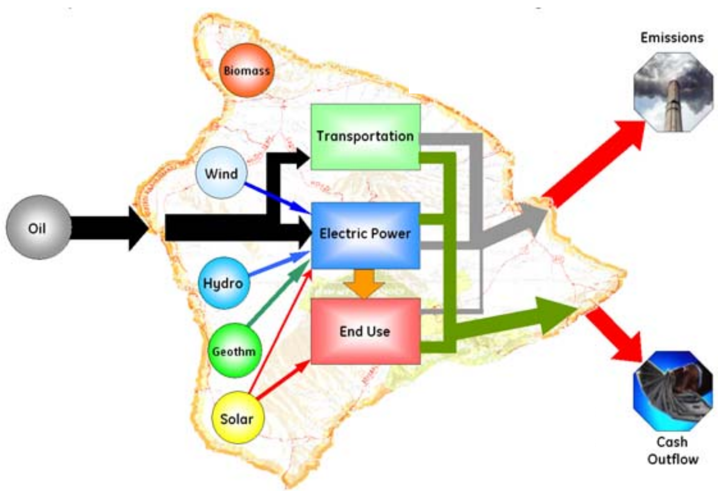
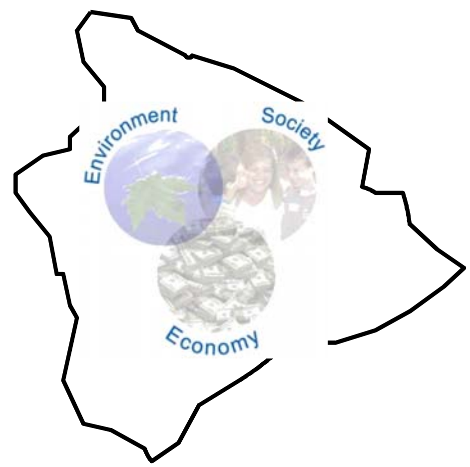
# Hawaii Energy Resource Technologies for Energy Security: Hawaii Energy Roadmap

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**US DOE** | **Hawaii Natural Energy Institute** | **State of Hawaii** | **GE Global Research GE Energy** | **Sentech** | **Hawaii Electric Light Company**

# Background: Hawaii Has Energy Concerns

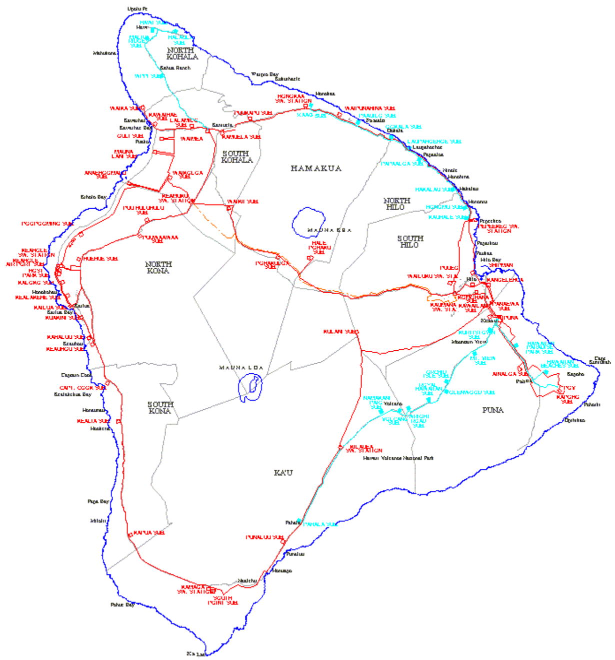
- 90% of the state's energy comes from imported oil
- $3B leave the economy each year to purchase fuel
- Some of the highest electricity and gasoline prices in the nation
- Small, sparse electricity grids pose an immediate challenge to renewables integration
- New renewable generation prices tied to oil prices

# Big Island's Energy Challenges

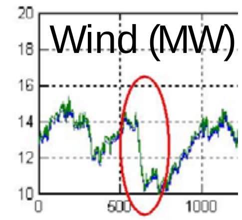
**<u>Transmission Congestion</u>**
**Hilo side = ~60% of load**
**Kona side = ~75% of generation**

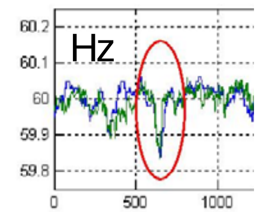
**<u>PPAs</u>**
**High cost of renewable energy (PURPA)**

**<u>High Energy Costs</u>**
**~$100/bbl oil**
**>35 ¢/ kWh electricity**




**<u>Utility Concerns</u>**
**Growing use of wind power is affecting grid stability & overall efficiency (spinning reserve)**




**<u>Economic Insecurity</u>**
**$3B/yr leaves State economy each year to purchase fuel**

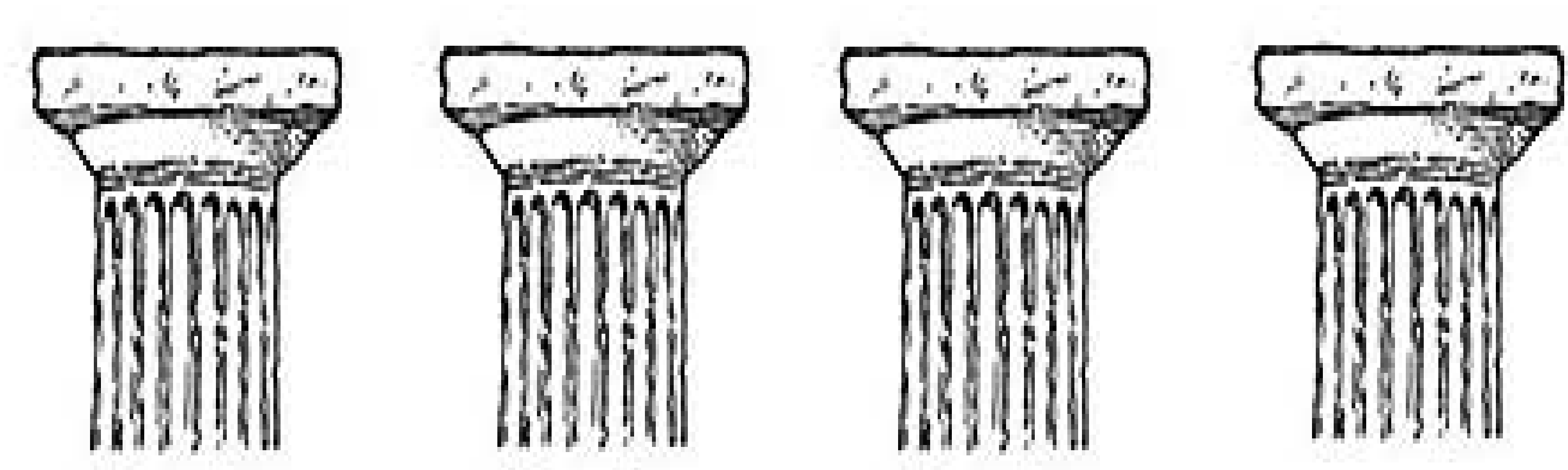
**<u>Energy Insecurity</u>**
**90% State dependence on imported petroleum**

