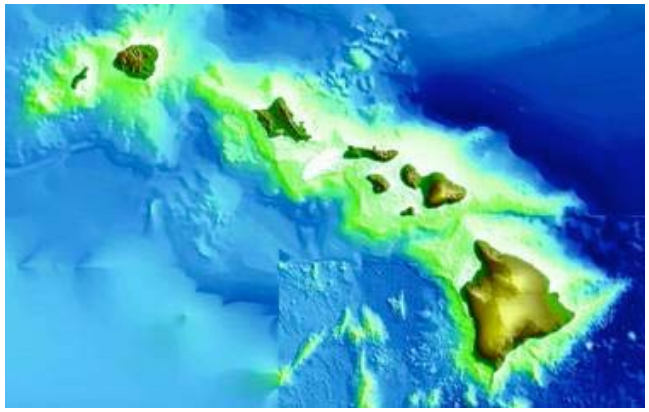
Hawaii Energy, Environment, and Sustainability: Aspects of Grid Integration of As-Available Resources



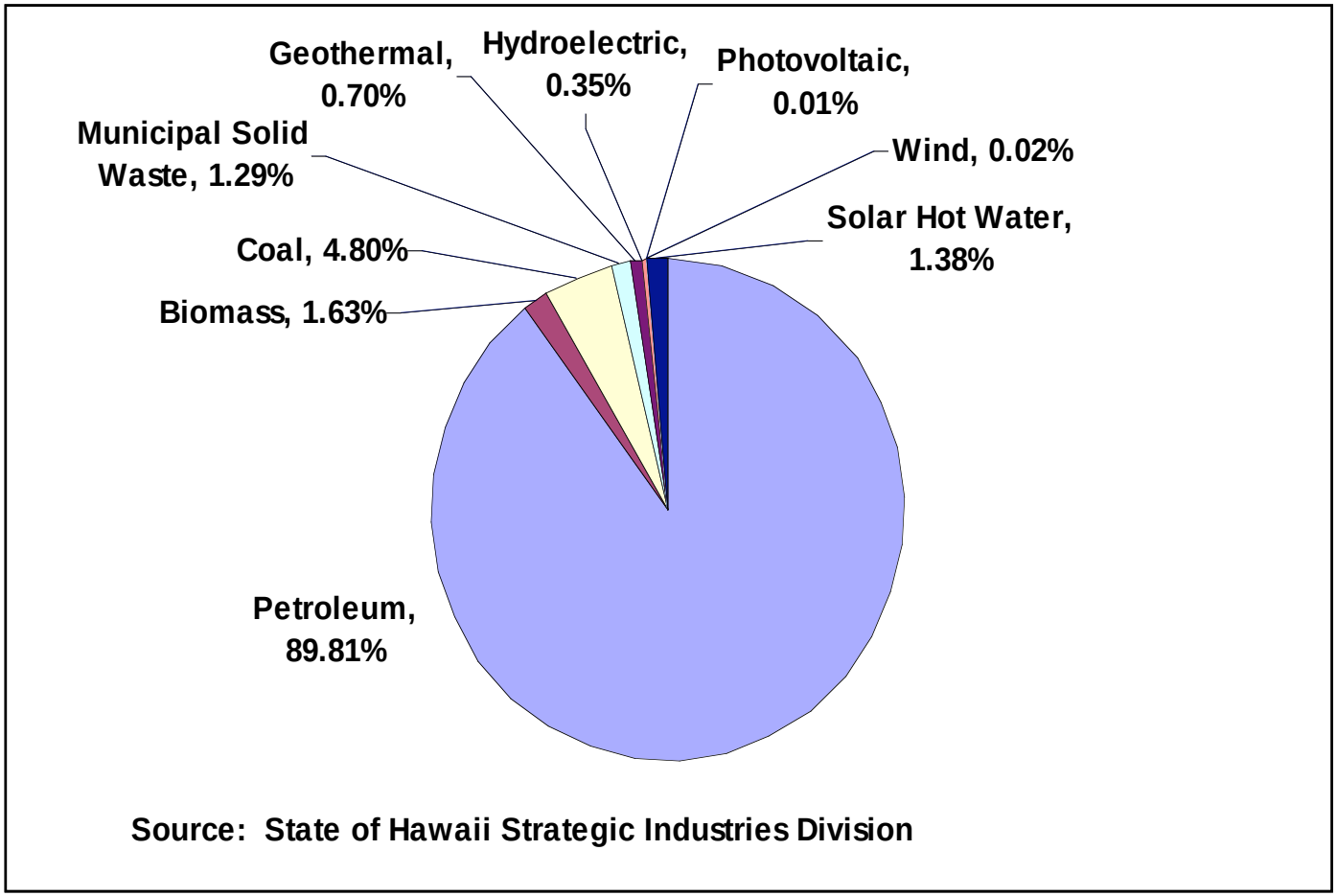
DOE-APEC REGIS Workshop

Terry Surles

Hawaii Natural Energy Institute

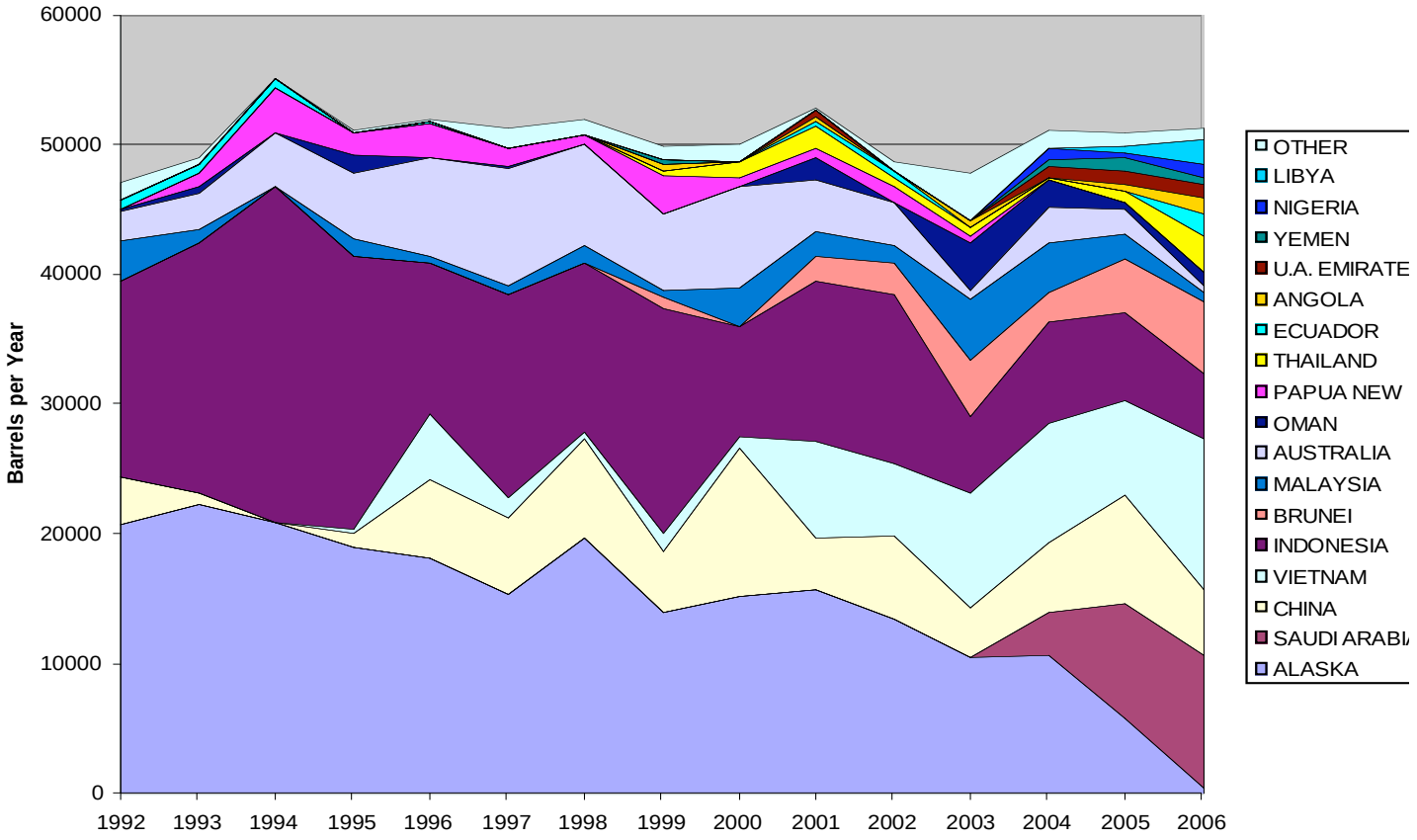
January 13, 2009

Hawaii Is Heavily Dependent on Petroleum for Energy Use



Hawaii's Dependence on Foreign Oil Is Headed in the Wrong Direction

Figure 2 Hawaii's Crude Oil Sources 1992-2006



Sources: State of Hawaii Strategic Industries Division and U.S. Energy Information Agency, 2007

Energy Challenge for Hawaii

How do we reduce dependence on oil while

- Keeping electricity and fuel costs competitive
- Managing environmental impact and public acceptance
- Maintaining reliability
- **Addressing greenhouse gas issues**

Meeting this challenge requires coordination from all stakeholders

- Well-conceived public policies – grounded by new technologies
- Validation and implementation of advanced energy systems
- Program continuity and consistency

Stakeholders want simple solutions, but in general the solutions are not simple – conundrum of as-available renewable energy – plentiful, but hard on the grid!

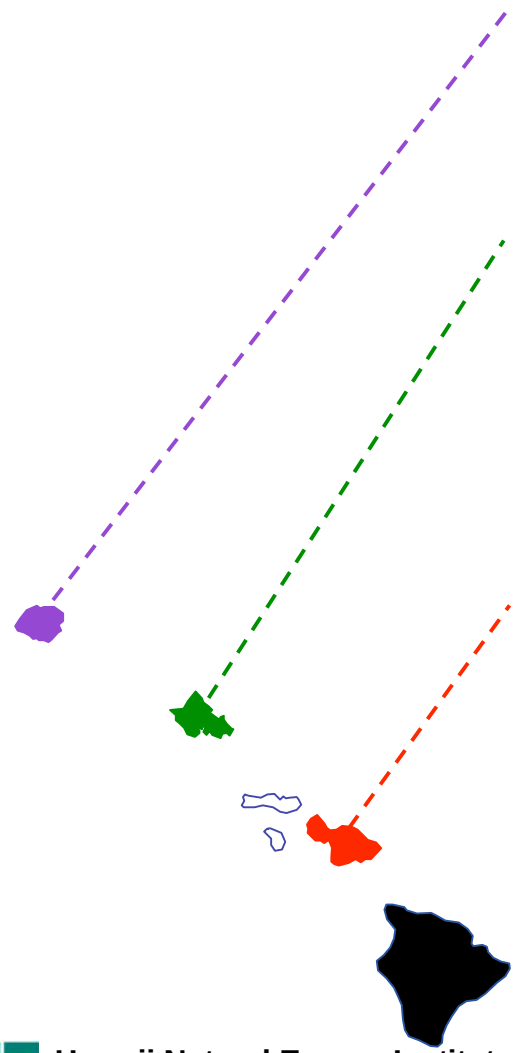
Focus on HNEI Activities Related to This Issue

- Hawaii PUC RPS goals evaluation
- Hawaii/New Mexico Energy Security Project
- Hawaii Renewable Energy Development Venture (with PICHTR)
- Maui Smart Grid

HNEI Analysis of Renewable Portfolio Standard for the PUC Confirmed Utilities Could Meet the 2010 Goals

- Statutes require 10% by 2010, 15% by 2015, and 20% by 2020 of delivered electricity to come from renewable electric technologies
  - At least 50% of these goals must be met by renewable electric energy
