Renewable Energy Integration On Island Systems

The Hawaii Experience

Japan-IRENA Joint Workshop
Accelerating Renewable Energy Deployment in the Pacific Region
-- Meeting the Challenges --

Okinawa, Japan
May 26, 2012

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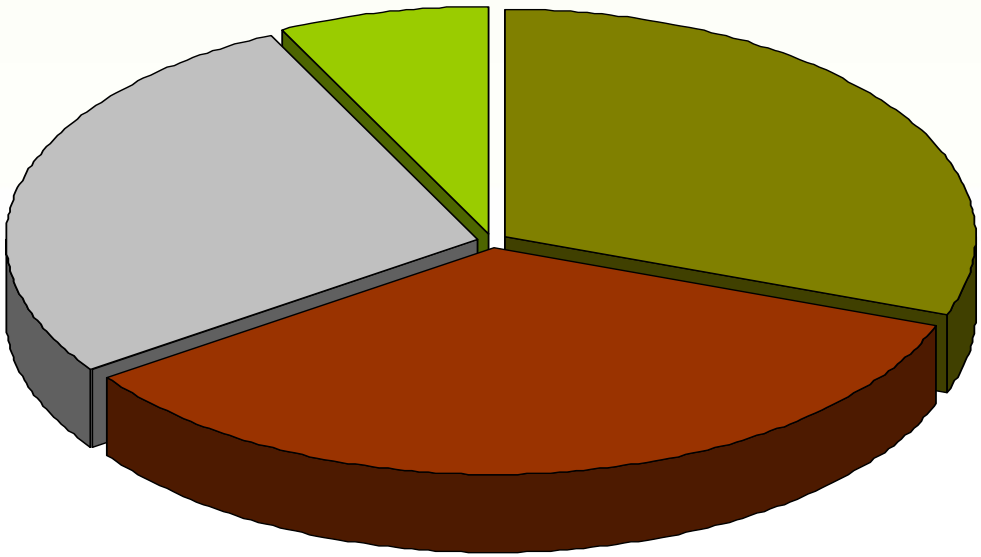
University of Hawaii at Manoa

Hawaii Today

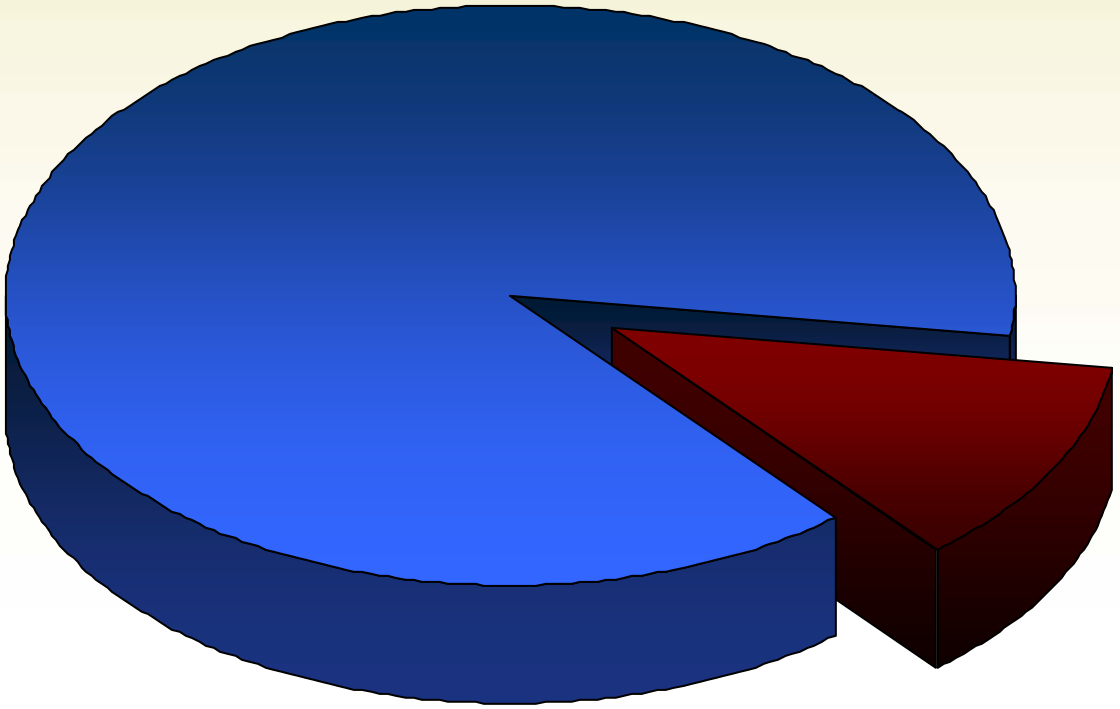
Primary energy: **90%** fossil fuel, all imported, most of it is crude oil refined:



