Hawaii Natural Energy Institute

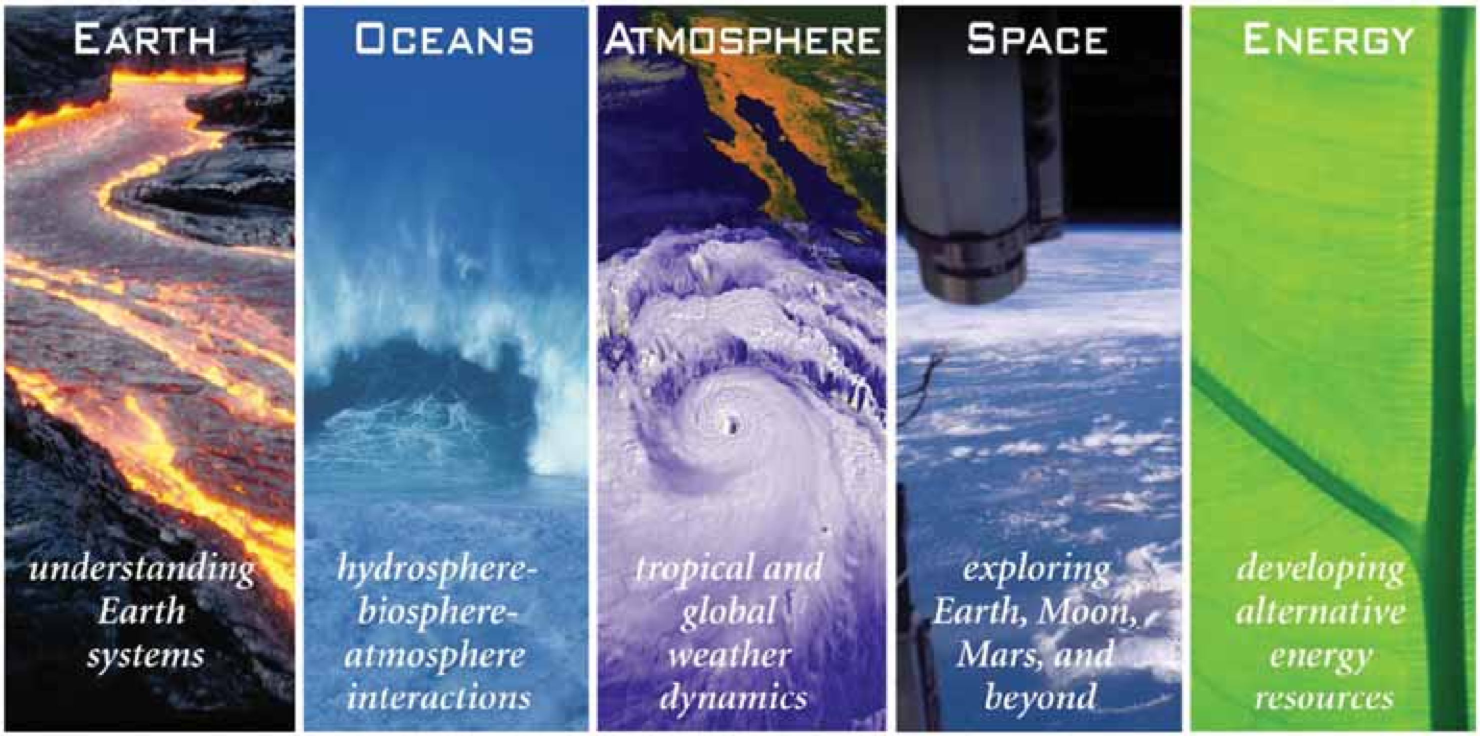
School of Ocean and Earth Science and Technology
University of Hawaii at Manoa

World Bank Study Tour

May 24, 2016

HNEI
Hawai'i Natural Energy Institute
School of Ocean and Earth Science and Technology
University of Hawai'i at Mānoa

- ✓ Established in 1907
- ✓ 3 universities & 7 community colleges
- ✓ Over 53,000 students
- ✓ Manoa is the largest and main research campus
  - 14,000 undergraduate students
  - 6,000 graduate students
  - State and tuition funding ~ $350MM



One thousand (1000) staff including 220 tenure track faculty
Five (5) academic departments with emphasis on graduate education
Four Organized Research Units: HNEI, HIMB, HIGP, SeaGrant
Over $100 million extramural funding per year

Hawaii Natural Energy Institute (HNEI)

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

- Founded in 1974, established in statute in 2007
- Established to work with government organizations to reduce state dependence on fossil fuels
- Diverse staff (~90)- engineers, scientists, lawyers; students and postdoctoral fellows, visiting scholars
- Primary funding from Dept of Defense, US Dept of Energy, State of Hawaii

Areas of Interest

- **Alternative Fuels**
- **Electrochemical Power Systems**
- **Renewable Power Generation**
- **Building Efficiency**
- **Transportation**
- **Grid Integration**

Core Functions

- **Research & Development**
- **Technology Validation & Implementation**
- **Analysis & Modeling**
- **State Energy Policy Support**
- **Education and Training**

HNEI

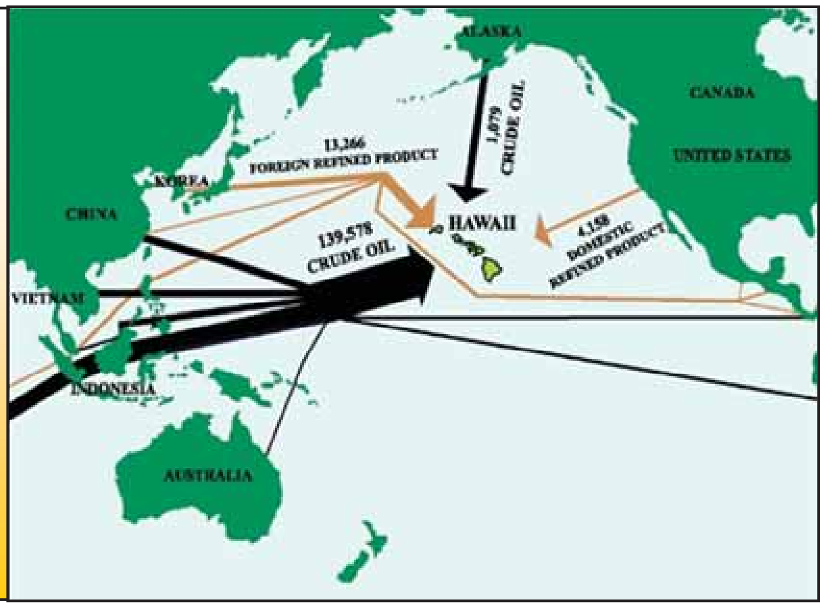
Energy Insecurity

46.3 million barrels of petroleum were imported for Hawaii's total energy use in 2012

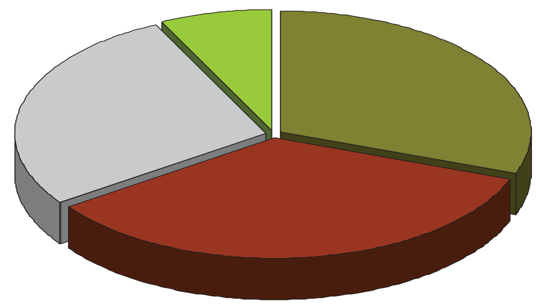
- **Primary energy: 90%** fossil fuel, all imported, most of it is crude oil refined
- That's 36 barrels of petroleum for every man, woman and child living in Hawaii
- $5.09 billion left the state to pay for imported petroleum