  - The other 50% may come from electrical energy displaced by other renewable energy technologies, i.e., solar hot water heaters or improvements in end use energy efficiency and demand-side management
- Five reports delivered to the PUC
  - The state utilities can meet the 2010 goals
  - Enabling technology and infrastructure will be necessary for achieving more aggressive goals
  - Definitions of what is renewable and what is efficiency must be clearer
  - **New agreement between utility and state proposes to separate renewable and efficiency goals**

Existing Partnership Activities in Hawaii as Part of the HI/NM Project



- **Kauai Energy Roadmap**
- Develop possible roadmap for increasing the penetration of renewable energy with Sandia and others

- **Oahu Grid (Big Wind) Study**
- Develop models to characterize the grid and to address wind projects that could impact the Island with NREL and others

- **Maui Grid Modernization**
- Deploy energy storage, generation and demand-side management technologies to reduce peak load and enable further expansion of renewable energy

- **Maui Grid Study**
- Develop validated power systems model to address impacts of increased wind and the necessary mitigation technologies

- **Big Island Energy Roadmap**

Evaluate scenarios to identify the impacts and benefits of various technology approaches to increase energy security and the penetration of renewable energy

HI/NM Program Unique in Being Able to Address Needs of Four Different End-Users plus the Stakeholders

–Meet DOE mission needs – transferability of analytical tools

- An understanding of the technical impact of renewable energy deployments as they relate to the mainland
- Lessons for mainland systems and analytical tools for mainland grids
- Mechanisms for addressing **stakeholder needs**