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

Energy Insecurity

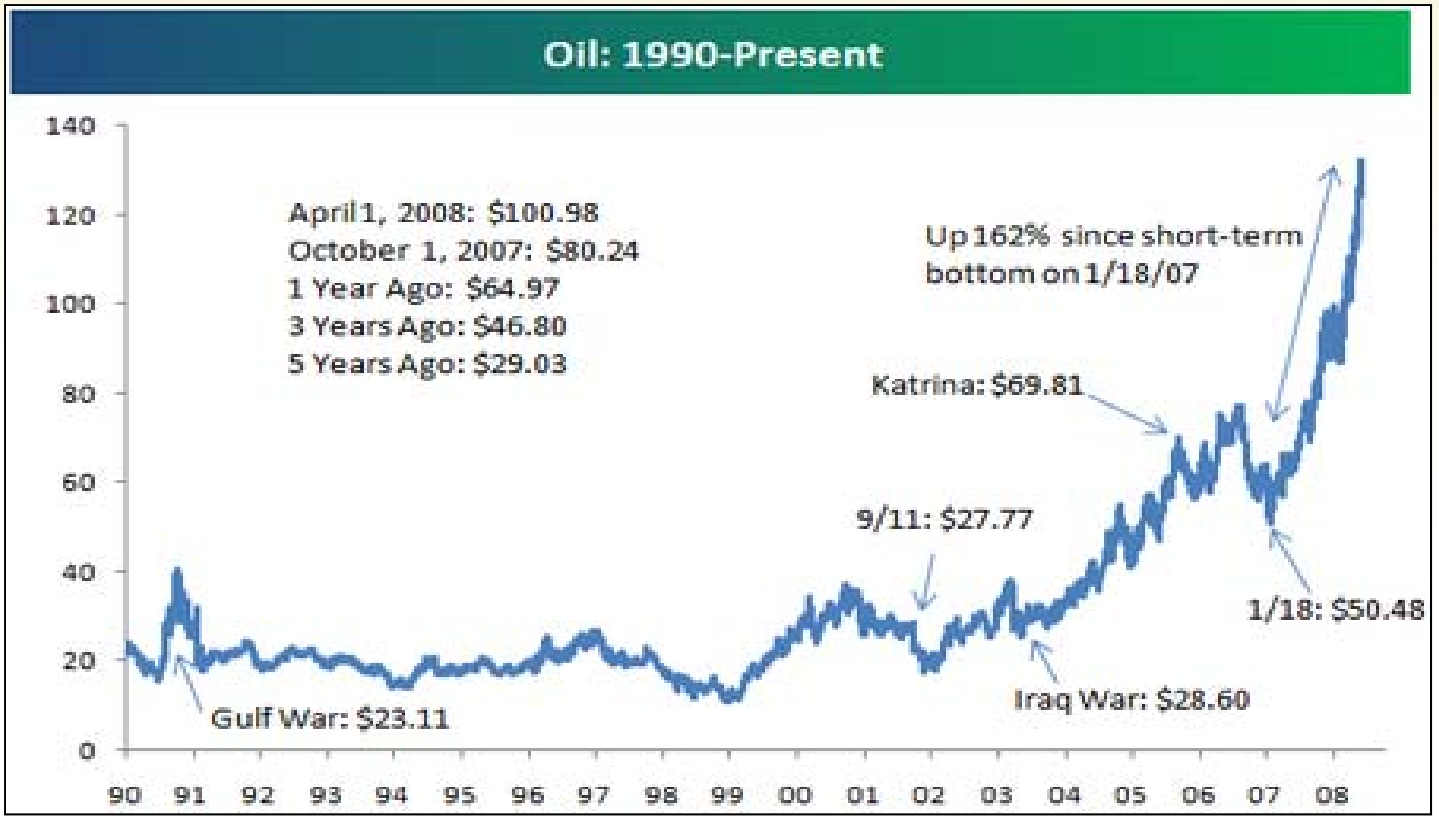
In 2008, energy accounted for 13% of Hawaii's Gross State Product



GROSS STATE PRODUCT	$63.8 BILLION
SPENDING ON ENERGY	$ 8.4 BILLION

Economic drain occurring again today ...