- **100% of the crude oil for the State is *imported***

Hawaii Department of Business, Economic Development & Tourism



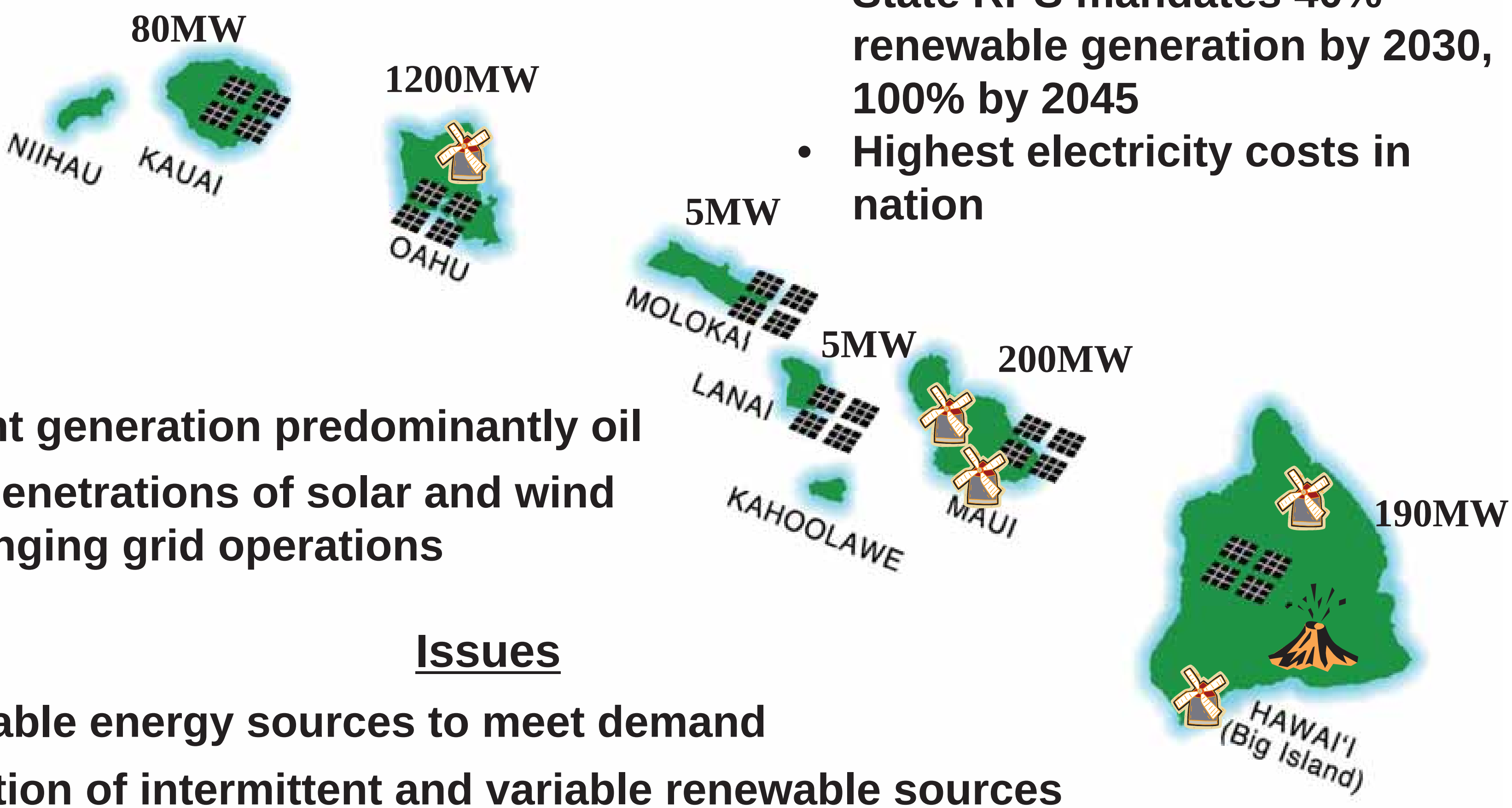
Crude Oil Supplies to Hawaii



JET FUEL	34%
ELECTRICITY	32%
GASOLINE/ MARINE FUEL	27%
OTHER	7%

UNIVERSITY of HAWAI'I MĀNOA

Hawai‘i Energy: Isolated Island Grids



- State RPS mandates 40% renewable generation by 2030, 100% by 2045
- Highest electricity costs in nation

- Current generation predominantly oil
- High penetrations of solar and wind challenging grid operations

Issues

- Renewable energy sources to meet demand
- Integration of intermittent and variable renewable sources
- Community acceptance especially for interisland connections

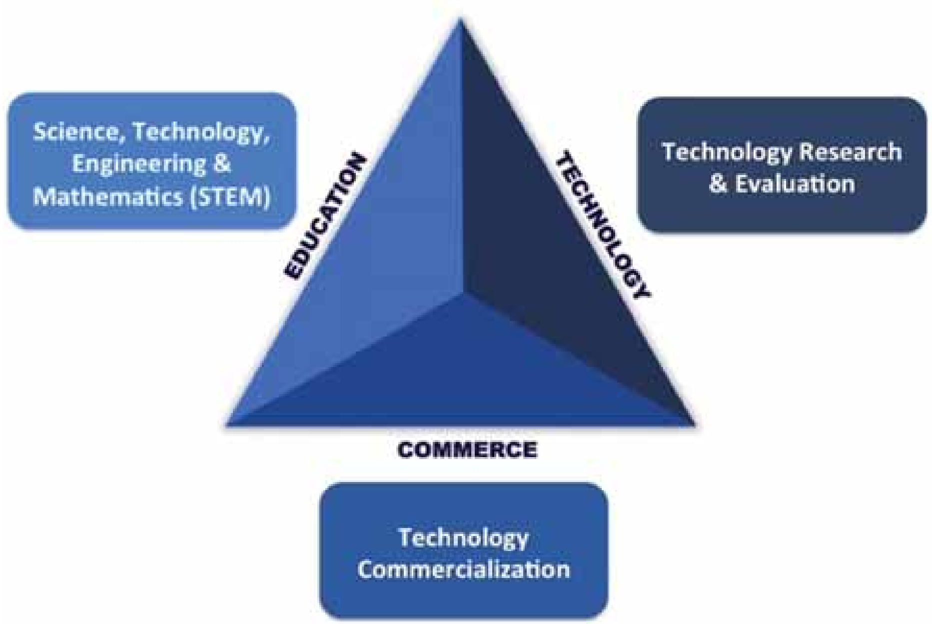
Opportunity/need to validate and deploy new technologies

HNEI Hawai'i Natural Energy Institute

Hawaii Natural Energy Institute (HNEI)

- 1974 - Established at University of Hawaii (1974)
- 1988 - Organized research unit in School of Ocean and Earth Science and Technology
- 2007 - Established in statute and selected to administer the Energy Systems Development Special Fund (2007)
- Approximately 90 staff
  - 11 UH positions (7 faculty, director, 3 administrative)
  - Diverse staff - engineers, scientists, lawyers, postdocs, students)
- Primary funding from
  - Dept of Defense (ONR, NavFAC)
  - US Dept of Energy (EERE, OE)
  - State of Hawaii (barrel tax)
- Work closely with HI Public Utilities Commission, DBEDT, HECO, and State Legislature on HI energy issues

HNEI is Key Performer for Technology Research and Evaluation in Support of ONR's APTEP



- Research and development
- Testing and evaluation of emerging energy technologies
- Integration of renewable energy systems
- Energy analysis
- Contribute to STEM and workforce development

Asia Pacific Technology and Education Partnership (APTEP) promotes commerce and partnerships in the Asia-Pacific region through advancements in alternative energy research, technology development and education.

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

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

Life Cycle Assessment – Systems Analysis – Water, Energy, Soil Sustainability

HNEI

HNEI Fuel Cell/Hydrogen Research

HI Sustainable Energy Research Facility (HISERF)

- Development and testing of fuel cell/battery power systems for manned and unmanned vehicles
- Development of technology for contaminant mitigation to allow operation of fuel cells in harsh environments.

Marine Corps Base Hawaii Dual Pressure "Fast-Fill" H2 Fueling Station

- Basis for design of public stations
- Support DOD testing of FC vehicles and other hydrogen technologies

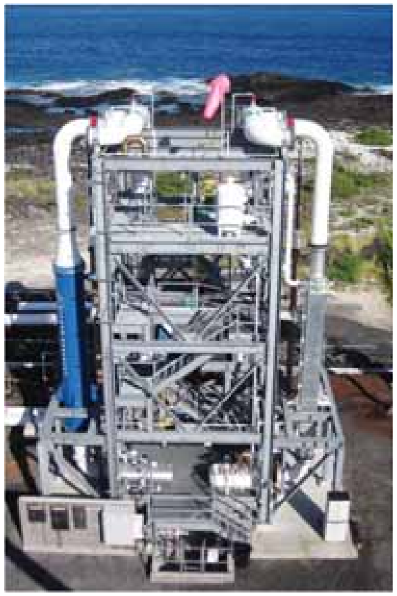
Hydrogen Energy Systems for Grid Management

- Demonstrate the use of electrolyzers to mitigate the impacts of intermittent renewable energy
- Supply hydrogen to shuttle buses operated by County of HI MTA and Hawaii Volcanoes National Park

HNEI

Ocean Resources

- **Hawaii National Marine Renewable Energy Center (USDOE)**
  - 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, environmental monitoring, design enhancements
- **Methane Hydrates**



Makai Ocean Engineering
OTEC Test site

Wave Energy Test Site (WETS) at MCBH, Kaneohe HI, - at-sea performance and survivability testing for further development and financing;