–Address utility system planning needs – with accurate and usable tools

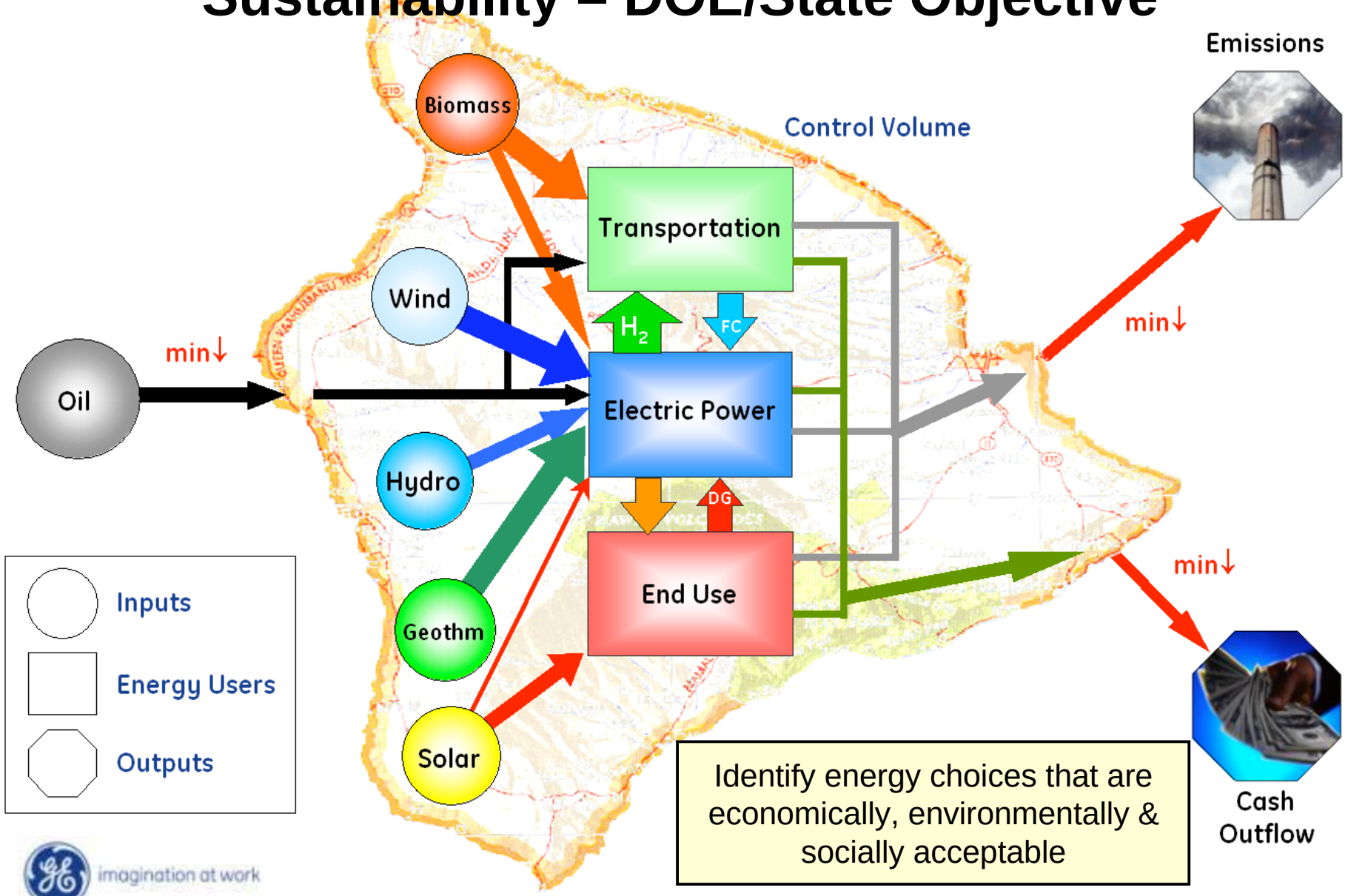
- Mechanism for evaluating new technologies to address system impacts
- An understanding of impacts of renewable energy technology deployments

–Address state (DBEDT and PUC) initiatives

- A methodology and tool for State policymakers to analyze the impacts and tradeoffs of technologies (high penetration renewable energy) and policies (RPS).
- An in-state capability to perform further energy analyses – starting with the PUC

–Provide information to commercialize clean energy products and respond to concerns of multiple business-environment-consumer stakeholders in Hawaii

Thrust of the Big Island Program Is Based on Sustainability – DOE/State Objective



Stakeholder Summit

What we expected:

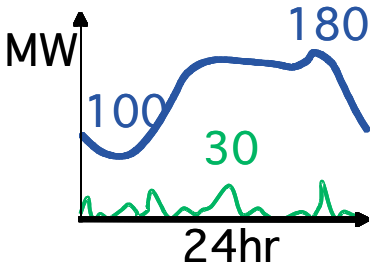
What we got:

While there were clear areas of disagreement, we found a surprising amount of consensus on objectives, concerns, and desire for cooperation.

High Wind Penetration Scenario

Given the trends in Hawaii for increased wind farm development, a renewable energy strategy consisting mainly of increased wind utilization was considered. **Wind capacity was increased at each of three wind farms on the Big Island.**

In 2007…

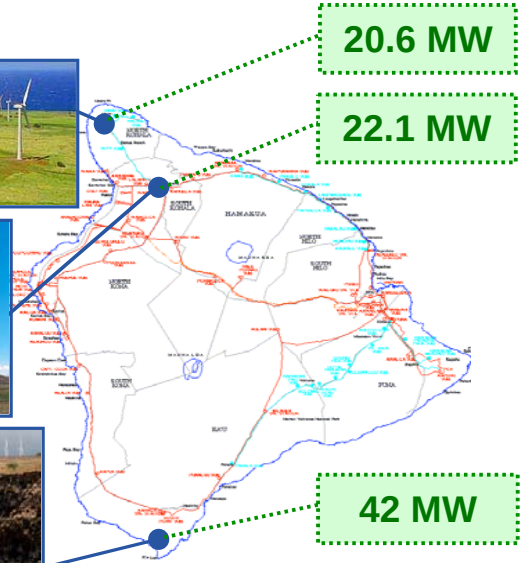


Power (MW)
- **Day ~ 15%**
- **Night ~ 30%**

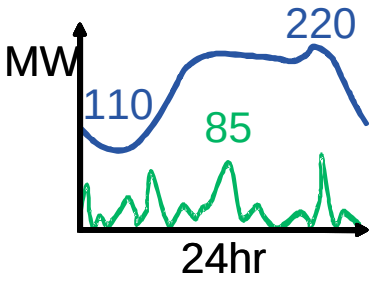
Hawi Renewables 10.5MW
V47 660kW

Lalamilo 1.5MW
Jacobs 20kW

Apollo 20.5MW
GE 1.5MW



In 2018…

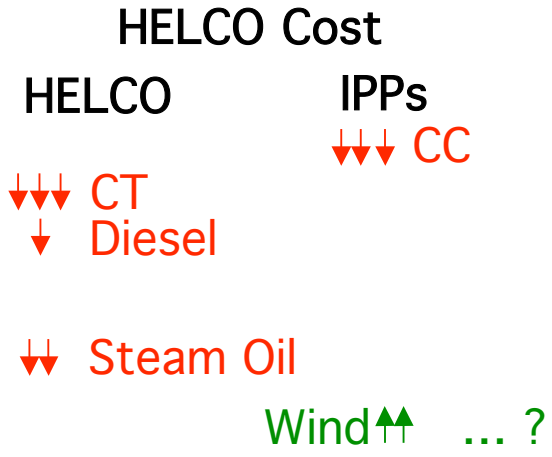


Power (MW)
- **Day ~ 40%**
- **Night ~ 70%**

Project Models Provide "What-if" Capability

What if 1MW of wind power were added to the island?

		Fuel Use	Emissions (tons)		
	GWh	MMBtu	NOx	SOx	CO_2
Combined Cycle	-2.1	-15545	0	-2	-1352
Combustion Turbine	-1.3	-13905	-1	-2	-1245
Diesel	0.0	-341	0	0	-29
Puna Geothermal	0.0	0	0	0	0
Small Hydro	0.0	0	0	0	0
Steam Oil	-0.6	-7582	-1	-1	-726
Wind	4.1	0	0	0	0
Solar	0.0	0	0	0	0
Grand Total	0.1	-37374	-2	-6	-3352



- With no other changes to the system, an increase in wind power offsets fossil fuel generation and reduces emissions and carbon footprint **but**..
- More spinning reserve will be needed - oil must be burned so utility can respond to rapid changes in wind, often inefficient use of fuel
- If wind developer is paid avoided cost, consumer may actually pay more for power

Is there more to this story?

