii Natural Energy Institute
Energy Programs

Presented to
Mr. Thomas Hicks
DASN for Energy

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Hawaii Natural Energy Institute
School of Ocean Earth Science and Technology
University of Hawaii at Manoa
Hawaii Natural Energy Institute

Organized Research Unit in the School of Ocean and Earth Science and Technology, University of Hawaii at Manoa

- Basic and applied research (R&D) across many energy technologies
- Testing and evaluating (T&E) of renewable generation and energy efficiency technologies
- Supporting State of Hawaii energy assessments and policy development
- Managing public-private partnerships to demonstrate energy solutions in real world (on-grid) settings
- Contributing to STEM and workforce development

HNEI programs are multi-disciplinary with significant cost share from industry
HNEI Alternative Energy Research

• **Alternative Fuels**
  – Biomass and biofuels; Hydrogen; Methane hydrates

• **Electrochemical Power Systems**
  – FC for unmanned vehicles, FC contaminant mitigation
  – Battery testing, Electric vehicles

• **Renewable Power Generation**
  – Ocean Energy (OTEC, Wave)
  – Photovoltaics

• **Energy Efficiency**
  – Building technology; Ice production/water purification
  – Sea water air conditioning (SWAC)

• **Systems Integration/Energy Security:**
  • Grid modeling and analysis
  • Smart grid development
  • Microgrids
  • Hydrogen for grid management
  • Grid-scale storage
Biofuels
Ocean Energy
Energy Efficiency
Hydrogen
Systems Integration/Energy Security
Research and the Bioenergy Industry Value
HNEI works across value chain

Feedstock Production | Feedstock Logistics | Conversion | Distribution | End Use

Agriculture ---- Industry ---- Investors ---- Government ---- Community

Feedstock Production - CTAHR
Gasification & Contaminant Removal - HNEI

Fuel Fit for Purpose

Technology Assessment

Resource Assessment
GIS Tools Development

Technology Development

Anaerobic Digestion for Dilute Waste Streams

Ten (10) liter lab high-rate anaerobic digester for evaluation of packing materials and operating conditions (e.g. hydraulic retention time and packing density)

Five thousand (5000) liter demonstration at local waste water treatment facility to reduce BOD of primary effluent (operating)

One thousand (1000) liter demonstration at local grease-trap waste facility (under development)
Biofuels
Ocean Energy
Energy Efficiency
Hydrogen
Systems Integration/Energy Security
HiNMREC- Wave Energy at WETS

Support Navy and DOE to Facilitate Deployment and Characterization of Grid-Connected Wave Energy Conversion Devices at MCBH

- Advise/ support NAVFAC on their ongoing design and Environmental Assessment (EA);
- Develop test protocols and validate power performance of devices;
- Provide real time wave and ocean current data to developers during testing;
- Evaluate acoustic and electromagnetic field (EMF) signatures of devices under test;
- Conduct seawater chemical composition and ecological surveys to quantify the environmental impact due to WEC device operation.

Northwest Energy Innovations (WET-NZ) selected by USDOE as first tenant at WETS (9/26/12)
Ocean Resources

- Hawaii National Marine Renewable Energy Center (HiNMREC) - US DOE funded Center to:
  - Facilitate commercial development of wave energy conversion devices
  - Reduce technology risk for ocean thermal energy conversion (OTEC)

- Sea Water Air Conditioning (cost reduction)
  - Plume modeling to characterize impacts of discharge depth
  - Environmental monitoring to verify performance
  - Analysis of alternative designs such as increased intake temperature and performance enhancement technologies

Kaneohe Bay
WETS

OPT Buoy at MCBH

Honolulu SWAC
Ocean Thermal Energy Conversion (OTEC)

Makai Ocean Engineering (HI), under contract to HNEI, is conducting testing of alternative materials, alternative heat exchanger and turbine designs (funded by NavFAC and ONR)

- Development and testing of advanced design Al heat exchangers
- Corrosion and biocorrosion studies
- Fully operational OTEC plant planned
  - Integrated NH$_3$ system operational
  - Integrated turbine system by 1$^{st}$ Q 2013

- USDOE - Resource and environmental assessments to support industry

Makai OE Heat Exchanger Test Facility at NELHA
Biofuels
Ocean Energy
Energy Efficiency
Hydrogen
Systems Integration/Energy Security
High Performance Buildings

Validate performance and durability of High Performance (HP) modular, readily deployed building platforms.