Oil Price *Changes* Drive Electricity Price *Volatility*



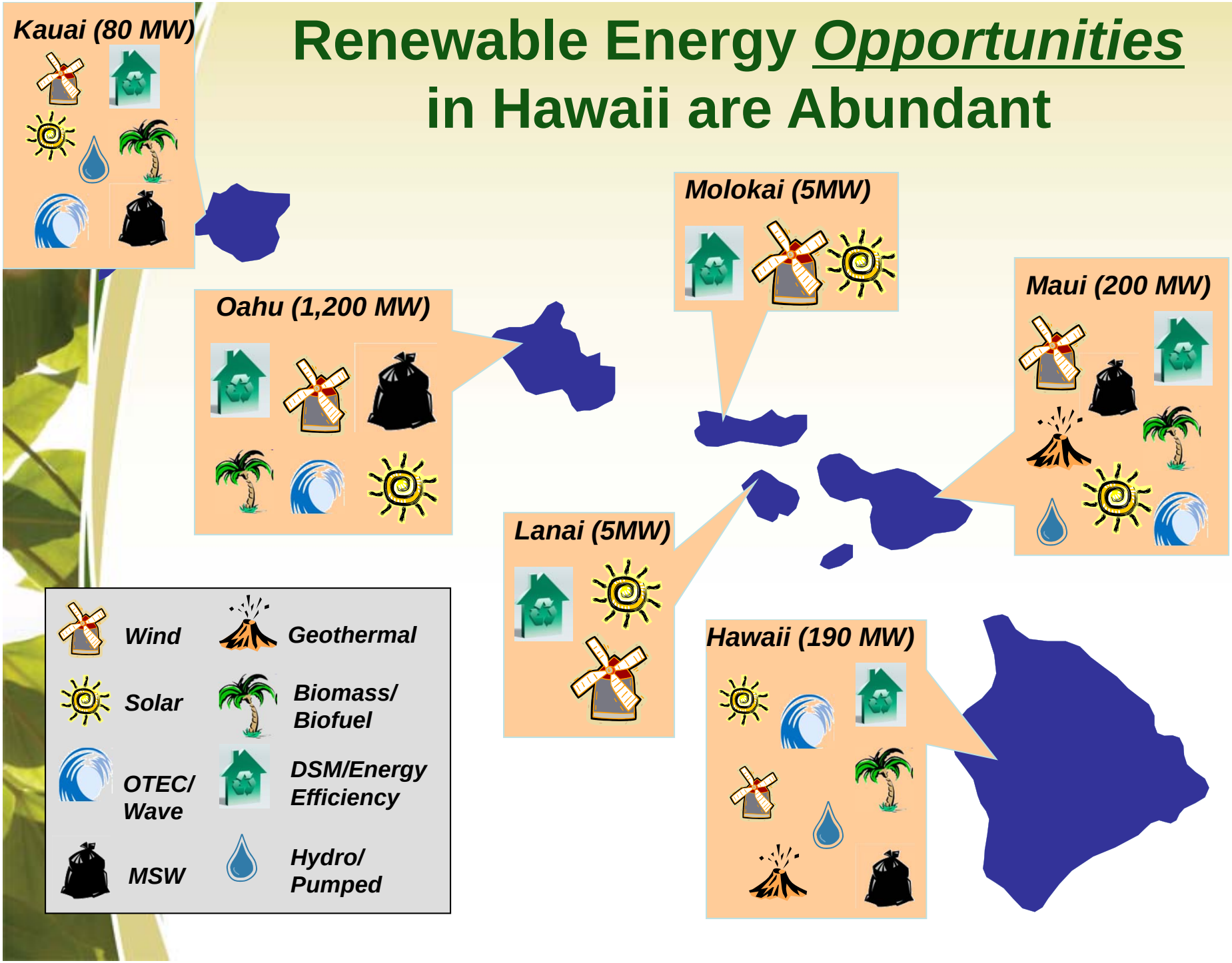
Electricity price *volatility* makes it difficult for users to plan and budget