Cost Adders

Wind power reduces the island's carbon footprint, and reduces the amount of imported petroleum, but…

↑ **Utility - More spinning reserve will be needed -** More oil must be burned so some generation is ready to quickly meet changes in the system load or wind farm output, and/or

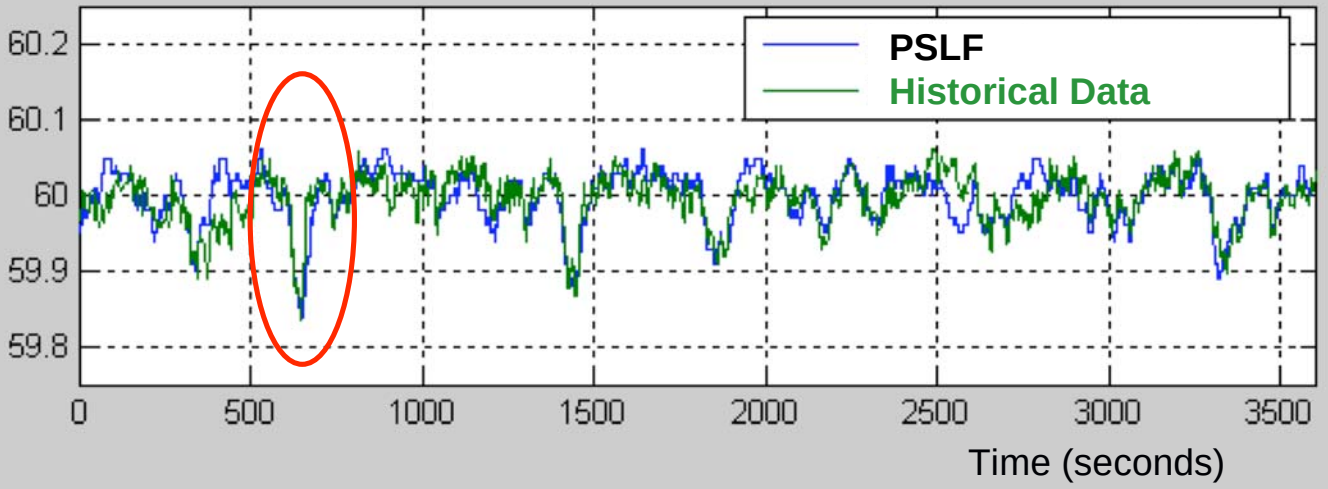
↑ **Utility - New technologies** can be used to mitigate the intermittency of wind power.

? **Policymakers - Price paid to wind producers** matters. If HELCO pays a wind producer more than it costs them to produce electricity from fossil fuel generation, more wind power will cost the island more (avoided oil costs)

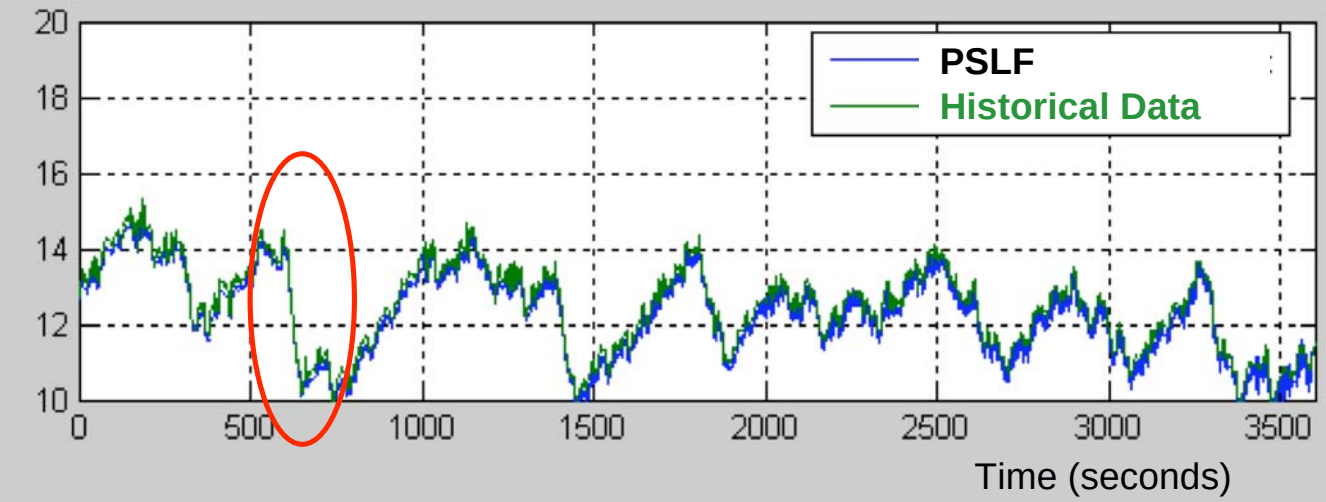
Transient Performance Model Validation

Significant Wind Fluctuation (04/03/07)

Frequency (Hz)



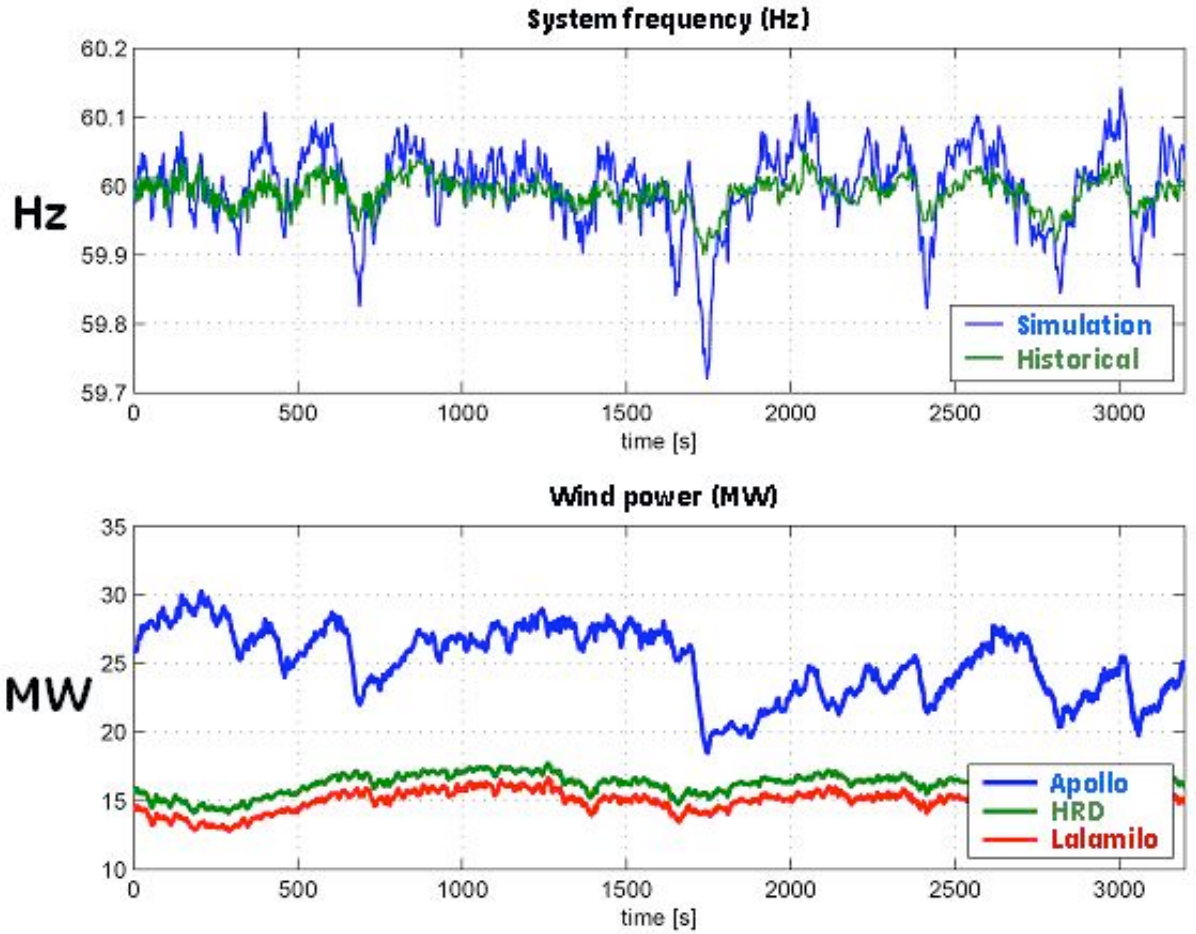
Apollo Windfarm (MW)