# Challenges Have No Simple Solutions

- Big Island utility not keen on wind due to system stability problems
- Counter-intuitive realities
  - More wind = more expensive electricity
  - Important to know true "cost of wind" and its carbon footprint
- Stakeholders initially wanted simple, straightforward solutions
- GE invests in program for better understanding of marketplace
- New technologies and policies have supporters and detractors
  - Business model uncertain for use of energy storage
  - Particularly true when stability is not a IPP problem
  - BUT, does model work if IPP is "dumping" a lot of wind

# HNEI Catalyzes Partnerships Critical For Addressing Overarching Issues Facing Electricity Systems

## Electricity System Issues



**Grid Modernization:**
**Renewable Technologies**
**Peak Demand**

**Global Climate Change**

**Energy Security:**
**Fuel Supplies, Critical Infrastructure Protection**

**Environment Quality:**
**Life cycle analyses**

**None Of These Issues Can Be Resolved Without Partnerships**

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# Scope of Hawaii Energy Roadmap
## (One of Three Activities in the Hawaii-New Mexico Effort)

- Develop strategic energy roadmap to identify economically viable technologies to transform Big Island energy infrastructure
  - Develop and validate baseline models for electricity and transportation
  - Rigorously link development of analytical tools to both DOE mission and utility system operations needs - no small trick (planning vs. operations)
  - Objective is to develop comprehensive,technology-neutral process that can be used elsewhere by DOE
- Identify scenarios for deployment of new energy systems
  - Develop site-specific conceptual designs, i.e., incorporation of energy storage and renewable energy systems to support the electricity grid
- Address systems integration (grid stability) and institutional (impacts of PPA contracts, etc.) issues

# Program is Unique in Being Able to Address Needs of Three Different End-Users – Plus 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, avoid "shelf-ware" problems**

– 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**

**Respond to concerns of multiple business-environment-consumer stakeholders in Hawaii**

***Big Island is a potential showcase (for DOE, Hawaii, HECO, and GE) for renewable energy and other innovative technologies***

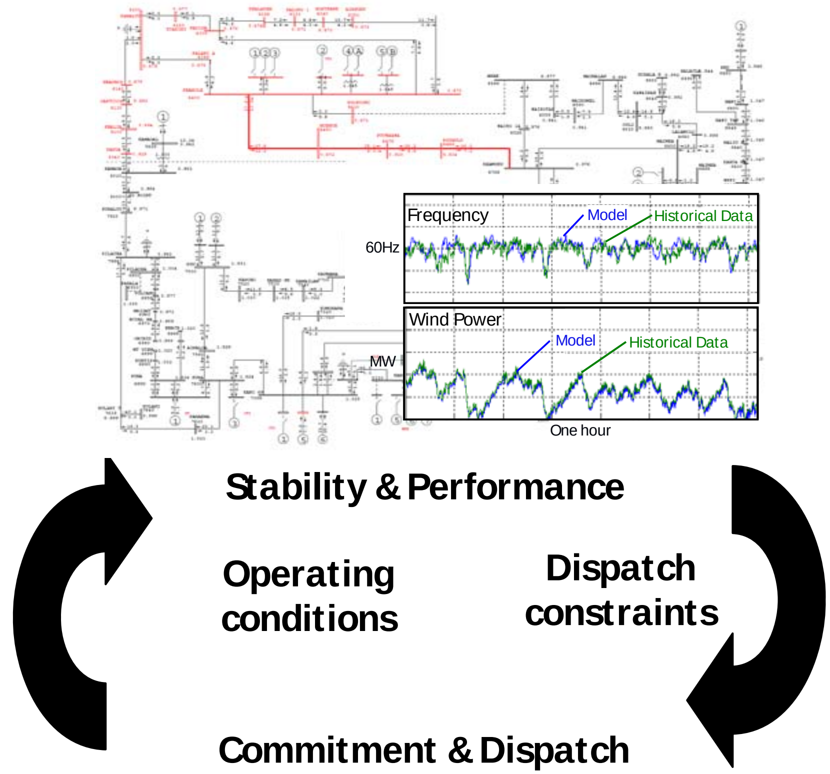
# Electricity Infrastructure Modeling

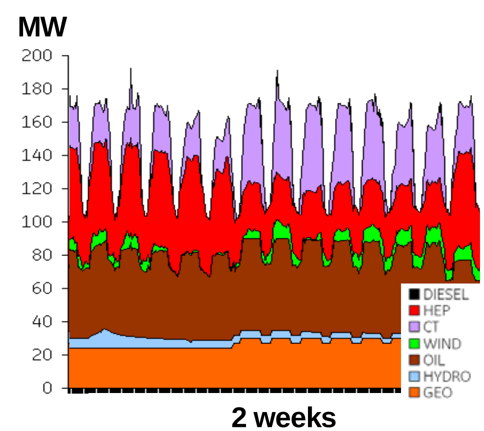
## Transient Performance (GE PSLF™)

- Full network model, incorporating generator governors and AGC
- Transient Stability Simulation
- Long-Term Dynamic Simulation
- **Sebastian Achilles – GE (Germany)**

## Production Cost (GE MAPS™)

- Representation of dispatch and unit commitment rules
- Hour-by-hour simulation of grid operations for a full year
- **Nick Miller Gene Hinkle, et al – GE Energy**

