Renewable Energy Integration on Island Grid Systems

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**Alternative Fuels:** Biomass and biofuels

**Electrochemical Power Systems**
- Fuels Cells, Batteries

**Renewable Power Generation**
- Ocean Energy
- Photovoltaics

**Energy Efficiency**
- Building technology
- Sea Water Air Conditioning

**Systems Integration**
- Grid modeling and analysis
- Smart grid development
- Grid-scale storage
Hawaii Today

- Primary energy: 90% fossil fuel, all imported;
- Electricity 88% fossil, 90% of that petroleum
- 10% ethanol in gasoline, all imported
- Highest electricity rates in the United States $0.35 - $0.45 per kWh
- Energy expenditures account for 13% of Hawaii’s Gross State Product
- Abundant renewable resources but only 12% of electricity produced from renewables

**Leads to**
- Energy insecurity
- Economic drain
- Price volatility
- Environmental harm
Integration of Renewables – What’s needed

• **Vision and Collective Buy-in**
  – Government – Industry partnerships
  – Community engagement and dialog

• **Policy – Regulatory Compacts**
  – Framework for implementation

• **Analysis**
  – *Site specific roadmaps based on existing infrastructure, generation mix, renewable resources, reliability requirements*
  – *Intermittency at both transmission and distribution level*
  – *Power quality, interconnection*

• **Validation and Testing**
  – *Performance and lifetime of innovative technologies*

• **Project Development – financing, permitting**

• **Implementation**
Renewable Energy Opportunities in Hawaii are Abundant

- **Oahu (1,200 MW)**
- **Molokai (5MW)**
- **Lanai (5MW)**
- **Maui (200 MW)**
- **Hawaii (190 MW)**

Other energy sources include:
- Wind
- Solar
- Geothermal
- Biomass/Biofuel
- OTEC/Wave
- DSM/Energy Efficiency
- Hydro/Pumped
- MSW
Integration of Renewable Energy Resources is Complicated

- Intermittency solar and wind
- No island interconnections;
- Resources not evenly distributed
- Resources not near population
- Large gap between peak and base load

Opportunity to validate and deploy new technologies
Hawaii is Moving Forward

- **Hawaii Clean Energy Initiative:** 70% clean energy by 2030
  - 30% Renewable Energy  40% Energy Efficiency
- **Tools:**
  - Renewable Portfolio Standards, Net Metering, Feed-in tariff, Reliability standards, Fuels standards, Building code
  - Aggressive state tax policy

**Uncertainties**

- Undersea cable between islands
- Alternative fuels (biofuels, LNG)
- Disruptive technologies (e.g. OTEC)
- Energy efficiency and demand response
- Energy Storage
- Smart grids

*Courtesy OPT*

*Courtesy Makai Ocean Engineering*
HAWAII ISLAND INTEGRATION STUDIES

Develop and use 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 DEMONSTRATIONS

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

TECHNOLOGY VALIDATION

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

Inform Policy
Work-force training
Regulatory Infrastructure
Hawaii Island Integration Studies

- Rigorous analytic modeling of electricity grids identify technical and economic feasibility of operational, infrastructure and technological strategies to enable high penetrations of renewable energy.
- Identify and analyze wide range of potential solutions:
  - Wind and solar forecasting
  - Refined reserve requirement
  - Reduced min power of baseload units
  - Seasonal cycling
  - Modified generator controls
  - Advanced wind turbine controls
  - Demand response
  - Electric Vehicles
  - Storage
  - Smart grids

Modeling across many timescales.
Recently Completed/Ongoing Analysis

• Oahu Wind Integrations Transmission Studies (complete)
  – With appropriate system modifications (no storage, no smart grids), Oahu can reliably accept 25% of its energy - from 500 MW Wind and 100 MW of PV

• Oahu- Maui Integration study (1st Q 2013)
  – Analysis of two way flow between counties to quantify benefits and impacts of undersea connection of Maui and Oahu

• EV charging study (1st Q 2012, 2nd Q 2013)
  – Evaluate use of EV to utilize curtailed energy under very high penetration scenarios

• Hawaii Solar Integration Studies (4th Q 2012)
  – Analysis of wind plus high penetrations of photovoltaics for the islands of Oahu and Maui
The Maui island Experience
72 MW of Wind Power, 18MW PV, Curtailment

Rapid Growth in PV

- 2008 < 2MW
- 2010 ~5MW
- 2012 > 18MW

Load ranges from 85 to 200 MW each day
Maui Solar Integration Study (HSIS)

OBJECTIVES

• Examine challenges of high renewable penetration
  – 72MW wind, up to 45MW solar
• Recommend strategies to enable high levels of solar and wind power on the Maui grid

KEY RESULTS

• Up to 25% total electricity can be accepted from renewable sources
• Significant curtailment of wind during minimum load
• Regulation requirements (contingency and regulating) required for reliability a significant limiting factor

FUTURE EFFORTS

• EV analysis, demand response, storage for ancillary services, smart grids
Grid-scale Energy Storage—photos courtesy of Altairnano

**Testing and Evaluation of BESS for Grid Support**

**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

**HECO 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, ~100kW community BESS,
- Operating reserves, frequency regulation, smoothing, peak shifting.