Navy Wave Energy Test Site at MCBH

3 grid-connected berths – 30m, 60m, 80m

1 device deployed, 2nd Nov 2015, 3 more 2016-18

NAVFAC

APPLIED RESEARCH LABORATORY
UNIVERSITY OF HAWAI'I

Funding

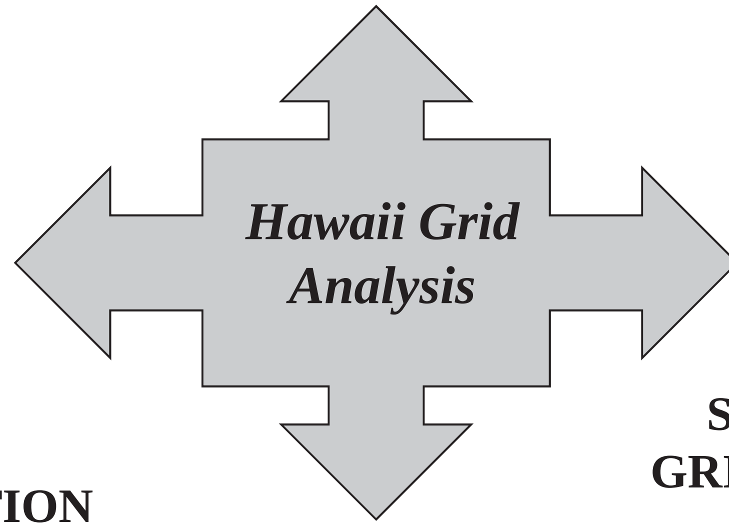
- Navy: Infrastructure, Developer Support, ARL/HNEI Support
- USDOE: HI National Marine RE Center, Developer Support
- ONR: Technology Support
- State of HI: Technology Support

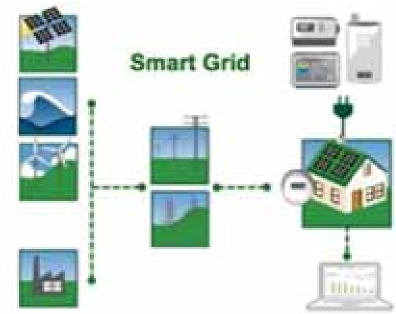
HNEI Role

- Support NAVFAC EA process and deep berths design
- Environmental impacts, incl. acoustic & EMF signature, eco surveys, sediment xport
- Independent evaluation of device power output/durability
- Provide site-dedicated support vessel for developers and researchers

HAWAII ISLAND INTEGRATION STUDIES

Analysis to support decision making, policy and project development.





TECHNOLOGY VALIDATION

- Grid-scale storage
- Photovoltaics
- Small wind systems
- Advanced grid controls
- Ocean energy systems
- Demand response technology
- Energy efficiency

Inform Policy

Work-force Training

Regulatory Infrastructure

SMART AND MICRO-GRID DEMONSTRATIONS

- Maui Smart Grid Project
- Japan-US Smart Grid Demonstration Project
- Smart Grid Inverter Project
- Coconut Island microgrid
- Molokai microgrid opportunity

Grid Scale BESS Projects (HNEI)

Conduct experiments to assess BESS performance and lifetime for high value grid applications

Haw'i 10 MW Wind farm at Upolu Point Hawaii Island (1MW)

- Frequency regulation and wind smoothing

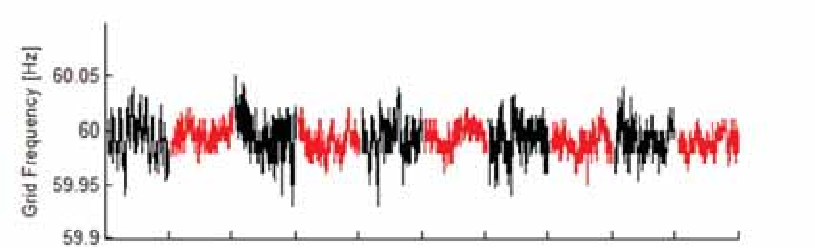
Cambell Park industrial feeder with high penetration (1MW)

- Power smoothing, voltage and VAr support, and frequency regulation

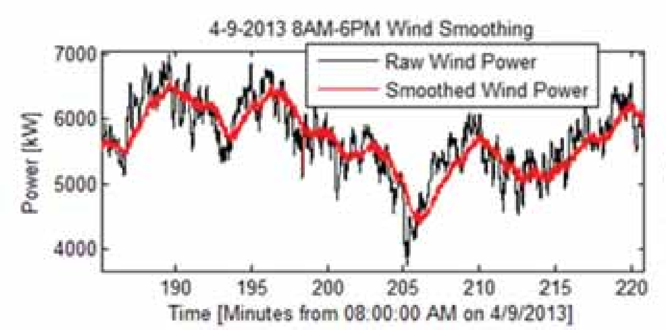
Molokai Secure Renewable Microgrid (2MW)

- Operating reserves, (fault management), frequency regulation, power smoothing, and peak shifting

photos courtesy of Altairnano



Frequency regulation on HELCO grid



Power smoothing from 10MW Hawi wind farm

HNEI Hawai'i Natural Energy Institute

Renewable Integration and System Modeling

Transitioning to a Renewable Energy Future

Achieve RPS goals at minimal cost while maintaining system reliability

Hawaii's Renewable Portfolio Standard

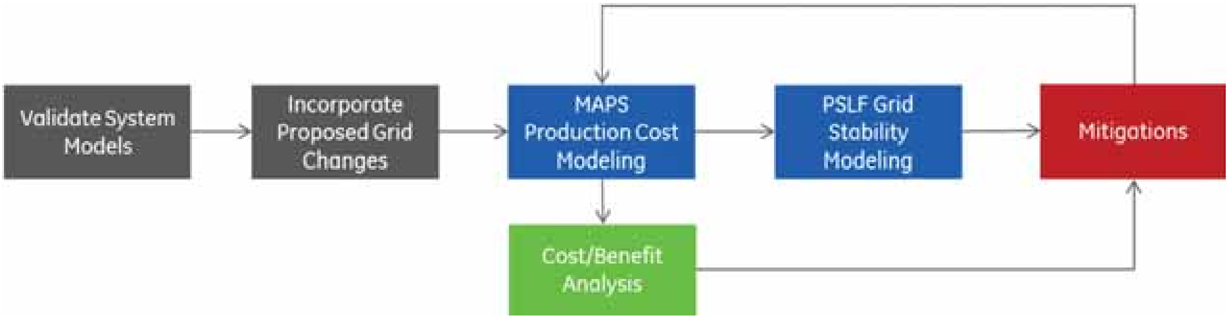
30% by 2020 → 40% by 2030 → 70% by 2040 → 100% by 2045

- Optimize unit dispatch
  - Maximize renewable penetration
  - Minimize curtailment
- Maintain reliability
  - Operating & contingency reserves
  - Generation capacity & resource adequacy
- Maintain grid stability
  - Frequency response
  - Voltage support
- Plan for annual and inter-annual resource variability
- Assess long-term impacts to state economy

Grid Analysis Team

- Established team with technical capabilities and experience to address Hawaii energy systems and policy
  - HNEI: Technical lead, overall coordination
  - GE: Validated system models, substantial Hawaii experience
  - Steering committee including HPUC, DBEDT, USDOE, HECO, MECO, HELCO, energy developers
- Models, procedures, and data vetted by broad range of stakeholders
- Six studies including 2015 RPS assessment completed
- Potential pathways to higher renewable penetration (~40%) identified
- Studies initiated to address reserves, reliability, stability at high penetration