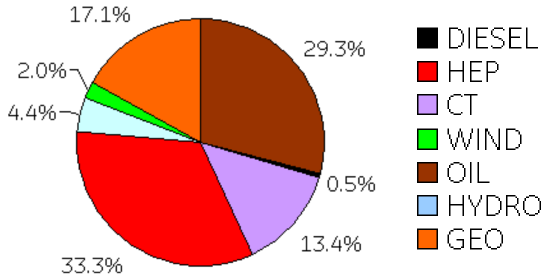


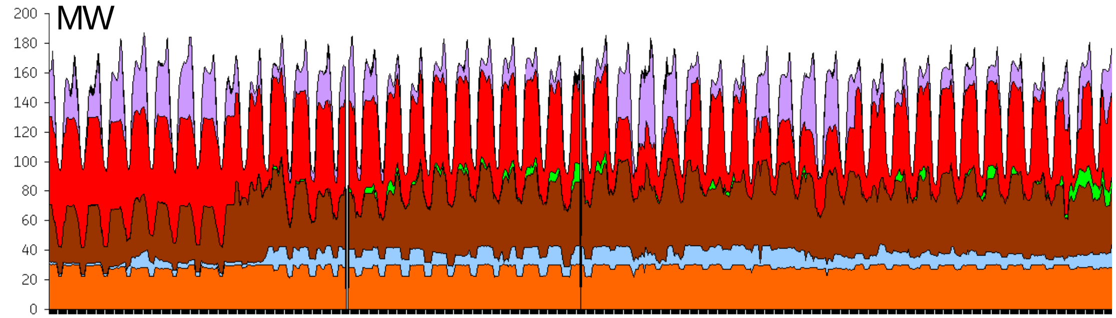



# Production Cost Model Validation

## 2006 Historical Production

Annual GWh

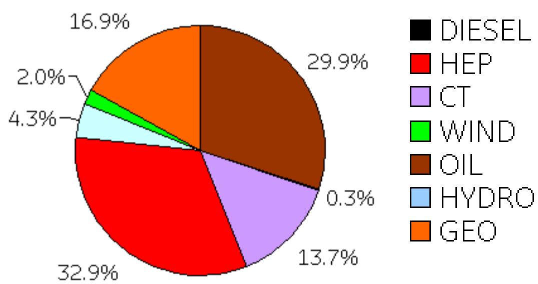


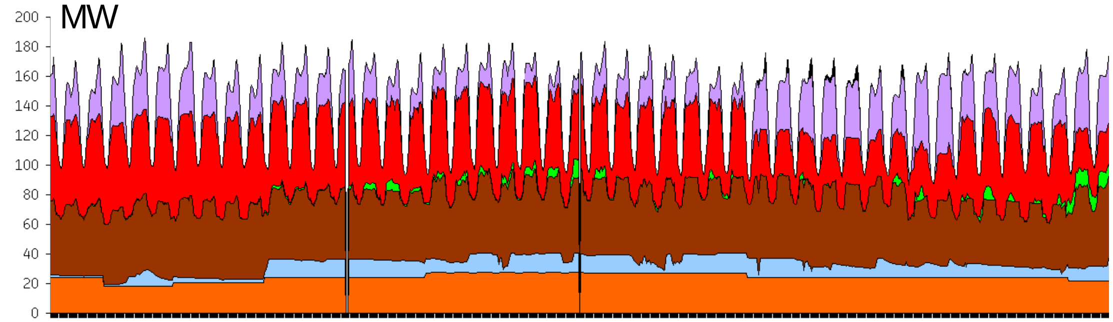




40 days of production

## MAPS Production Cost Simulation

Annual GWh




40 days of production

**Less Than 1% Error By Fuel Type**

# An ability to analyze "What-if" scenarios

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

| | GWh | Fuel Use MMBtu | Emissions (tons) 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 |

**HELCO Cost**

**HELCO**

↓↓↓ CT

↓ Diesel

↓↓ Steam Oil

**IPPs**

↓↓↓ CC

Wind ↑↑ …?

- With no other changes to the system, an increase in wind power offsets fossil fuel generation and reduces emissions
- From a cost of energy perspective, the price paid to wind producers matters
- Additionally, HELCO must maintain their system frequency at 60Hz and sudden changes in wind power will affect the frequency

# 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

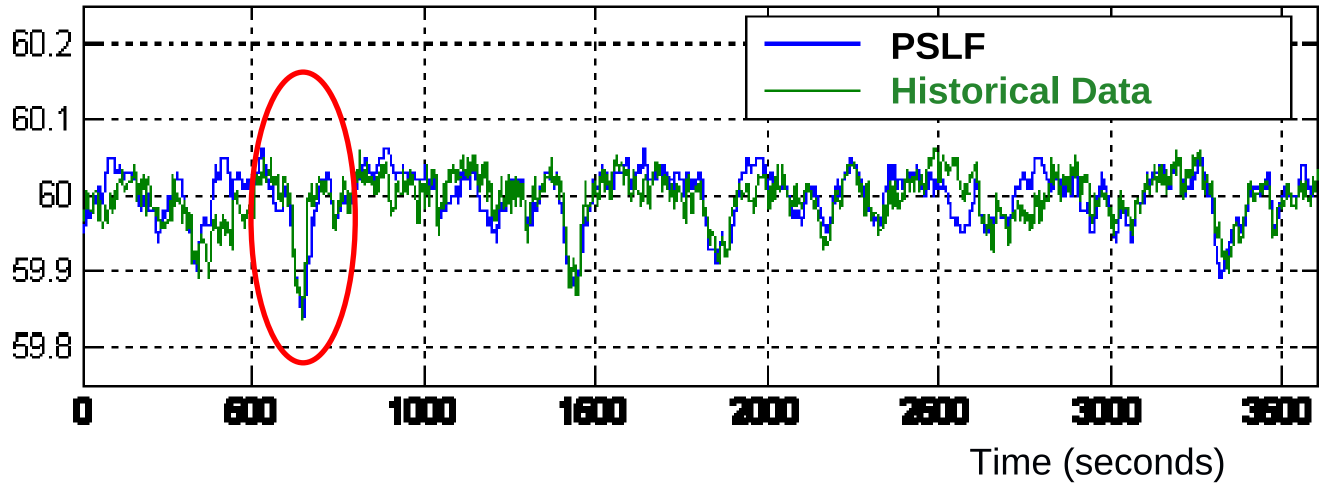
↑ **Utility - New technologies** can be used to mitigate the intermittency of wind power.