“Higher Wind Penetration”

System Performance severely affected

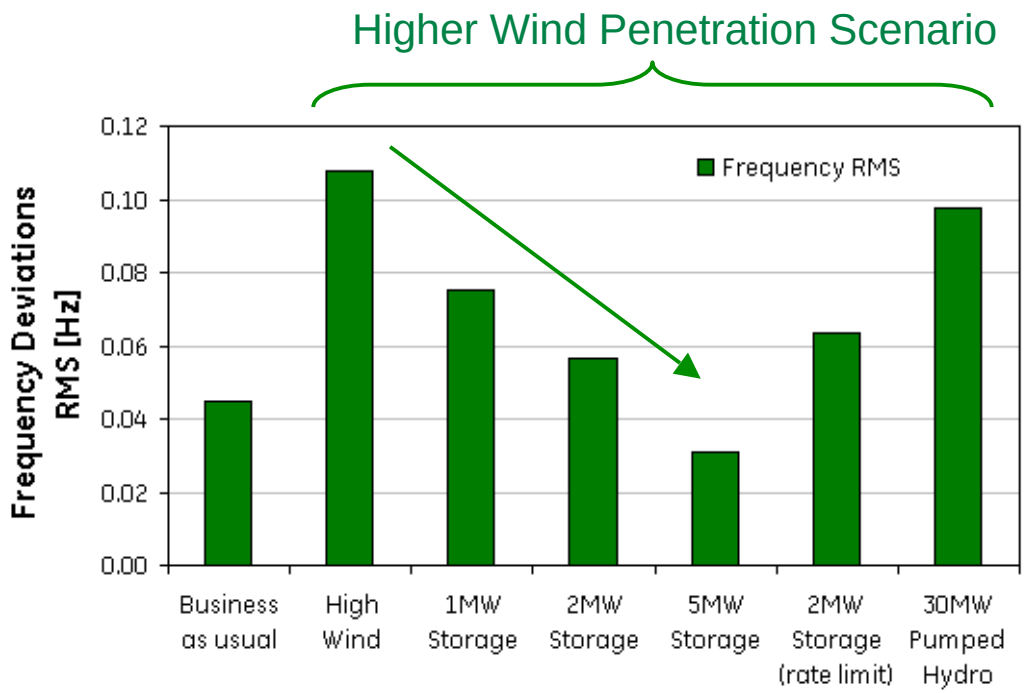
- Same 1 hour window as previous slide.
- Wind power capacity was increased from ~32MW to ~85MW.
- Historical load & scaled wind production were used to drive the simulation.
- Units specified for this hour were used to initialize the simulation



“Higher Wind Penetration”

Impact of “fast, inter-hour” energy storage

A 5MW storage device reduces system frequency RMS to below that of the “Business-as-usual” case



- Compare the RMS frequency deviation, for a one-hour window, for different scenarios, storage devices, and charging strategies.
- As the size of the storage device increases, the system frequency RMS decreases.
- 3-5 minutes of energy storage (at Pmax) was needed for the simulation.

Higher Wind Penetration

Performance

One potential solution includes:

- **+ 5MW of fast energy storage to address challenging inter-hour wind fluctuations**
  - Results in **similar frequency performance** as baseline scenario.
- **+ 5MW of additional dispatchable energy storage, 20min of energy storage.**
  - Reduces the hours in which additional generation was needed from **358 to 164 hour/yr.**
- **IPP owned South Point & Hawi, HELCO owned Lalamilo**
- **End user cost down, but not that much**

Comparing Higher Wind Penetration to **Baseline**

	Capacity MW	Energy GWh	Fuel MMBtu	NOx tons	SOx tons	CO2 tons
Combined Cycle	0	-124	-958546	-140	-144	-8334(
Combustion Turbine	0	-31	-421448	-16	-54	-3142:
Puna Geothermal	0	0	0	0	0	0
Small Hydro	0	0	0	0	0	0
Steam Oil	0	-31	-379130	-533	-61	-3552:
Wind	52	189	0	0	0	0
% Change	16%	0%	-15%	-45%	-14%	-14%

Substantial Reduction in Fuel Use and CO_2 emissions

Big Island Project Scenario Results and Summary

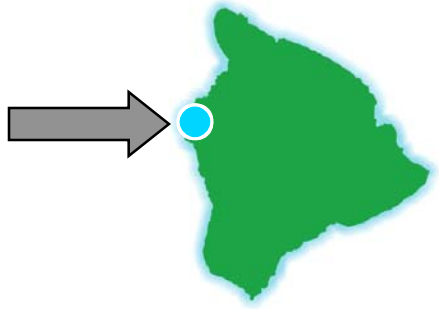
BASELINE	HIGHER WIND PENETRATION
REDUCED ENERGY VULNERABILITY	ENHANCED ENERGY MANAGEMENT

	Energy Security: Imported Petroleum Reduction (%)	Environmental: CO_2 Emissions Reduction (%)	Economic: Ratepayer Variable Cost Reduction (%)	Economic: Island Variable Cost Reduction (%)	Sustainability: Renewable Energy Delivered (%)
"Baseline"	0%	0%	0%	0%	27%
"Enhanced Energy Management"	6%	6%	5%	8%	28%
"Higher Wind Penetration"	15%	14%	3%	16%	39%
"Reduced Energy Vulerability"	11%	10%	0%	13%	36%