Power Systems Modeling for Planning



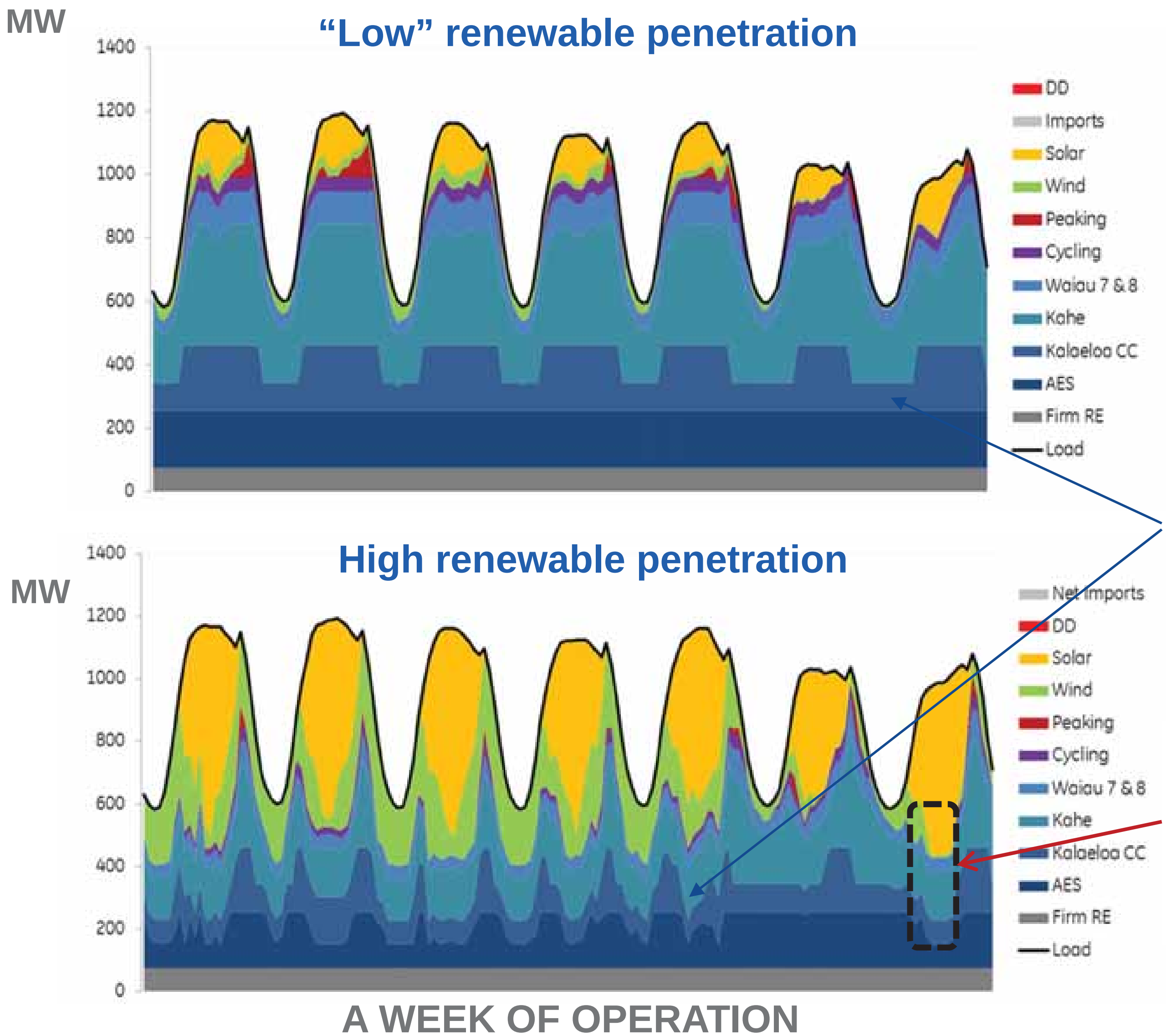
- **Postulate new energy systems and analyze impact on production cost and curtailment**
  - Different resource mixes (wind, central and distr PV, other)
  - Alternative fuels (LNG, hydrogen, biofuels)
  - Grid configuration (independent or connected)
  - Changes due to load and load-profiles (end-use efficiency, alt transportation)
- **Identify and analyze mitigation methods to address curtailment**
  - Advanced controls, unit cycling, reduced minimum run, improved forecasting
  - Energy storage, smart grids, advanced inverter technology, microgrids, demand response, integration with transportation
- **Analyze reliability and stability – additional mitigations**

2015 RPS Study

Identified and evaluated cost-effective pathways that support the RPS goals for Oahu & Maui

- Analyzed 18 scenarios with up to 55% “available” renewable electricity
- Focused on differing mixes of wind and solar but also included
    - Independent and connected islands
    - Changes to grid operation such as retirements; new, fast generators; and changes to min run rules
    - Alternative fuels including LNG
    - Demand response
    - Storage for reserves
- Storage for energy arbitrage, smart grids, and emerging technologies not included
- Preliminary capacity reliability modeling conducted (evening peak)
- Cost analysis completed for each of the scenarios

System Dispatch with Increased Variable Renewables



Generation-load balance essential for frequency control

Increased cycling of baseload units to accommodate intermittency

Curtailment occurs when all dispatched thermal units are at minimum power and cannot cycle off

Characterizing Variability

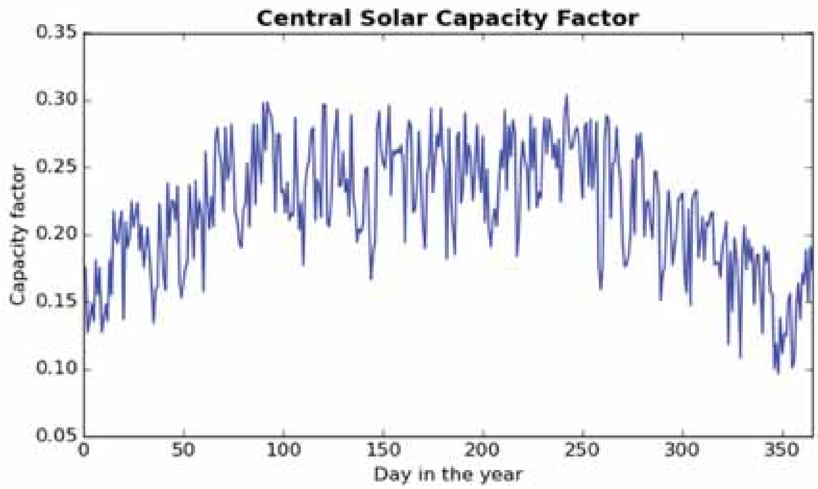
Uncertainty

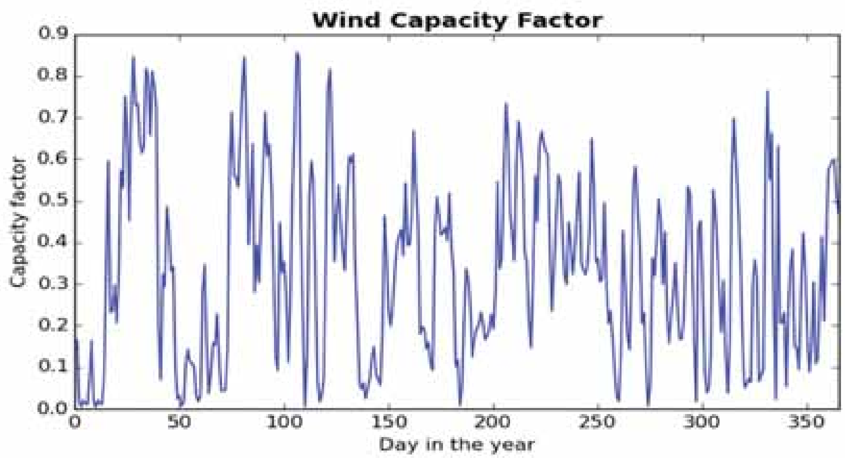
- Wind and solar generation are not always available when called upon
- Are not dispatchable… output is predicted by a forecast
- Actual power output is different than forecast output

Variability

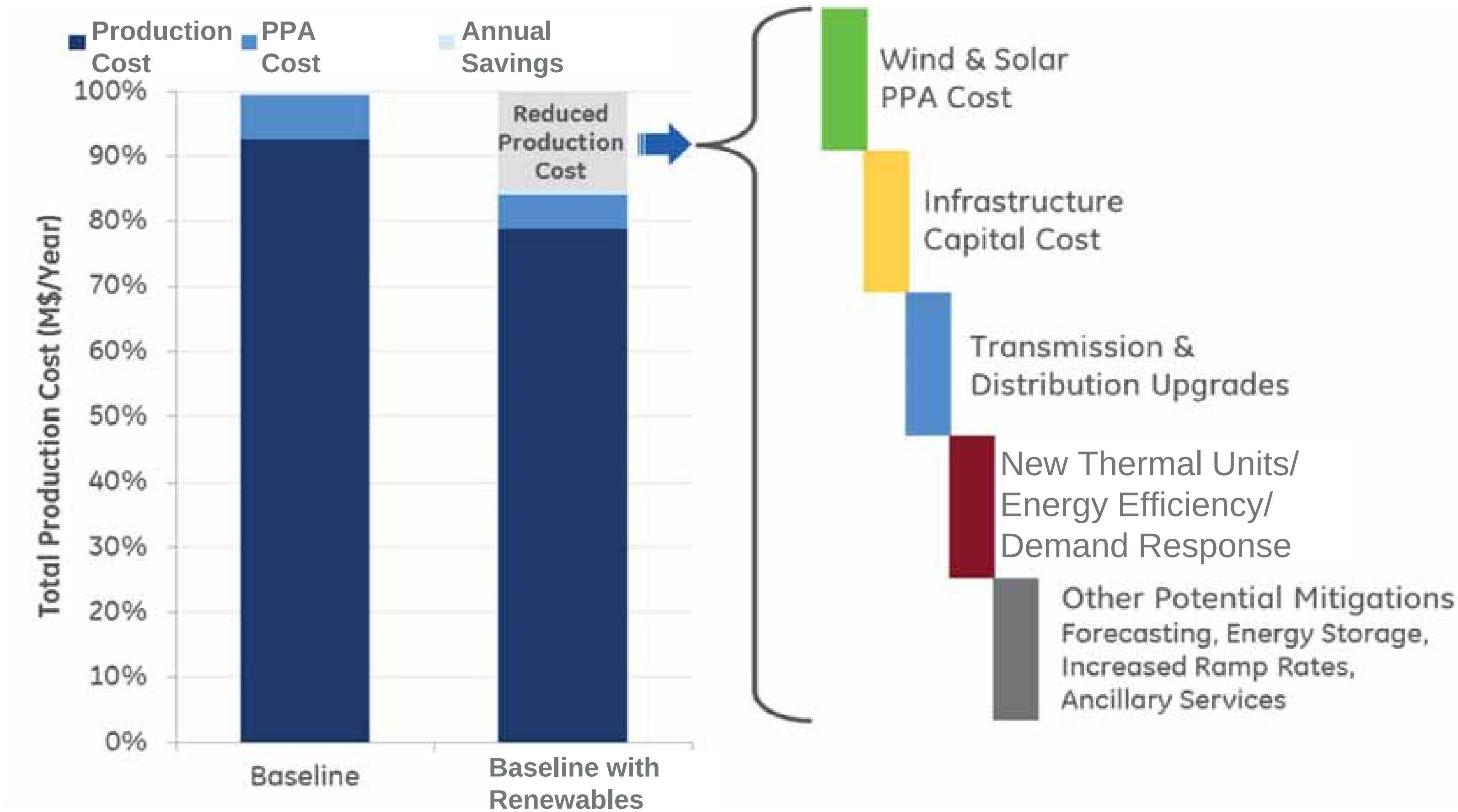
- Wind and solar generation vary with the intensity of their energy sources
- Multiple timescales to consider … minute (regulation), hour (ramping), daily, seasonal, **annual**