? **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)

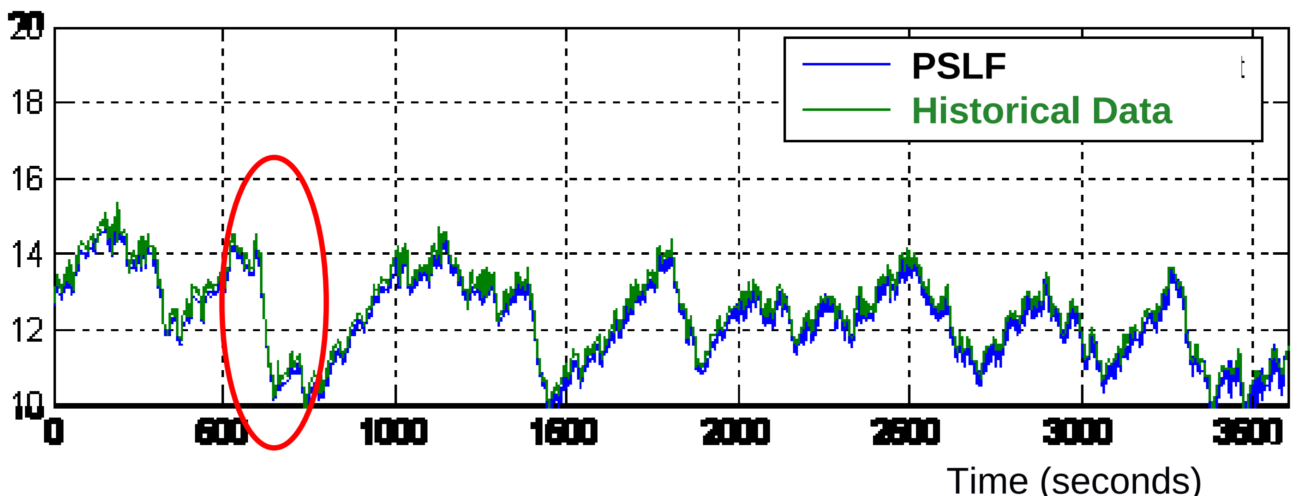
# Transient Performance Model Validation

## Significant Wind Fluctuation (04/03/07)

**Frequency (Hz)**

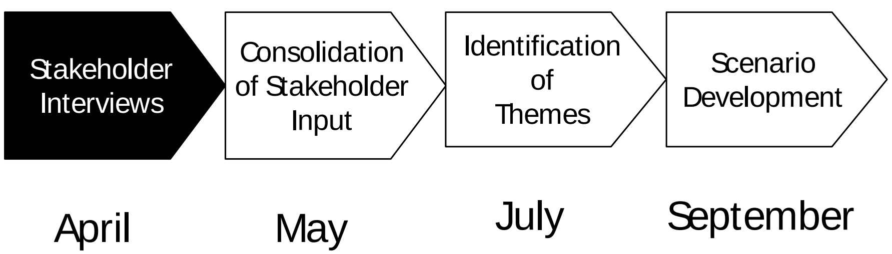



**Apollo Windfarm (MW)**



# Stakeholder Interviews - the Start of Phase 2

- What are your key energy-related **metrics**?
- What are your **energy goals** for 2020?
- Is 2020 an appropriate **target** for the study?
- What do you see as **key global influences**?
- What do you see as key **energy technologies**?
- What **policies** should Hawaii implement?
- What other **energy issues** concern you?

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Pete Hoffmann
**Hawai'i Island Economic Development Board**
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Karl Stahlkopf
**Hawai'i Electric Light Company, Inc.**
Hal Kamigaki, Chengwu Chen, Art Russell, Lisa Dangelmaier
**Hawi Renewable Development**
Jim Nestman, Raymond Kanehaikua
**Hilton Waikoloa Village**
Rudy Habelt (Director of Property Operations)
**Kohala Center**
Betsy Cleary-Cole (Deputy Director)
**Life of the Land**
Henry Curtis (Executive Director)
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Mark Glick Yuko Chiba
**Powerlight**
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**State of Hawaii, Public Service Commission, Division of Consumer Advocacy**
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**Tesoro Hawaii Corporation**
Carlos De Almeida
**University of Hawaii at Manoa**
Makena Coffman

# Stakeholder Summit

## What we expected: What we got:

# Scenarios Selected by Stakeholders

- Addresses metrics of interest to all groups

**HIGHER WIND PENETRATION**

*Given the trends in Hawaii for increased wind farm development, a renewable energy strategy consisting primarily of increased wind utilization will be considered.*

**ENHANCED ENERGY MANAGEMENT**

*Using new and/or innovative approaches, such as demand-side management, energy efficiency programs and plug-in hybrid electric vehicles to reshape the load profile and alter system operation.*

**INCREASING ENERGY SECURITY**

*Based on a specific technology deployment that is focused on using indigenous resources, especially renewable resources (wind, solar, geothermal).*

# For each Scenario we need to consider other variables…

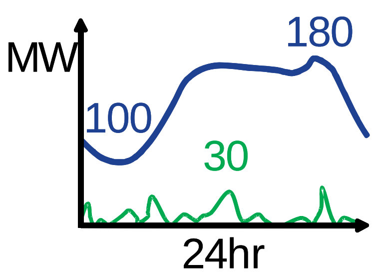
| Scenario Elements | Impact |
|---|---|
| **Energy Storage Technologies** | Maintains power system stability by providing support for intermittent renewables, while minimizing the curtailment of renewables. |
| **Oil Price** | Fluctuations in the oil price will impact the cost of electricity, transportation, citizen behavior. |
| **Carbon Policy** | The economics of lower carbon-emitting technologies will be enhanced relative to fossil-fuel counterparts. |
| **Renewable Portfolio Standards** | Alternative target dates and percentages could affect the cost of energy in a non-linear fashion. |
| **Power Purchase Agreements** | Changes to this policy will affect the price HELCO and ratepayers pay future independent power producers. |

# Example Scenarios:
# #1 - Higher Wind Penetration
# #2 – Enhanced Energy Management

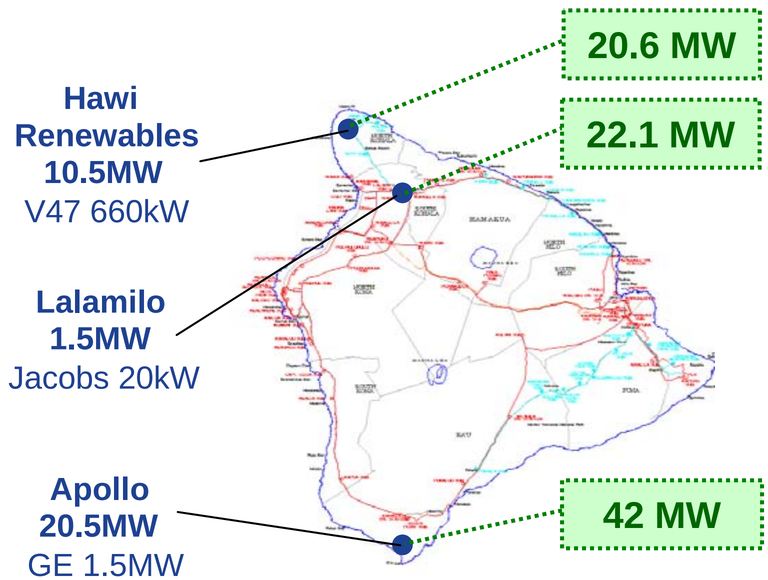
# Higher Wind Penetration Scenario

- A substantial wind penetration was selected.
- The capacity of each wind farm was increased.