- Designed to optimize human performance using
  - Efficient lighting and daylighting
  - Natural cooling and ventilation
  - Advanced energy controls
- Three (3) Project Frog test platforms deployed to assess impact of environment and use patterns.
- HNEI developing second design for off-grid, modular and re-locatable applications
- HP designs facilitates net-zero energy for on-grid or off-grid uses with rooftop PV.

HP platforms instrumented to allow analysis and comparison of alternative designs.
Performance Contracting

Develop design specifications and protocols to achieve aggressive energy performance contracting with target to achieve 30% greater energy savings than traditional energy retrofits.

- UH/Industry team developing specifications and protocols integrating state-of-the-art advanced technologies for greater energy efficiency.
- Partnering with Kauai County and performance contractor to implement protocols and validate performance savings.
Energy and Sustainable Inventory

Use energy, comfort and other client-defined criteria to assess and rank large aggregations of buildings to optimize allocation of capital improvements.

HNEI working with UH School of Architecture and industry partners (MKThink) to develop methodology and data-driven tools to prioritize sustainability opportunities in existing institutional building stock:

- Categorize “common” building typologies
- Develop “common” building models to evaluate impact of micro-climates
- Optimize improvement options using parametric analysis
- Rank facility-specific projects for maximum cost benefit

Tools to be validated with HI DOE building stock, approximately 5000 bldgs across several micro-climates.

Process will be applicable to any large aggregation of buildings
Biofuels
Ocean Energy
Energy Efficiency
Hydrogen
Systems Integration/Energy Security
H2 Program R&D Goals

Evaluate Role of Hydrogen in DoD Smartgrids & Microgrids

- Provide high-pressure (700 bar) fueling infrastructure with to support Navy and ONR evaluation of FC vehicles on Oahu for non-tactical applications.

- Evaluate use of hydrogen production to provide ancillary services to grids with high penetration of intermittent renewable generation.

- Develop and validate mitigation measures for operation of fuel cells in high contaminant environment including back-up power systems.
Hydrogen Production for Ancillary Services

- Develop strategies for dynamic operation of electrolyzers without loss of life
- Develop business models to assess feasibility of large-scale hydrogen deployment

<table>
<thead>
<tr>
<th>Service</th>
<th>Electrolyzer</th>
<th>Battery</th>
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<tbody>
<tr>
<td>Up Reserve</td>
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<td>Yes</td>
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<tr>
<td>Down Reserve</td>
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<td>Yes</td>
</tr>
<tr>
<td>Up Regulation</td>
<td>Yes</td>
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<td>Yes</td>
</tr>
<tr>
<td>Fuel Production</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Voltage/VAR Support</td>
<td>No</td>
<td>Yes</td>
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</table>
Hawaii Fuel Cell Test Facility

*Characterize and optimize performance of proton exchange membrane fuel cell energy systems for use in harsh environments*

- Performance and durability testing of single cells and stacks from 15 W to 5 kW with air or oxygen.
- Continuous long-term testing for performance and lifetime studies
- High resolution diagnostic tools for contaminant analysis
- High speed hardware-in-the-loop (HiL) test station to characterize fuel cell system response for UUV and UAV applications
- Custom designed impedance spectroscopy analyzer to analyze fuel cell stack and battery pack degradation mechanisms
Biofuels
Ocean Energy
Energy Efficiency
Hydrogen
Systems Integration/Energy Security
RENEWABLE ENERGY GRID INTEGRATION STUDIES

Develop ground-breaking analytic tools for analysis of island(ed) grid systems with high penetration renewables

Identify solutions to inform technology selection and decision making groundbreaking use of analytical tools

SMART AND MICRO-GRID DEMONSTRATION PROJECTS

- Maui Smart Grid Project
- Japan-US Smart Grid Demonstration Project
- DOE SEGIS Smart Inverter
- Coconut Island Microgrid
- Molokai Microgrid opportunity

T&E of ENABLING TECHNOLOGY

- Grid-scale storage
- Photovoltaics
- Small wind systems
- Dynamic Load Control
- Hydrogen emergency backup
- Variable load ice/water production

Policy
Work-force training
Regulatory Infrastructure
Renewable Energy Grid Integration Studies