Dispatchable reserves must allow for variability and uncertainty; and contingency events (load or gen loss)



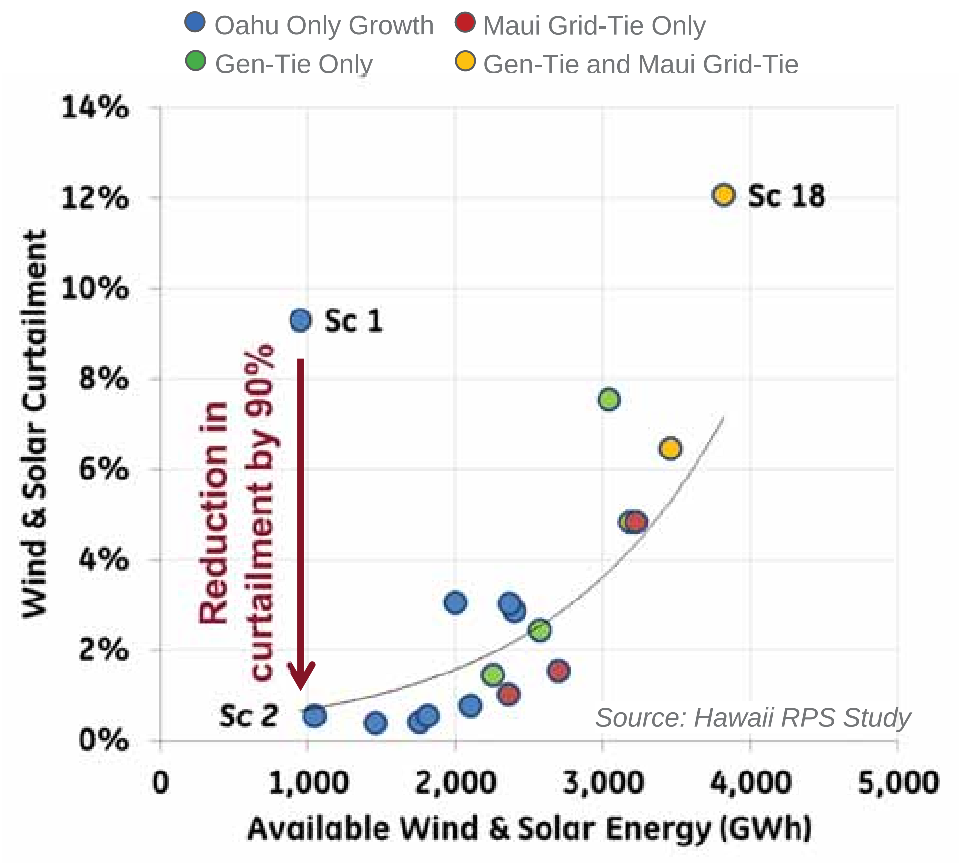


Production Cost Savings
The Economics of Renewable Integration



Savings from wind and solar may be partially offset by necessary grid upgrades

Supporting Increased Renewable Integration



Enablers

- **Flexible thermal fleet**
  - Faster quick starts
  - Deeper turn-down
  - Faster ramps
  - Baseload cycling
- **Controllable wind and solar for reserves**
- **Wind forecasting**
- **Energy storage for reserves**
- **Spatial diversity of wind/solar**

Increased renewable integration will require additional grid investment and modifications

A Long Way to Go

Near Future (Oahu Only)

125 MW Wind (+25)	~383 GWh (~4.9%)
375 MW DPV (+20)	~591 GWh (~7.6%)
152 MW CPV (+137)	~293 GWh (~3.8%)
69 MW Waste	~390 GWh (~5.2%)
120 MW Biofuel	~36 GWh (~0.5%)
Total RE	~1696 GWh (~21.8%)

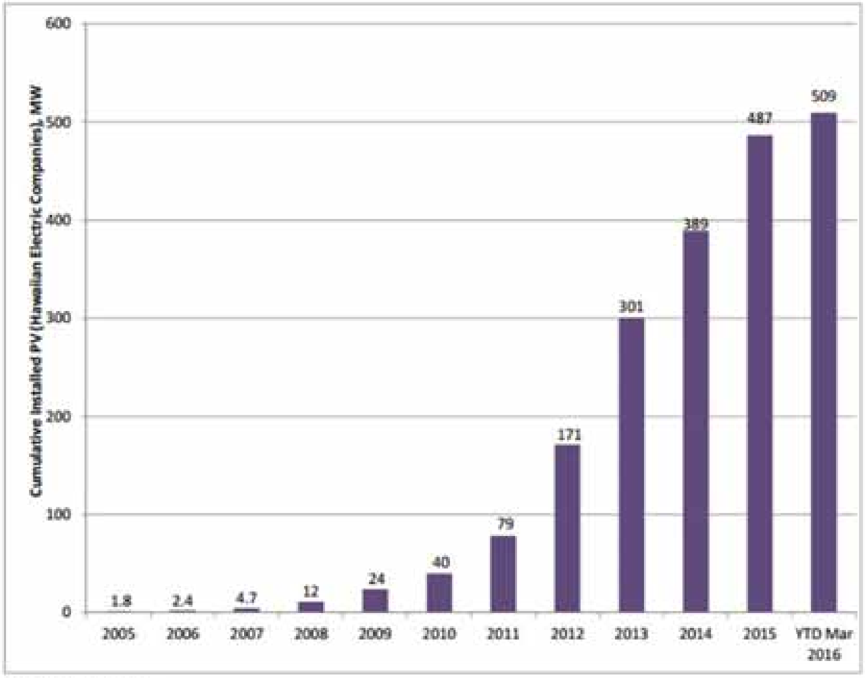
*Assumes no curtailment

350 MW of Distributed PV contributes only ~7% of annual energy on Oahu

(assumes 17% Capacity Factor)

Cumulative Installed PV -- As of Mar. 31, 2016

	Number of PV Systems			PV Capacity, MW		
	Number	% Residential	% Commercial	Capacity	% Residential	% Commercial
Hawaiian Electric	43,067	97%	3%	356	64%	36%
Hawai'i Electric Light	10,186	94%	6%	73.3	65%	35%
Maui Electric	10,060	93%	7%	80.3	64%	36%
Total	63,313			509		



Data subject to change

Hawaiian Electric
Maui Electric
Hawai'i Electric Light

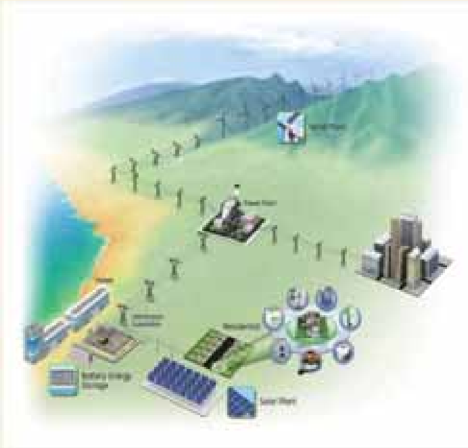
HJ1

GridSTART

Hawai'i Natural Energy Institute | University of Hawai'i

Grid System Technologies Advanced Research Team

Expertise & Focus:



- *Renewable Energy Grid Integration*
- *Smart Grid Planning & Technologies*
- *Power Systems Planning*
- *Power Systems Operation*
- *Power Systems Engineering and Standards*
- *Project Management and Execution*
- *Energy Policy*
- *Communications Design and Testing*
- *Data Center and Cloud infrastructure Design and Testing*

University of Hawai'i Mānoa

Slide 25

HJ1 Hsun Jou, 5/23/2016

Island Grid and Renewable Energy Collaboration

Opportunities in Hawaii, Okinawa and extended Asia-Pacific region

500 kW Grid

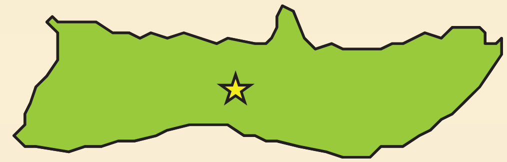
Coconut Island is an opportunity to test advanced technologies and microgrid control strategies for high reliability loads in a challenging marine environment

Moku o Lo'e Secure Microgrid (Coconut Island)

5 MW Grid

Molokai is an opportunity to address very high levels of distributed PV while maintaining grid reliability and resiliency

~ 2 MW of Distributed Rooftop PV



MOLOKAI

Molokai Island Grid

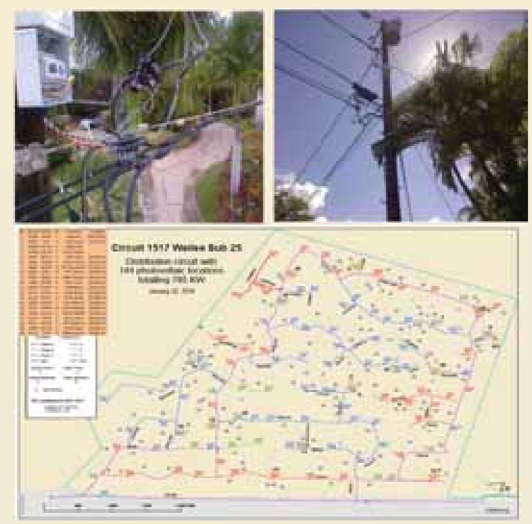
25 MW Grid

UH Mānoa campus is an opportunity to evaluate advanced systems for energy management, efficiency and control of distributed energy resources aimed at energy cost reduction

University of Hawaii – Mānoa Campus Microgrid

Maui Smart Grids

The Maui Smart Grid projects provide an opportunity to research, test, demonstrate and evaluate new smart grid technologies in a real world setting collaborating with both the customers and the utility.



Wailea and Kihei

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Moku o Lo'e Secure Microgrid
(Coconut Island)

Coconut Island offers a unique opportunity for technology and material testing:

- Scale: ***0.5 MW grid connected microgrid***
- UH owned/controlled island facility
- High penetration of distributed renewable energy resources (particularly rooftop PV)
- Marine research laboratory with critical loads and high energy ***reliability*** needs
- Persistent coastal winds result in a highly corrosive marine environment yielding a micro-climate representative of many island nations

Test advanced clean energy technologies and integrated control strategies such as:

- Photovoltaic systems
- Distributed wind turbines
- Energy storage systems
- Fuel cells
- DC distribution, motors, & lighting
- Load management
- Building controls & energy efficiency
- Advanced communications and microgrid control
- Alternative fuel vehicles (EV car/boat)
- And more ….

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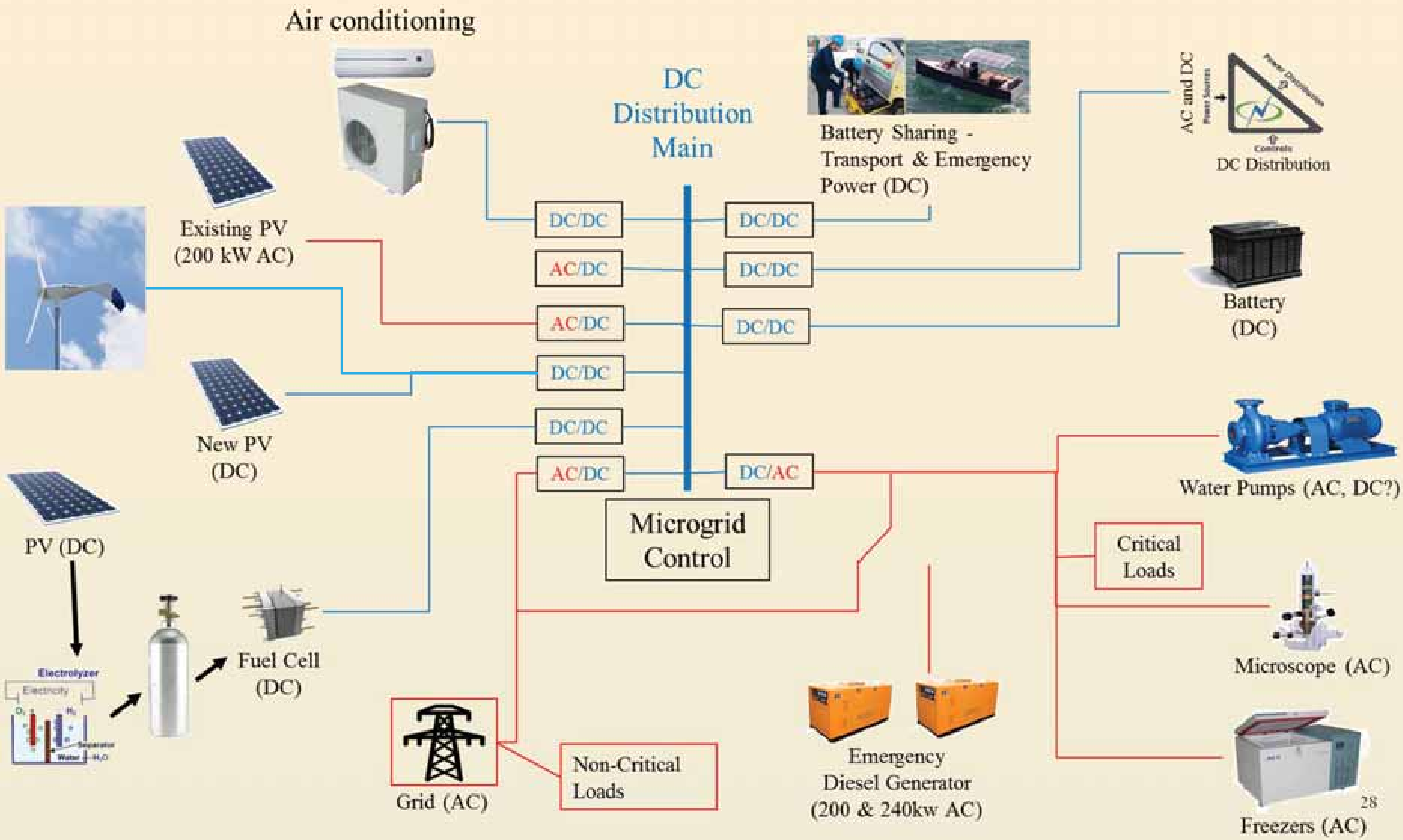
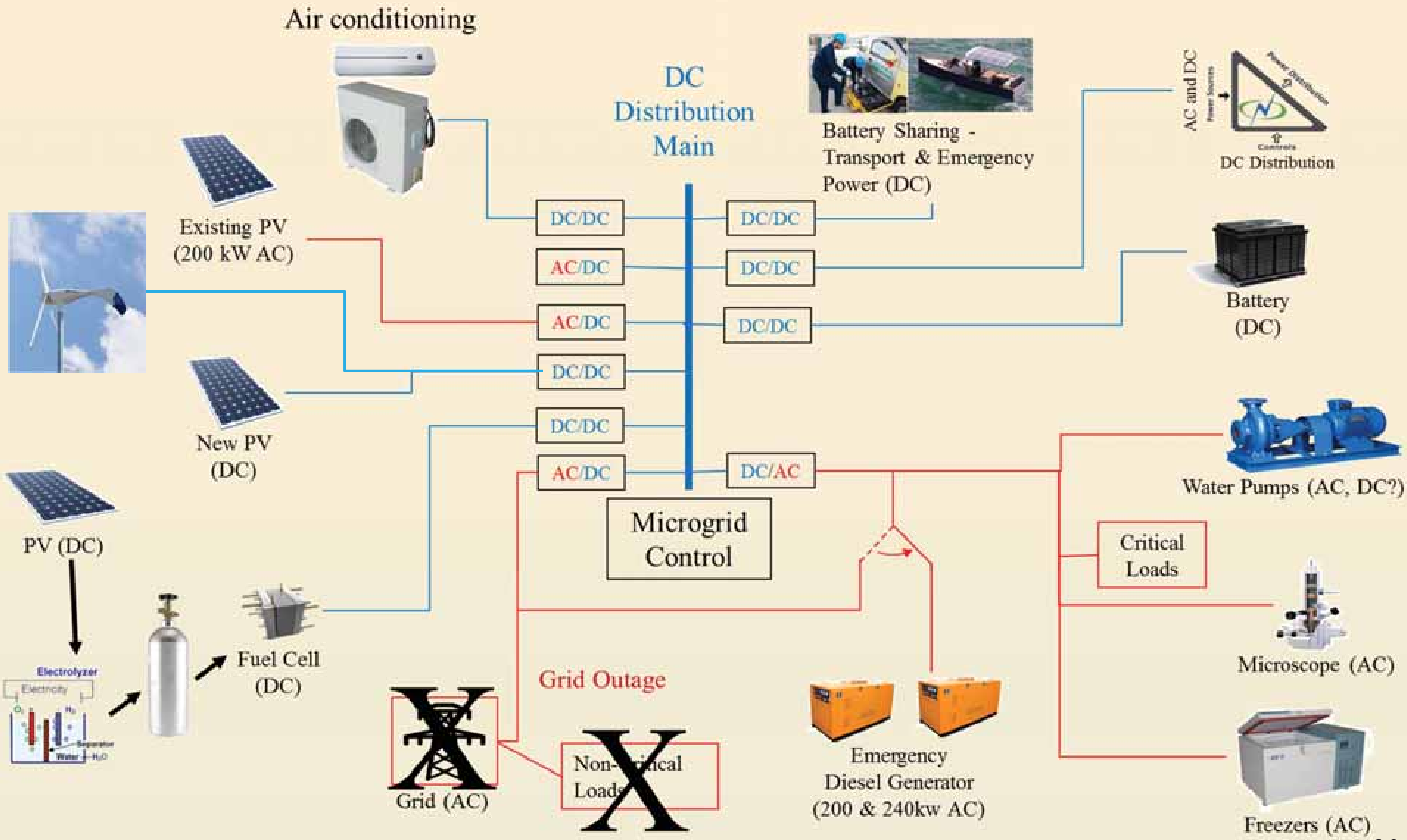
Normal (Grid Connected)