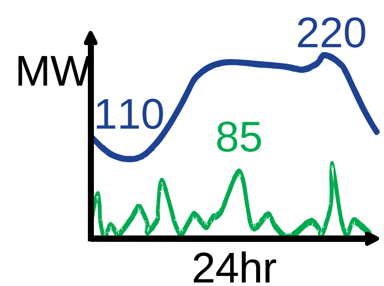
## In 2007…




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




## In 2018…



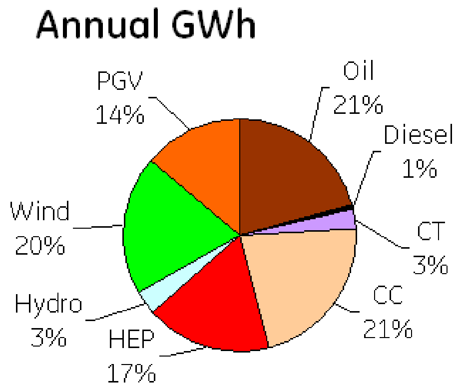

Power (MW)
- Day ~ 40%
- Night ~ 70%

**32.5MW of wind power capacity**

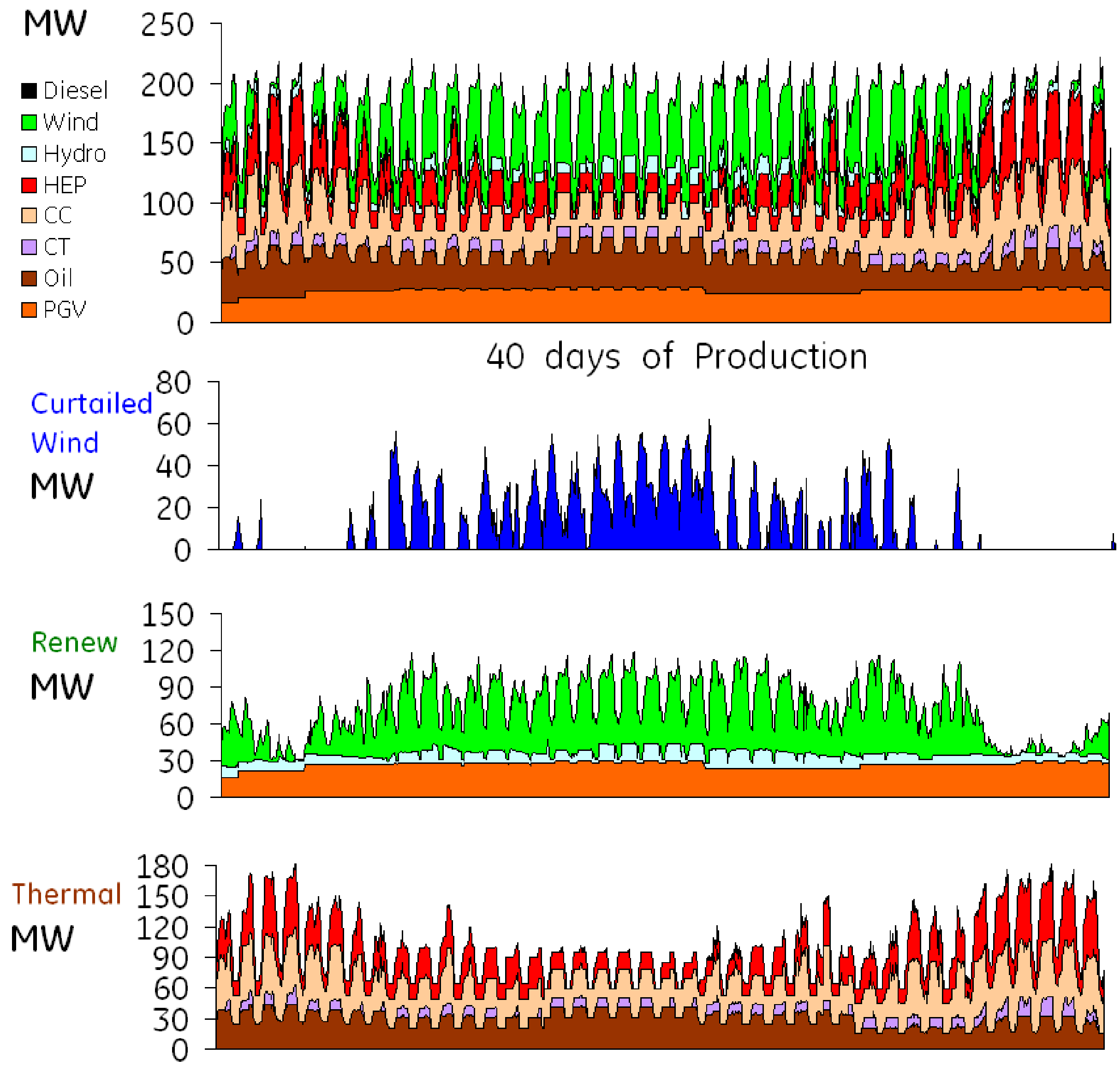
**84.5MW of wind power capacity**

# Higher Wind Penetration Scenario

## Build multiple cases in MAPS



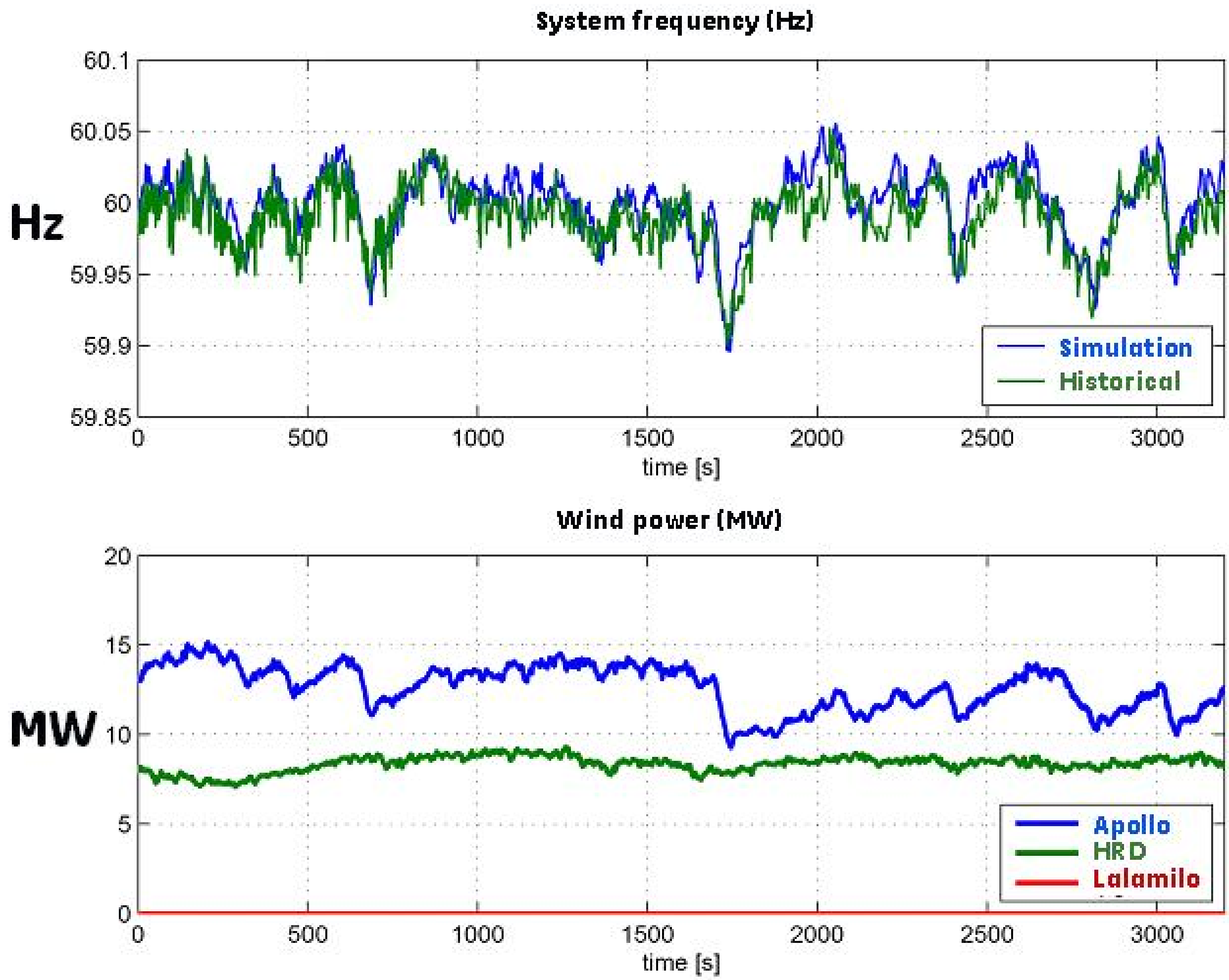

| Delivered | Curtailed |