- **In the Baseline scenario, 27% of electricity is generated from renewable energy.**
- **Energy efficiency, load control & PHEVs reduced variable cost and reduced wind curtailment. "Enhanced Energy Mgmt" results are additive, albeit not linearly, to the renewable energy scenarios.**
- **"Smart Grid" technologies needed to accommodate substantial penetration of as-available generation. These technologies should reduce variable cost and yield environmental benefits.**
  - **New technologies (controls, energy storage, coordinating thermal generation, etc) will be needed to enable substantial increases in the penetration of wind power.**
  - **It is not clear how to pay for these technologies. What is the business case and regulatory support that is needed?**
- **Initial analyses have shown that additional geothermal systems could lead to the retirement of oil-fired power plants that could achieve the stakeholder metrics.**

RD&D, Testing, Evaluation, and Validation of Distributed Energy Resource Technologies

- Evaluate and demonstrate emerging technologies with industrial and national laboratory partners
  - Energy storage: flow batteries, ultra-capacitors
  - Monitoring, measurement, verification for "Smart Grid" systems
  - Hydrogen energy systems
  - Renewable resource utilization: biomass, PV, wind
- **Integration of this project into other related activities**
- **Low opportunity costs for industry and DOE**



Big Island Power Park Sites

1 Kahua Ranch – Small-scale Integrated PV-Wind-Hydrogen Test Bed

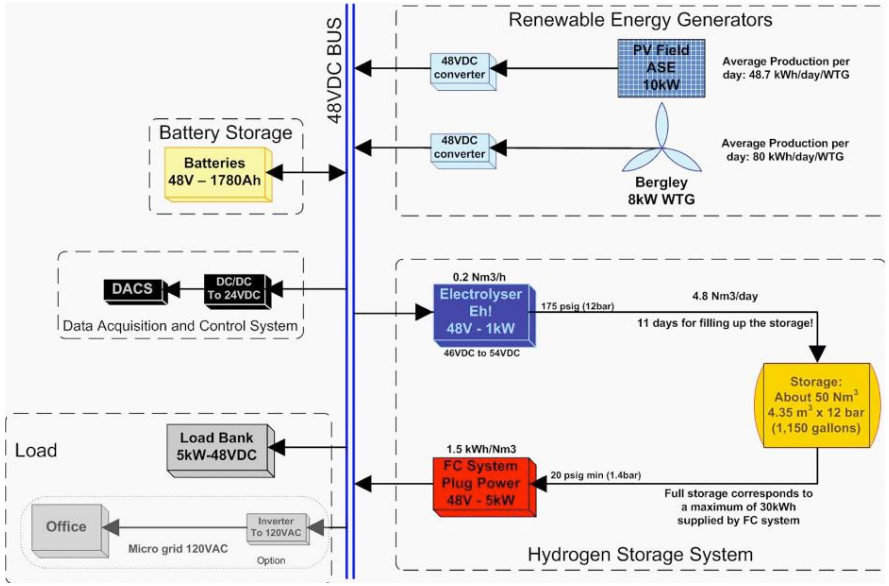
- 7.5 kW wind turbine + 5 kW PV
- 2kW Pressurized PEM electrolyzer
- 5 kW PEM Fuel Cell

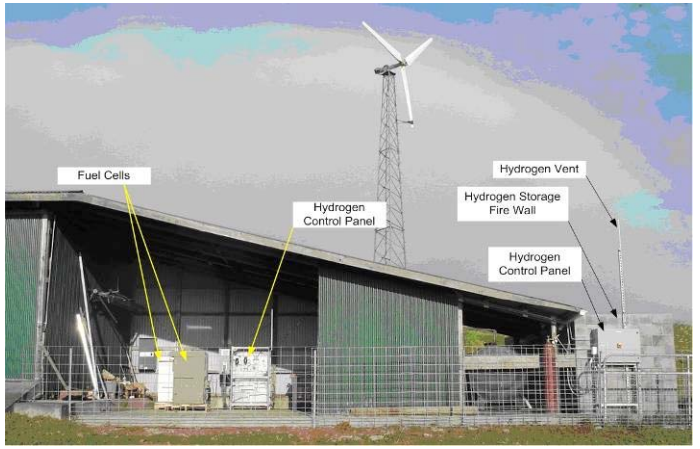
Hawaii Volcanoes National Park (HAVO)

2 Up to 6 plug-in hybrid - hydrogen shuttle buses

- Renewable powered electrolysis
- Multi-agency partnership involving USDOE, State of Hawaii, DOT, DOI, DOD

Hawaii Hydrogen Power Park - Kahua Ranch
PV-Wind-Hydrogen System



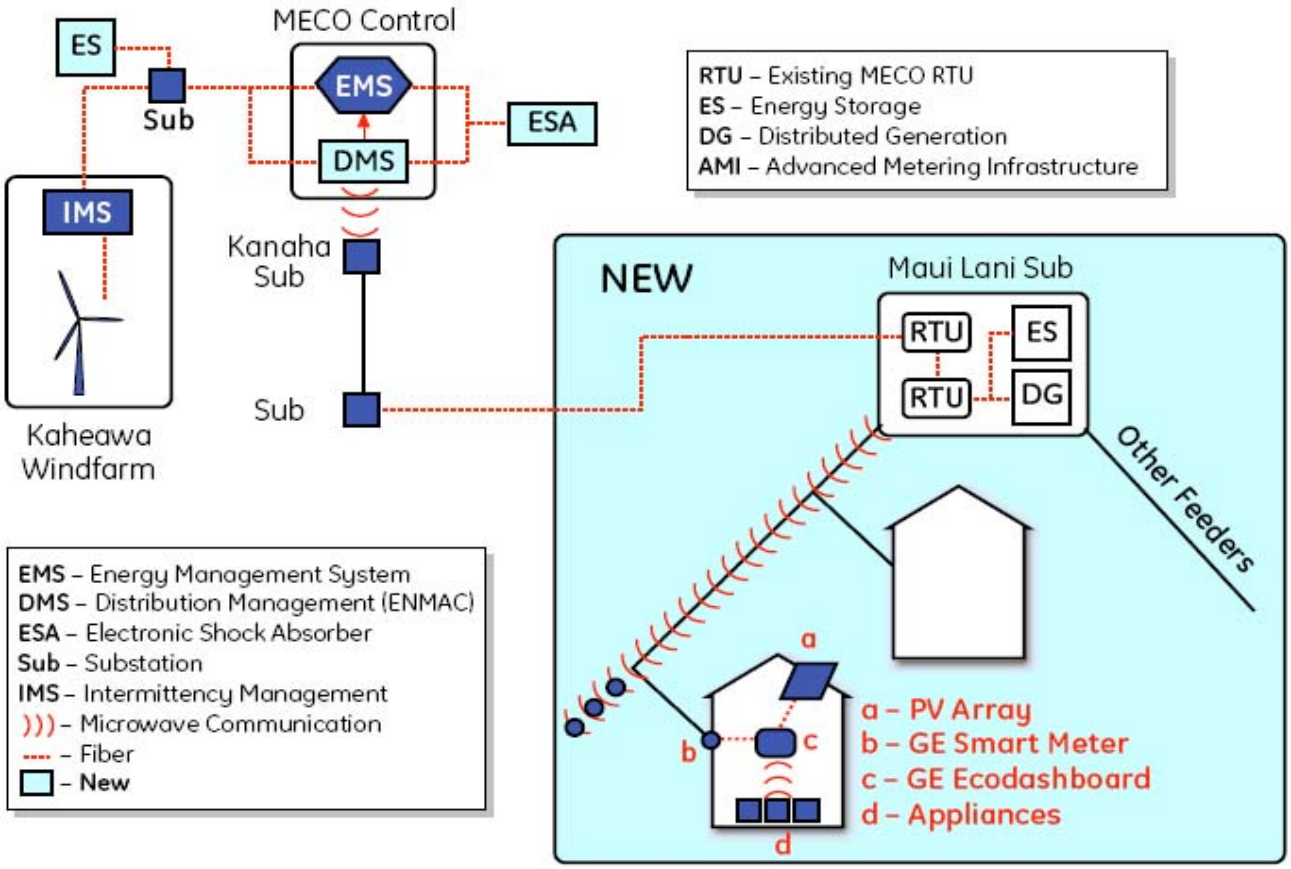


- **Integrates PV, wind, batteries, electrolyzer, and fuel cell with remote operation via internet.**
- **Test bed for validation of emerging hydrogen and renewable technologies**
- **Proposed as focal point for renewable energy outreach and education**
- **Partners include Kahua Ranch, PICHTR, Plug Power, and EH.**