Emergency (Grid Outage)



Molokai Island Grid Initiative

Phase 1

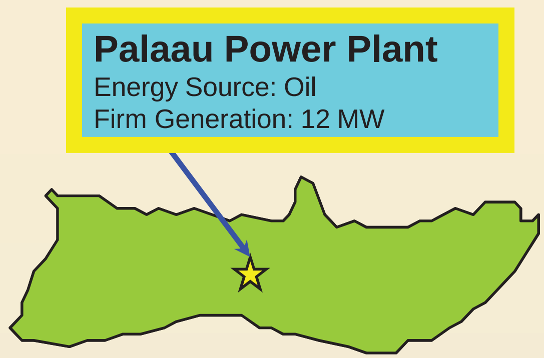
- Address current and near term grid stability issues

Phase 2

- Reduce/stabilize energy costs
- Expand energy from local renewable resources
- Improve grid reliability and resiliency
- Clean energy education and job opportunities

➢ **Scale:** ***5 MW island grid***

- 5.7 MW peak demand
- 2000 Customers
- Five major 12kV feeders
- Single diesel fired power plant
  - Three 2.2 MW diesel generators
  - Six 1 MW diesel generators
  - One 2.2 MW gas turbine
- 2.36 MW distributed rooftop PV Installed/approved
- 845 KW in the Queue



MOLOKAI

Opportunity to extend demonstration projects as a scalable model to other Asia/Pacific regional sites

University of Hawaii – Mānoa
Campus "Microgrid" Project

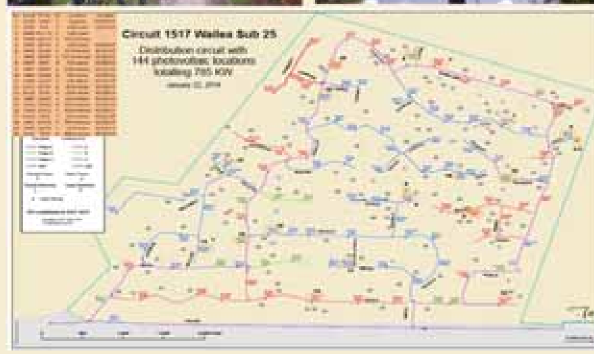
The UH Mānoa campus project objectives:

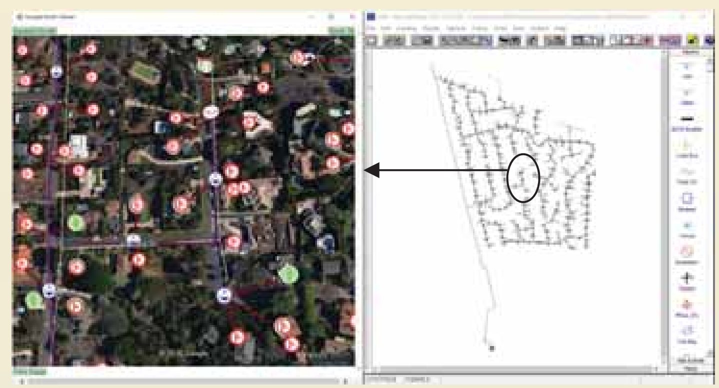
Scale: ***25 MW microgrid***

- Managing the high cost of electricity
  - Support development and implementation of renewable energy technologies
  - Renewable resource scenarios and economic assessment
  - Demonstrate the use and value of on-site generation to address high electricity cost
- Improve operation, reliability and quality of service
  - Extend visibility of the system with system monitoring devices
  - Improve campus grid reliability and operations via system modeling and assessment
- Advanced grid modernization
  - Support development of vehicle to grid and other new technologies to support campus microgrid and Oahu island grid operations.

Smart Grid Inverter Project

- The focus of this project is to implement, on operating utility distribution feeders with a high penetration of rooftop PV, enhanced capability “smart” inverters to achieve improved operational visibility, performance and control
- Focus areas of research will include:
  - Test inverter control algorithms
  - Grid integration of high penetration PV
  - Distribution feeder modeling with operational performance data validation and iteration
  - Enhanced tools for utility control room operators





Navy Projects

- **Energy Assurance Project**– Coordinate with DoN and NAVFAC to develop ***grid modernization and renewable energy integration action plan*** to meet Navy needs/goals in Hawaii. Includes integration of distributed renewable generation and the capability of energy surety (safety, security, reliability, sustainability, and cost effectiveness) for critical power needs (ONR via ARL)
- **Navy Marianas Infrastructure Modernization & Renewable Integration Project**: Initial data gathering to support development of a power grid modernization strategy and renewable energy integration action plans to meet base needs and Navy renewable energy goals. (NAVFAC via ARL)
- **Okinawa**: Ongoing discussions to initiate integrated planning effort

BESS Projects (HNEI)

Haw'i 10 MW Wind farm at Upolu Point Hawaii Island

- 1MW, 250kW-hr at wind and utility interface; Li-ion Ti
- Control algorithms for frequency regulation and wind smoothing

Photo courtesy of HECO

CIP industrial feeder with high penetration (~3 MW of distributed PV)

- 1MW, 250 kW-hr at substation; Li-ion Ti
- Control algorithms for power smoothing, voltage and VAr support, and frequency regulation

photos courtesy of Altairnano

Molokai Secure Renewable Microgrid

- 2MW, 333kW-hr, Li-ion Titanate;
- Control algorithms for managing operating reserves, (Disturbance management, frequency regulation)

Evaluation of Alternative Ownership Options
for Electric Utilities
on the Islands of Oahu and Hawaii

HNEI contracted with Filsinger Energy Partners
Final Report May 2016

Scope of Analysis

- Oahu and Hawaii Island
  - Oahu: Hawaiian Electric Company, Inc. (“HECO”)
  - Hawaii: Hawaii Electric Light Company, Inc. (“HELCO”)
- Electric utility assets
  - Excludes independently-owned generation assets
  - Excludes American Savings Bank and other non-utility assets currently owned by Hawaiian Electric Industries, Inc. (“HEI”), the parent holding company of HECO and HELCO
- Three types of utility ownership structures (potential benefits/challenges)
  - Investor-owned
  - Public
  - Cooperative
- Two types of utility functional structures
  - Generation, transmission, and distribution
  - Transmission and distribution only

Ownership Options Considered

Investor Owned

- Raise debt and equity through public and/or private capital markets
- Management accountable to shareholders
- Usually overseen by Board of Directors
- Publicly-traded companies subject to SEC reporting requirements
- Interest on debt is taxable to investors
- Generate nearly 80% of electricity produced in U.S.