- Develop rigorous analytic models of electricity grids on each island (e.g. MAPS, PSLF)
- Analyze impact of new energy systems including renewable generation and novel transportation systems
- Identify and analyze solutions to address systems integration issues resulting from intermittent renewable technologies (e.g. wind and solar)
  - Advanced controls
  - Forecasting
  - Demand management, EV
  - Storage
  - Smart/micro-grids
- Analysis conducted at grid scales applicable from deployed forces to naval bases to island communities

Developing demonstration projects to validate proposed technology solutions
Energy Storage for Power Systems Management

Validate performance and lifetime of Battery Energy Storage Systems (BESS) and quantify value of ancillary services for grid systems with high-penetration renewable energy generation

Applications
- Frequency regulation
- Ramp rate control
- Voltage regulation
- VAR support
- Excess energy curtailment mitigation
- Peak load shifting
- Operating reserve

Process
- Grid requirements (analysis)
- BESS technology selection
- Site selection and preparation
- Development of closed-loop controls and algorithms
- Validation of control algorithms (on-site and / or at national lab)
- On-site qualification testing
- Field testing

Field Tests, Data Collection, Analysis, Assessment, Reports and Publications
**HNEI BESS Projects**

Hawi 10 MW Wind farm at Upolu Point Hawaii Island
- 1MW, 250kW-hr Li-ion titanate at wind/utility interface
- Frequency regulation, wind smoothing, power quality
- Expected to reduce freq variability by 2x

Waiawa feeder with high penetration (>1 MW Distributed PV)
- 1MW, 250 kW-hr Li-ion titanate at substation
- Voltage, VAR, Frequency regulation, power quality

Molokai Secure Renewable Microgrid
- 2MW, 375kW-hr Li-ion titanate, location TBD
- < 100kW community BESS, technology, location TBD
- Frequency regulation, smoothing, peak shifting
- Operating reserves.

Kauai Waste Water Treatment Facility
- ~1MW, 2MW-hr integrated into MW PV system
- PV smoothing
- Energy storage/load shifting
- Secure operations
Evaluation of Photovoltaic Technologies

- Commercially available PV deployed in different microclimate environments
- Synchronised data sets to assess performance and contribute to understanding of grid-intermittency on Hawaiian Islands.

**Performance Ratio from Hawaii Island Site**

Electrical output differs by up to 8% for same name-plate capacity
Maui: Smart Grid Test Site

- Maui Smart Grid Demonstration Project (2009) ~$12 M
  - HNEI led project to integrate smart grid technology to achieve reduced peak load on a distribution circuit and better management of intermittent renewable energy

- Japan-US Island Grid Project (2011) ~$40 M
  - NEDO funded, Hitachi led project to integrate high levels of PV, wind energy, and EV into an island wide smart grid environment

- Smart Grid-Enabled PV Inverters (2012) ~$12 M
  - HNEI led project to develop and demonstrate advanced PV inverter functionality in a smart grid environment

Three projects have partners in common, leverage funding from multiple sources and propose to share hardware, results, and lessons learned
**Maui Smart Grid Demonstration Project (2009)**

- Funded by US DOE with cost share from partners
- Implement advanced communications and control technologies to improve grid performance
- Demonstrate new “Smart Grid” technologies to:
  - Reduce peak demand by 15%
  - Better integrate wind and solar power
  - Improve grid reliability
  - Inform consumer demand decisions

**Hawaii Natural Energy Institute**
University of Hawaii at Manoa
Project will Manage Distributed Energy Resources (DER) to Support Grid Operations

**Advanced Metering Infrastructure**
- Two-way comms
- Voltage monitoring
- Outage detection

**Distribution Management System**
- Aggregate DER
- Decision support
- Volt / VAr Control
- Improve visibility

**Battery Energy Storage System**

**Home Area Network**
- Demand response
- Monitor PV
- Customer feedback

**Distribution Monitoring**
- Current measurements

- SSN Data Center
- Internet
- MECO Data Center
- Wailea Sub Station
- Maui Meadows
- SSN Mesh
- GE DMS
- Areva EMS
- Battery
- Current monitoring device
- Load Control Switches
- Solar PV monitoring
- Smart Thermostat
- In-home display
- Distribution Monitoring System
- Voltage
- Monitor
- Outage
- Detection
- Current
- Monitoring
- Device
- Load
- Control
- Switches
- Advanced Metering Infrastructure
- Two-way comms
- Voltage monitoring
- Outage detection
- Home Area Network
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- Distribution Monitoring System
- Battery
- Current measurements
Japan – United States Smart Grid Demonstration Project (2011)