“Maui Smart Grid Project” Is Designed to Meet Federal, State, and Utility Needs

- “Overarching objective is to develop and demonstrate a distributed automation system that aggregates DG, energy storage, and demand response technologies in a distribution system to achieve both transmission and distribution level benefits.”
- Focus is on “reduction of peak demand by at least 15%” using a diverse mix of DG, storage, renewable energy, demand response
- **Effort to provide solutions for mitigating the effects of as-available renewable energy**
- Team consists of General Electric, Hawaiian Electric co, Maui Electric co, Sentech, First Wind, and New Mexico Tech
- Funded at $14M over three fiscal years
  - Just under $7M from DOE
  - Real “iron in the ground” and utility cooperation and enthusiasm for achieving primary goals for DOE/OE, the utility, and the state

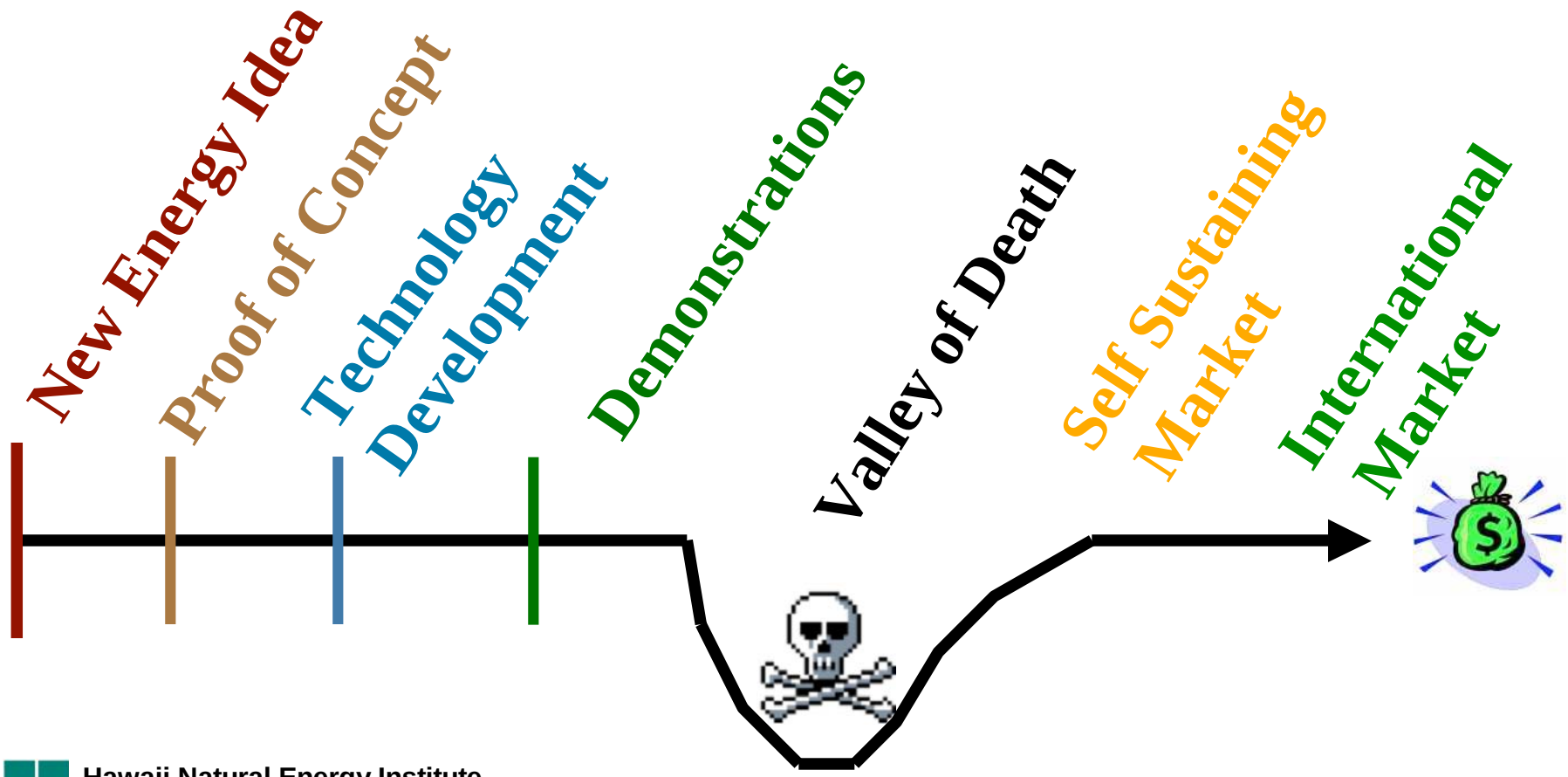
Proposed Architecture Addresses Both Goals of the Project