|---|---|
| 305 GWh | 73 GWh |



# Baseline: “Business-as-usual” Scenario

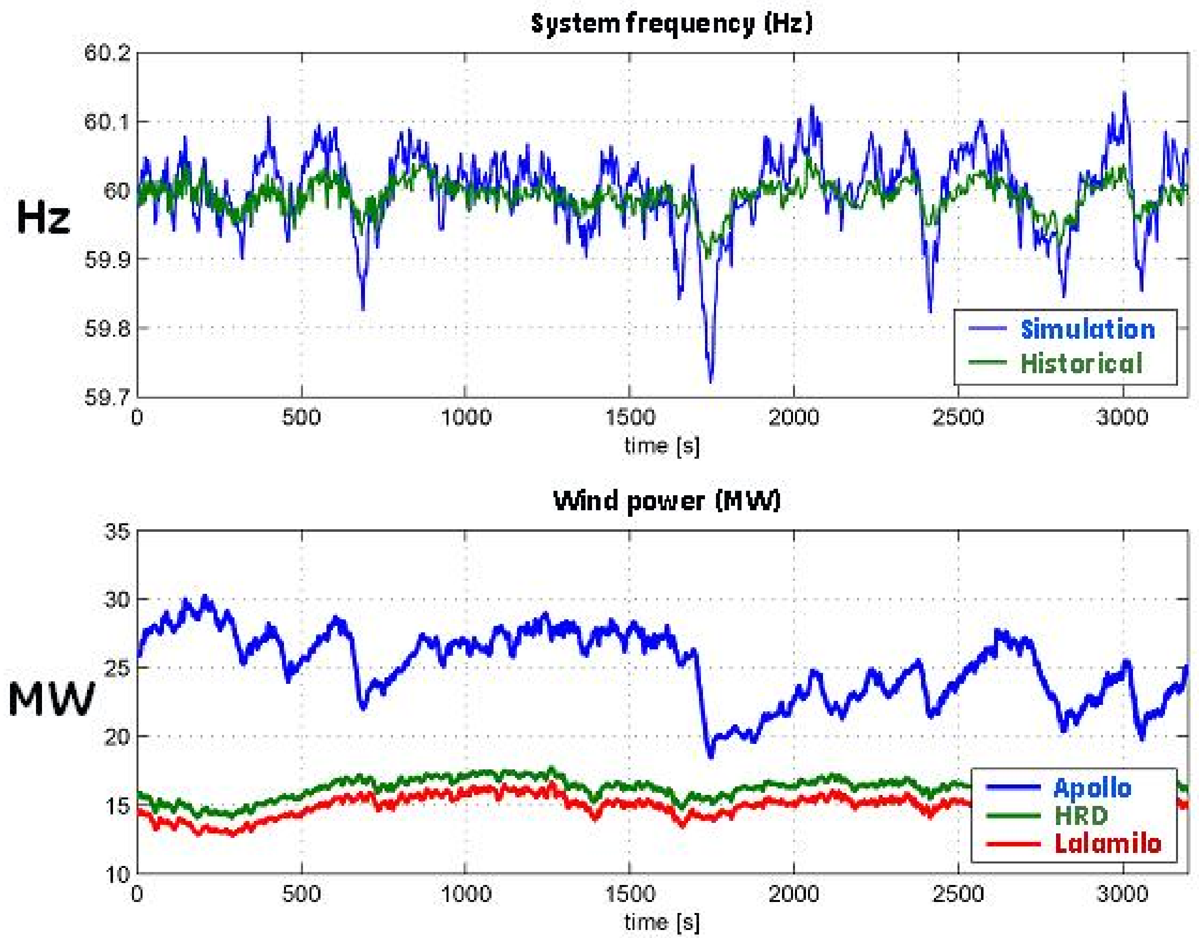
## One hour system frequency trace

- Consider the validated May 22nd historical window.
- Historical load & wind production were used to drive the simulation.
- An hour with low load and an intermediate wind condition was chosen in MAPS.
- Units specified for this hour were used to initialize the simulation.
- Similar performance was observed.