Other supporting partners
Nissan Motor Co., Ltd.
Advanced Energy Company
U.S. Verizon Gr.
Okinawa Electric Power Co.
NEDO Project Scope

Project Architecture

Part 1
- Utility Operations Control Center
- Information on cars and chargers
- Information on traffic flow
- Information on transformers
- Control EV Charge
- Information on storage battery
- Information on Power Generation and Demand

Part 2
- EV/PHEV-Management System
- Command for discharge and charge on EV storage batteries
- Monitoring of feeder and Substation transformer (V, A)
- Demand response (e.g., Direct control)
- Control PV output and reactive power (Smart inverter)
- Information on PV generation (Smart inverter)
- Information on storage battery
- Command for discharge and charge on storage battery
- Information on customer

Part 3
- Distribution Management System
- Direct load control to manage PV variability
- Control PV output and reactive power (Smart inverter)
- Information on PV generation (Smart inverter)
- Information on storage battery
- Command for discharge and charge on storage battery
- Information on customer
**Development and Demonstration of Smart Grid PV Inverters (2012)**

- Enable high-penetration residential PV
- Lower grid integration costs
- Demonstrate benefits of inverter control in differing applications

**Principal Investigator** – Program management and analysis of benefits and impacts of intelligent inverter control capability

**Technology Lead** – Provide end-to-end, standards based, intelligent communications for inverter control

**Inverter Technology Lead** – Provide inverter with advanced grid functionality (AGF)

**Services Lead** – Provide system installation, training, and customer support

**Co-Utility Leads** – Assess capability of inverter AGF to mitigate PV variability impact on distribution feeder and provide other utility benefits
### Solution Architecture

#### Utility Back Office Systems

**Inverter Management & Control Software**
- Provision inverter on network
- Manage PV Production Data
- Send control signals to inverter
- Monitor status of inverter

#### Smart Grid Network

**Silver Spring Networks Network Interface Card**
- SEP 2.0 over 2.4 GHz ZigBee
- 900 MHz utility smart grid network
- Retrieve PV production data
- Send inverter control signals through network

#### Home

**Based on Fronius IG Plus V Inverter**

**Advanced Grid Functionality (examples)**
- Remote generation curtailment
- Remote control of reactive power supply
- Low voltage ride through

**Customer IQ**
- Utility web portal
- Customer can see net bill impact & solar production

**WAN**

**Silver Spring Networks Access Point**

**Smart Meter**
- Utility owned
- Home's primary meter

**2.4 GHz**

**900 MHz**
Integrate Renewables and Transform the Maui Grid

Kihei area

Substation (Distribute)

Wind Farms

KWP (30MW)

KWP II (21MW)

μDMS

EV Energy Control Center

Wailea area

Rapid EV chargers to be provided by Hitachi via NEDO funded project

Wind Farms

EMS

EVECC

Kihei area

NEDO

18+ MW of Distributed PV

63,000 Customers

Daily Load Shape

Load (MW)

85

200

24hr

Wind Farm

AWE (21MW)

KWP II (21MW)

32

KWP (30MW)

University of Hawai‘i

Mānoa

32

University of Hawai‘i

Mānoa

University of Hawai‘i

Mānoa
Deploying Advanced Technologies and Integrated Control Strategies

**Moku o Lo’e (Coconut Island) Secure Microgrid**
- Representative of small < 1MW microgrids
- Highly corrosive marine environment representative of micro-climate encountered by forward deployed naval forces
- Marine research laboratory with critical reliability needs
- Proposed test site for integration/demonstration of PV, micro-wind turbines, advanced communications and control, cyber security, and energy storage

**Molokai Island Smart Microgrid**
- Existing: ~1200 kW Distributed PV; 5.5 MW Peak Load
- Partnership with Hawaii Electric Co, and Okinawa Enetech
- Expand energy production from local renewable resources with goal of 100%
- Community and grid storage systems
- Integrated generation/storage
- Stabilize grid while reducing costs for residents
- Clean energy education and job opportunities

Extend demonstration projects to other Asia/Pacific sites via international partnerships
Mahalo!
(Thank you)

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