Publicly Owned

- Government entities owned by taxpayers
- Typically raise debt through municipally-backed general obligation or revenue bonds
- Interest on municipal debt often tax-exempt to investors
- Cannot issue tax-exempt debt to acquire privately-held electric assets (i.e. "Rostenkowski Rule")
- Usually exempt from income, property, sales taxes; but often assessed "payment in lieu of tax" (aka "PILOT")
- 2013: over 2,000 public power organizations generated ~16% of electricity and served ~14% of US customers

Cooperative Utilities

- Democratically-controlled, not-for-profit organizations owned by the customers they serve
- Mainly serve rural areas - nearly 80% of U.S. counties across 47 states, only ~13% of customers in U.S.
- 838 distribution cooperatives and 66 generation and transmission cooperatives in U.S.
- Exempt from federal income taxes as long as at least 85% of income from member-owners to cover costs
- Unique financing options available - USDA Rural Utilities Service loans/loan guarantees, National Rural Utilities Cooperative Financing Corporation loans

Three Stages of Analysis

Any attempt to create and operate an electric utility on Hawaii should proceed along three general stages of evaluation:

Initial Steps

- Goals and Objectives
- Leadership Group
- Professional Team

Fatal Flaw Analyses

- Technical Analysis
- Rate Feasibility
- Ability to Finance
- Legal Feasibility
- Political Support
- Citizen Support

Detailed Diligence

- Detailed Legal Analysis
- Inventory of Assets / Separation Analysis
- CapEx Forecast
- Appraisal
- Model Rates
- Management Structure and Staffing Plan
- Governance Structure
- Integrated Resource Plan
- Approval of Financing

Cost and Timing Estimates

Analysis / Activity	Preliminary Cost Estimate	Preliminary Time Estimate
Definition of Goals/Objectives	Internal costs only	60 – 90 days
Appoint Leadership Group and Professional Team	Internal costs only	30 – 90 days
Fatal Flaw Analyses	$90K – $300K	60 – 120 days
Detailed Legal Analysis	$80K – $300K excluding regulatory/litigation support	30 – 90 days
Inventory of Assets and Separation Analysis	Validate existing inventories: $90K – $300K	60 – 120 days
	Develop new inventories: $300K+ per island	120+ days
Appraisal and Valuation including Future Capital Expenditures Budget	$90K – $300K per island	60 – 120 days
Model Customer Rates and Compare to Status Quo	$30K – $100K	60 – 90 days
Management/Staffing and Governance Plans	Mostly internal costs with possibility of professional fees	30 – 90 days
Integrated Resource Plan for 5-10 Years	$60K – $150K per island	60 – 120 days
Approval of Financing	Likely financing fees from 1% to 3% of transaction value	60 – 180 days
Negotiations and Legal/Regulatory Proceedings	Dependent upon multiple factors	TBD

HNEI Energy Efficiency Research:

Efficiency in Tropical Conditions

Jim Maskrey
Associate Specialist

May 24, 2016

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

Energy Efficiency Research at HNEI
(Tropical microclimates)

Net Zero Energy Building Performance (tropical microclimates)

- *5 constructed in Hawaii (3) existing (2) completion mid-July 2016*
- *Monitored and compared NZE structures with conventional structures*
- *Mixed mode: Natural ventilation combined with mechanical HVAC*

Heat Mitigation Analysis

- *Collaborative partnership with district to evaluate the potential for heat mitigation opportunities in schools*

Thermal comfort in tropical, naturally ventilated spaces

- *Developing simulation techniques using computational fluid dynamics (CFD) to predict*
- *Field validate modeling techniques*
- *Lab testing of radiant cooling and controlled air circulation*

Dessicant dehumidification technologies for tropical climates

- *Early stages of research*

Validation and testing of homes

- *Energy monitoring and performance testing of military housing in Hawaii*
- *Potential to impact up to 6000 homes*

Education and Awareness

- *Collaborate on training curriculum for building energy simulation*
- *Deployed energy dashboard for an off-grid community organization in Molokai*

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HNEI Energy Efficiency Tools and Areas of Interest

Energy Use Simulation

- *Energy utilization by end use*
- *Parametric studies of technologies*

Comfort simulation

- Computational fluid dynamics (CFD)
  - *Airflow analysis*
  - *Internal and external*

Building Demand Response

- *Demand reduction potential by building type and use*
- *Different programs and utility rate structures will have varying impact on grid.*
- *Intent to develop building level inputs to be model by grid simulators*

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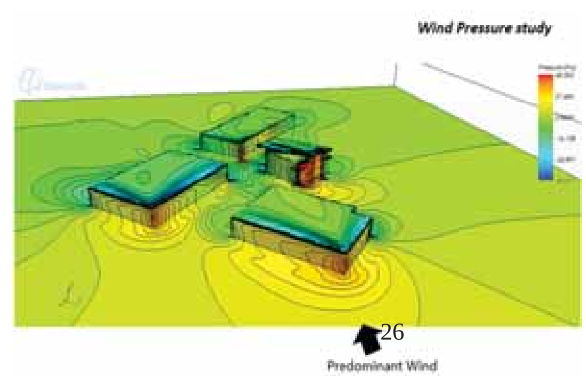
SOH Dept of Education: Facilities Assessment

Develop and validate a facility assessment protocol to guide design of comfortable learning environments with reduced energy consumption.

- *Funded by SOH Dept of Education*
- *Partnership between UH (HNEI and School of Architecture) with MKThink*
- *Comparing performance of different classroom types at Campbell complex using energy and environmental data*
- *Develop design guidelines applicable to DoE facilities statewide in future.*



Project recommendations are being used by DoE for modification of existing buildings

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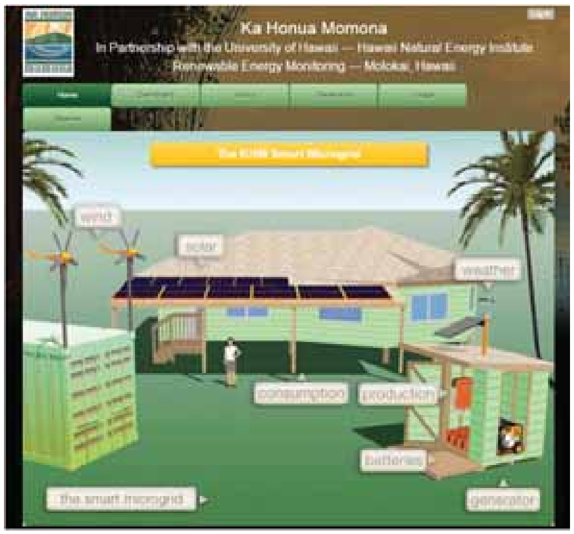
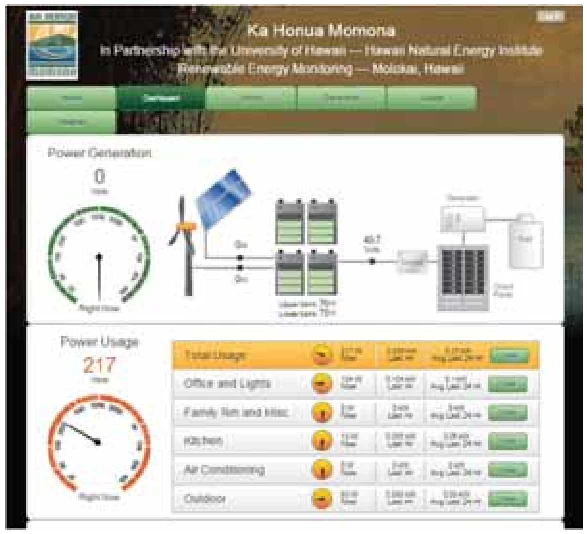
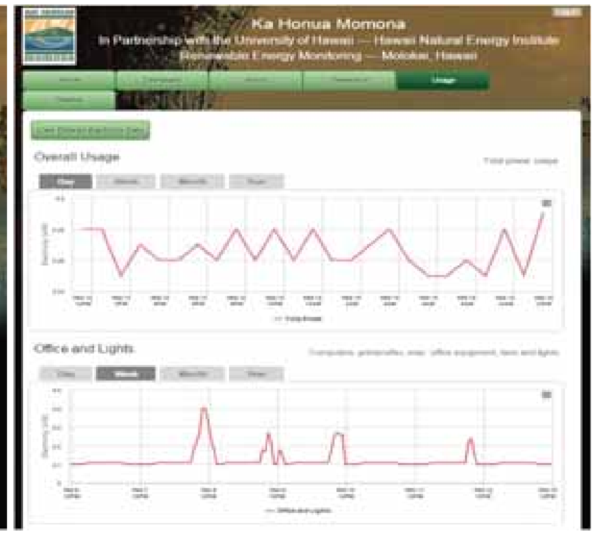
Off-Grid Micro-Grid Dashboard

- Small, not-for profit on Molokai
- Wind and solar on-site generation
- Monitor and disaggregate energy loads







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