# Higher Wind Penetration Scenario
## One hour system frequency trace

- Considering the same 1 hour window.
- 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
- **System performance was severely affected.**

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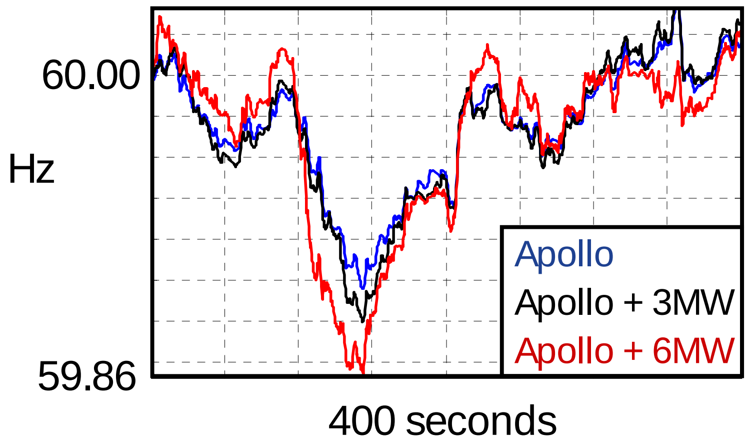
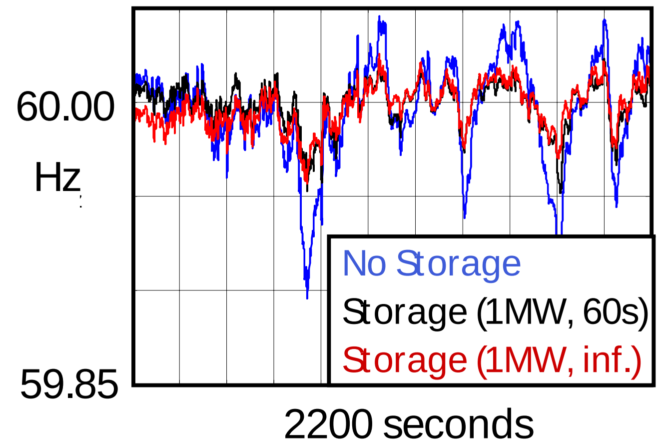
# Strategy for Improving Grid Stability

## **Is** short time-scale energy storage **a viable option?**

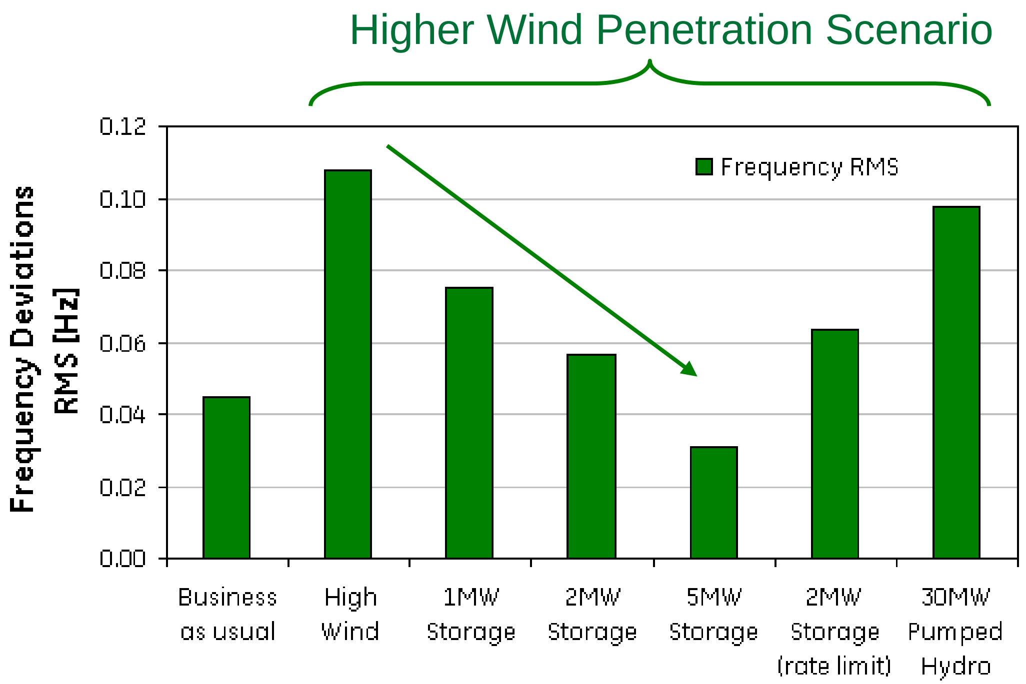
- Considering the same May 23rd historical window
- Expand the Apollo wind farm by 3MW, then 6MW
- Short time-scale energy storage showed substantial reduction in frequency sag.