**Kauai Waste Water Treatment Facility**
- ~1MW, 2MW-hr integrated into MW PV system
- PV smoothing, energy storage/load shifting
Smart Grid Solutions
Secure Integration of Two Infrastructures

Electrical infrastructure
- Embracing renewables
- Increasing productivity

Information infrastructure
- Empowering consumers
- Reducing CO₂ emissions
- Increasing efficiency

Better Management of Distributed Resources and Loads
Hawaii Smart Grid Demonstration Projects

- **Maui Smart Grid Demonstration Project (2009)**
  - USDOE funded, HNEI led project to manage home energy usage using smart grid technology allowing peak load reduction and management of intermittent renewable energy.

- **Japan-US Island Grid Project (2011)**
  - NEDO funded, Hitachi led project to integrate advanced PV, energy storage, and EV into island wide smart grid environment to enable high penetration of central and distributed renewables

- **Smart Grid-Enabled PV Inverters (2012)**
  - Demonstration of advanced PV inverter functionality in smart grid environment (V, power quality) in both high penetration and sparse distribution lines.

Three projects have partners in common and propose to share hardware, results, and lessons learned
The Molokai Opportunity

Current System

- 5.5 MW Peak Load
- ~2000 Customers
- Five major 12kV & 34.7kV “Transmission”
- Three 2,200 kW Diesel Generators
- One 2,220 kW Gas Turbine
- Six Smaller Diesel Generators
- ~1200 kW Distributed PV

Phase 1

- Address current and near term stability issues
- Energy Storage
- Partner staff exchange

Phase 2

- Expand energy production from local renewable resources – goal of 100%
- Reduce/stabilize energy costs for residents
- Validate advanced technology (EM)
- Create green job opportunities

Initial Partners: Hawaiian Electric / Maui Electric; HNEI, Okinawa Enetech
Summary Comments

- Every grid system is different - analytic models provide valuable tools to quantify barriers to integration of renewables and guide development of an economic and technically viable path forward.

- Community acceptance, siting, liability issues can extend timelines and cost for all energy projects including renewables

- Shared lessons even across seemingly dissimilar grid systems can help reduce cost of development

- Performance and value of innovative technologies needs to be validated in replicable, well quantified projects

- HNEI/Hawaii offer expertise in understanding of isolated grid systems.
MAHALO

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Backup slides
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

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ALSTOM
medb
maui economic development board, inc.
SILVERSPRING NETWORKS
Maui Electric Company, Ltd.
Hawaiian Electric Company
Project will Manage Distributed Energy Resources (DER) to Support Grid Operations

Advanced Metering Infrastructure
Two-way comms
Voltage monitoring
Outage detection

Home Area Network
Demand response
Monitor PV
Customer feedback

Solar PV monitoring
Smart Thermostat
In-home display

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

Battery Energy Storage System
Current monitoring device
Load Control Switches

Distribution Monitoring
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 Company
NEDO Project Scope

Project Architecture

- Substation
- Distribution Grid
- Wind turbine
- Photovoltaic
- EV/PHEV Management System
- Utility Operations Control Center

Information

- Part 1
  - Information on cars and charger
  - Information on traffic flow
  - Information on transformers
  - Control EV Charge
  - Information on storage battery
  - Information on Power Generation and Demand
- Part 2
  - 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
  - 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
Transitioning to High Renewable Energy

50% of Peak Load met by Renewables (25% annual energy)

Baseline
No Wind or Solar

High Renewables
500MW Wind & 100 MW Solar

 Thermal units are backed down, wind energy is sometimes curtailed at light load, and wind power changes are managed by ramping the thermal units.
Development and Demonstration of Smart Grid Inverters for High Penetration PV Applications

Funded by US Department of Energy with cost share from industry partners

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Maui Electric Company, Ltd.

Hawaiian Electric Company

OG&E
Power at the speed of life.

Fronius
POWERING YOUR FUTURE

SilverSpring Networks

NEDO
New Energy and Industrial Technology Development Organization

SolarCity
PV Inverters Integrated into Home Area Network (HAN) enabling two-way communication and grid support features

Integrate into Utility Software Applications

SSN Smart Meter

Smart Grid-Enabled Inverter

Fronius Inverter: 3 kW - 5 kW
Grid support features developed to meet German grid codes

Project will demonstrate inverters at two utility sites – Maui Electric and mainland site TBD