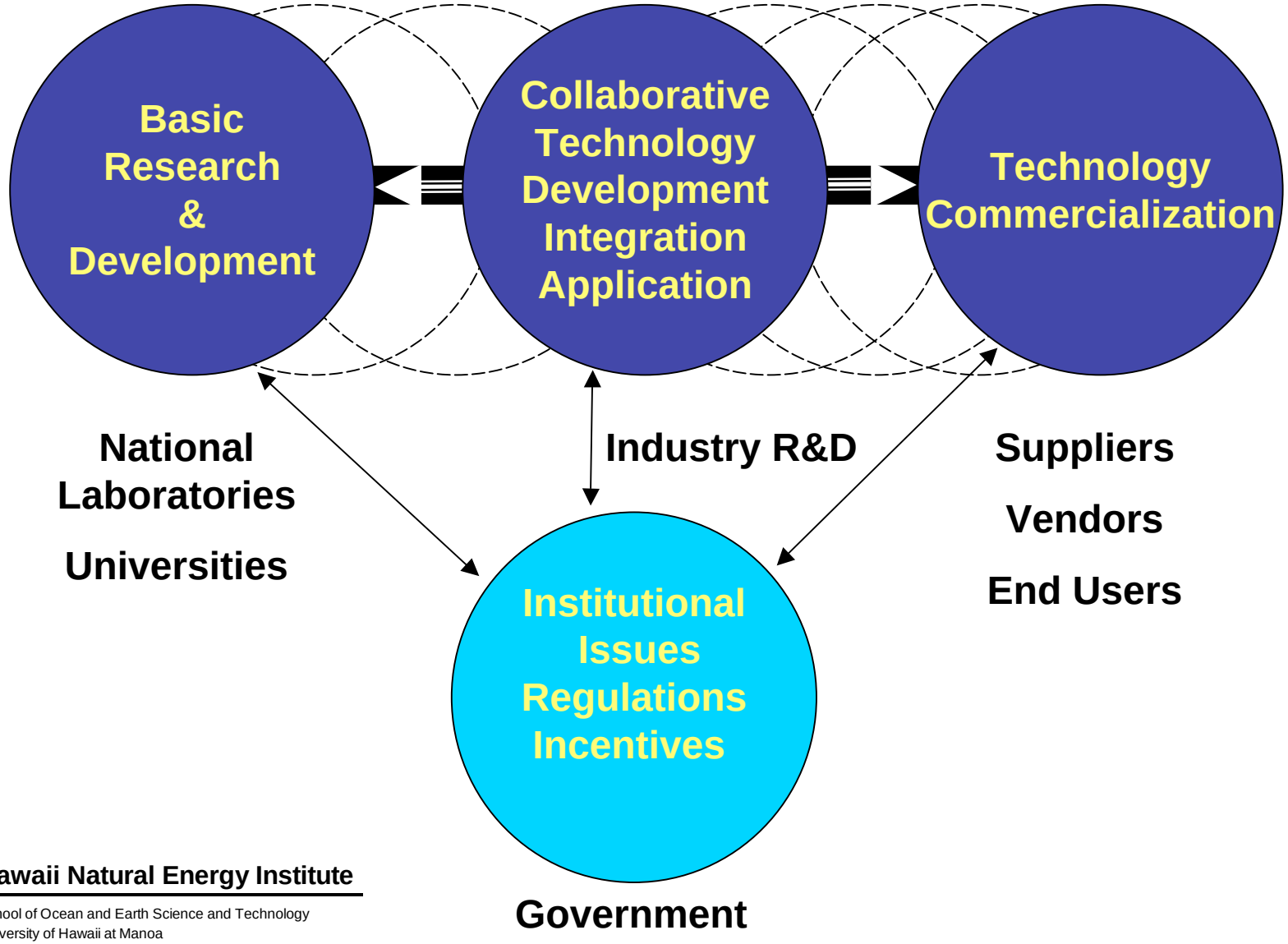
HNEI Supports the Hawaii Renewable Energy Development Venture

- The Pacific International Center for High Technology Research is leading HREDV that is funded by DOE/EE
- HNEI provides support for development of selection metrics
  - Commercial readiness
  - Specific technology areas
    - Utilization of indigenous renewable resources
    - Separate categories for transportation and electricity generation
    - Enabling technologies for greater utilization of renewable resources
    - End use efficiency and demand response technologies
  - Linkage to state and federal policies
  - Corporate qualifications
- Draft metrics developed draw on experience of other state R&D programs

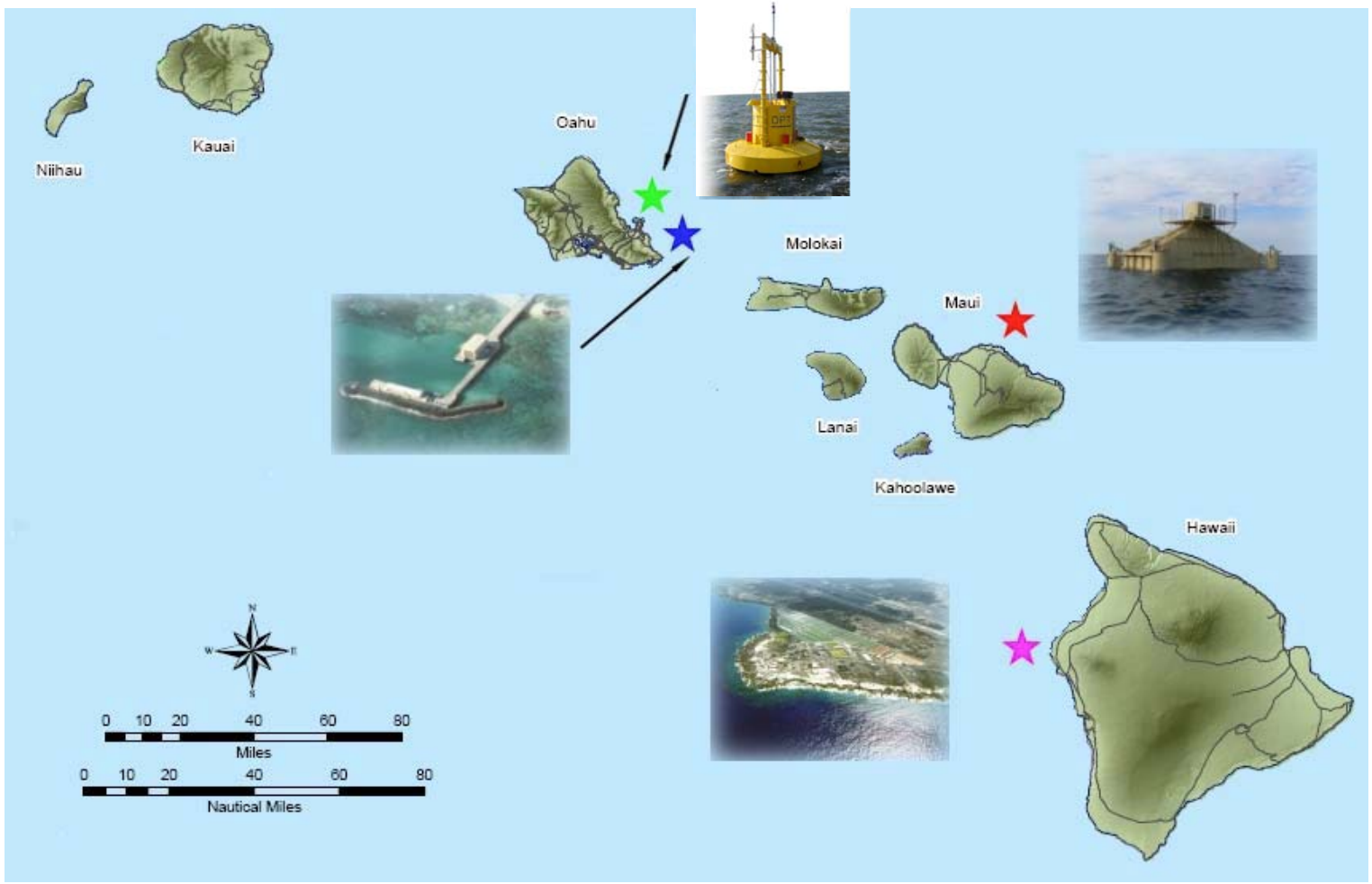
Integration of Projects' Results Can Lead to New Regulations and Policies and Provide Incentives to Accelerate Commercial Readiness



HNEI Creates Partnerships to Link R&D and Public Policy to Technology Commercialization



Ocean Energy Center Test Sites



A Sustainable and Secure Future: Hawaii Can be a Leader

- **Environment**
- **Energy**
- **Economics**
- **Equity**
- **Education**

Hawaii Natural Energy Institute

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