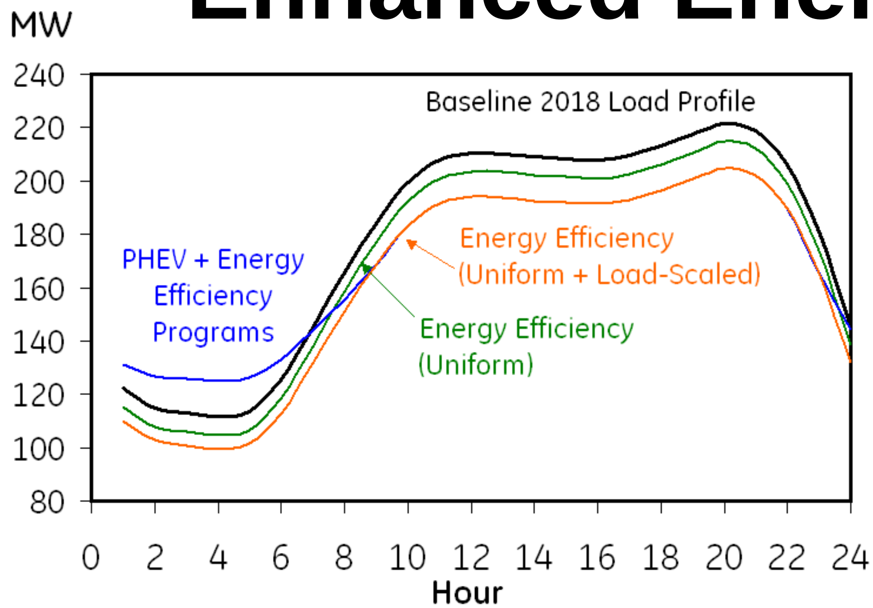
# Higher Wind Penetration Scenario

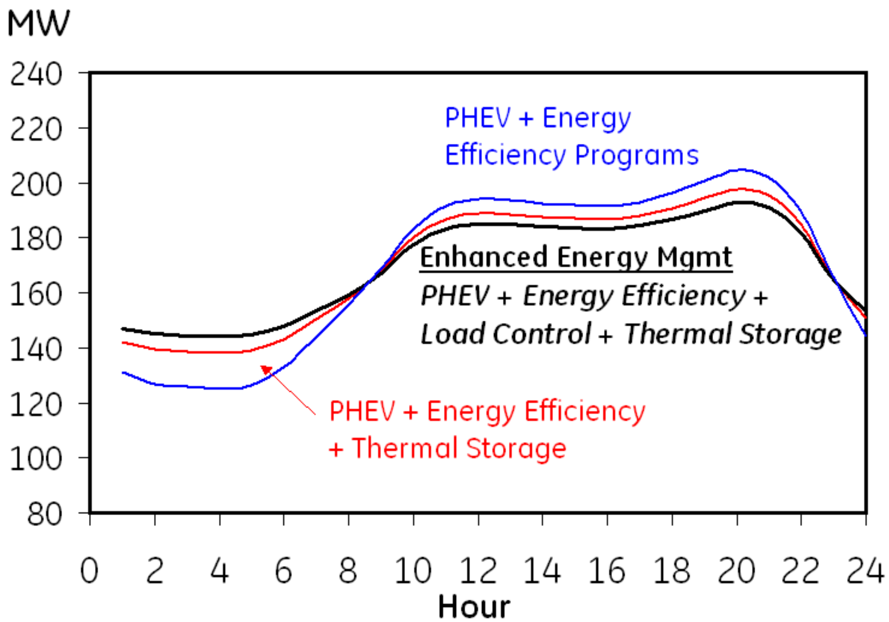
## System Frequency Performance




- **As the size of the storage device increases, the system frequency RMS decreases**.
- "Higher Wind Penetration" + 5MW storage device reduces system frequency RMS to below that of the "Business-as-usual" case
- 3-5 minutes of energy storage was needed for the simulation.

# Enhanced Energy Management




- 7MW uniform load reduction due to energy efficiency

+10MW reduction by load factor due to energy efficiency

+10% PHEV penetration (nighttime charging)

+7MW peak reduction shifted to nighttime due to thermal storage

+5MW peak shifted to nighttime due to residential load control

# Effort Allows DOE to Address National Problems While Solving Local Issues

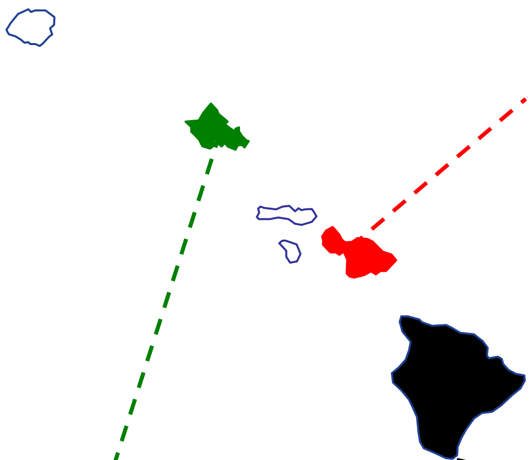
- Effect of non-dispatchable, intermittent renewables on the grid - Big Island is experiencing it first (200MW grid vs. 55GW system in CA)
- Future interconnections of transportation and electricity systems must be evaluated, i.e., PHEV
- Congestion issues - load centers versus generation, particularly for remote renewable resources and load centers on Mainland
- Developed effective mechanisms for addressing stakeholder concerns
- Informed regulatory leaders on cost and systems issues associated with greater penetration of renewables on grid
  - Incentivize the utility to promote renewables
  - Encourage utility to partner with customers and IPPs for DG, CHP, energy efficiency – **important to Stakeholders**
  - Evaluate power purchase agreement terms (PPA)

# These Systems Also Allow DOE the Opportunity to Examine

- O&M stresses as a result of ancillary services
  - reduced heat rate and other sub-optimal operating conditions for spinning reserve
- New storage, power electronics, and information systems to improve system reliability and stability with relatively large penetrations of intermittent renewable energy
- Nature of current IPP contract agreements
  - Just buying watts, no consideration for reactive power, grid stability, use of storage systems
  - Tied to avoided costs for oil, doesn't address spinning reserve
  - Use of oil goes down and electricity prices go up

**These lessons learned are *immediately* applicable to Mainland systems.**

# Use of These Tools Will Also Evaluate State RPS Goals as Funded by the Hawaii PUC



## Maui Grid Study – Utility and DOE

**Phase 1** – Model & validate the power system

**Phase 2** – Evaluate scenarios in order to understand:

- The economic & performance impacts of more wind
- The mitigating technologies (e.g. storage, controls) required to increase wind capacity.

## Oahu Wind Study - Utility

To evaluate key, wind projects that would impact the Island, including the **Lanai (300MW) / Molokai (200MW)** wind projects with underwater HVDC to Oahu **(discussions underway)**

## Big Island Energy Roadmap – DOE and Utility

**Phase 2** - Evaluate scenarios to identify the performance of various technology approaches.

**Proposed Phase 3** – Demonstration project – "Iron on the ground"

# An ongoing public/private partnership

**Our unique team (DOE, HNEI, GE, Sentech, HECO, DBEDT) offers an unprecedented opportunity for linking R&D and public policy to the commercialization process**