A Paradigm Shift Is Required

- Energy insecurity > Energy security
- Economic drain > Economic engine
- Price volatility > Price stability
- Environmental harm > Environmental compatibility

The Opportunity

Renewable Energy *Opportunities* in Hawaii are Abundant



Hawaii Clean Energy Initiative (HCEI)

Hawaii	The most petroleum-dependent state in the US is on track to increase its clean energy (efficiency and renewables) to 70% by 2030 and will have the greatest penetration of variable renewables on a grid in the US

Objectives

The State of Hawaii, US DOE, and local utility launched HCEI in January 2008 to transform Hawaii to a 70% clean energy economy by 2030:

- ***Increasing Hawaii's economic and energy security***
- ***Fostering and demonstrating Hawaii's innovation***
- ***Developing Hawaii's workforce of the future***
- ***Becoming a clean energy model for the U.S. and the world***

Editorials

TUESDAY | OCTOBER 21, 2008

Ambitious energy agreement charts right course

A promising new agreement between the state and Hawaiian Electric Co. is expected to make some significant progress in reducing Hawai'i's dependence on fossil fuels.

It calls for streamlining the regulatory process to achieve some worthy goals, including sending wind energy from Maui, Lāna'i and Moloka'i to O'ahu via state-of-the-art undersea cables, and developing a "smart grid" so customers can get lower rates during off-peak hours.

That's the good news. But

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the 50-page agreement also lacks some key details. Perhaps the most important one, given these tough economic times, is how much will it all cost, and how much of that cost will the consumer be asked to bear?

Admittedly, it's a difficult question to answer, given the scope and complexity of the plan. Still, looking out for ratepayers' and taxpayers' interests will be crucial. Part of that responsibility rests with one of the agreement's signatories, consumer advocate Catherine Awakuni, and the Public Utilities Commission.

Awakuni and the PUC have the obligation to ensure that the average ratepayer isn't unfairly burdened by the cost of developing the new, renewable-energy infrastructure.

There will be significant upfront investment costs. The undersea cable alone could run in the hundreds of millions of dollars, and the state should maximize opportunities for federal funding through the Department of Energy or similar sources.

And even with federal funding — U.S. Sen. Daniel K. Inouye attended the signing ceremony for the new agreement — ratepayers will likely be asked to pick up some of these costs as an investment in the state's renewable energy future.

Certainly, this future is the direction in which the state needs to be moving. Achieving the state's goal of 70 percent clean energy by 2030 is a laudable plan that sets us on the right path. Indeed, Hawai'i is uniquely positioned to be a leader in the area of wind, wave and solar energy efforts.

And in the long term, renewables offer an unlimited supply of environmentally friendly energy and reduces our over-reliance on fossil fuels — a more sensible and sustainable future.

It's an ambitious plan. If the agreement's goals are met, the result will be a fundamentally changed energy model. A more unified, more efficient grid will support different energy sources, primarily wind; HECO will move from a sales-based company to an energy services provider; and the consumer will have more control over energy costs with new ways to conserve using technology.

The Lingle administration hopes the agreement will be a win-win for everyone — the state, HECO and consumers. Refining these details will help ensure that success.

New *Regulatory Compact*

- Renewable & Energy Efficiency Portfolio Standards
- Net Energy Metering
- Feed in Tariff
- Financially sound utility
  - Utility is the off-taker for energy sales from IPPs
  - Decoupling utility rates from energy sales
  - Grid investment

Hawaii State Capitol

Hawaiian Electric offices

New *Societal Compact*

- ***Collective buy-in needed***
  - Government-industry partnerships
  - Commercial partnerships
  - Community dialogue & partnerships
    - Open and truthful about the investment necessary and time it will take to be successful
    - Empower customers to manage their energy use

Where Are We Now?

2010 RPS Goal Was Met
20% Renewable Energy & Energy Efficiency
(~50% / 50%)

State RPS Goal of 70% by 2030
30% Energy Efficiency
(4,300 GWh reduction by 2030)
40% Renewable Energy
(2015 - 15%; 2020 - 25%)

- **Legal mandate is 40% renewable energy by 2030**
- **Goal is 100% *local* renewable energy as soon as possible**

Rapid Development of Renewable Resources *Today*

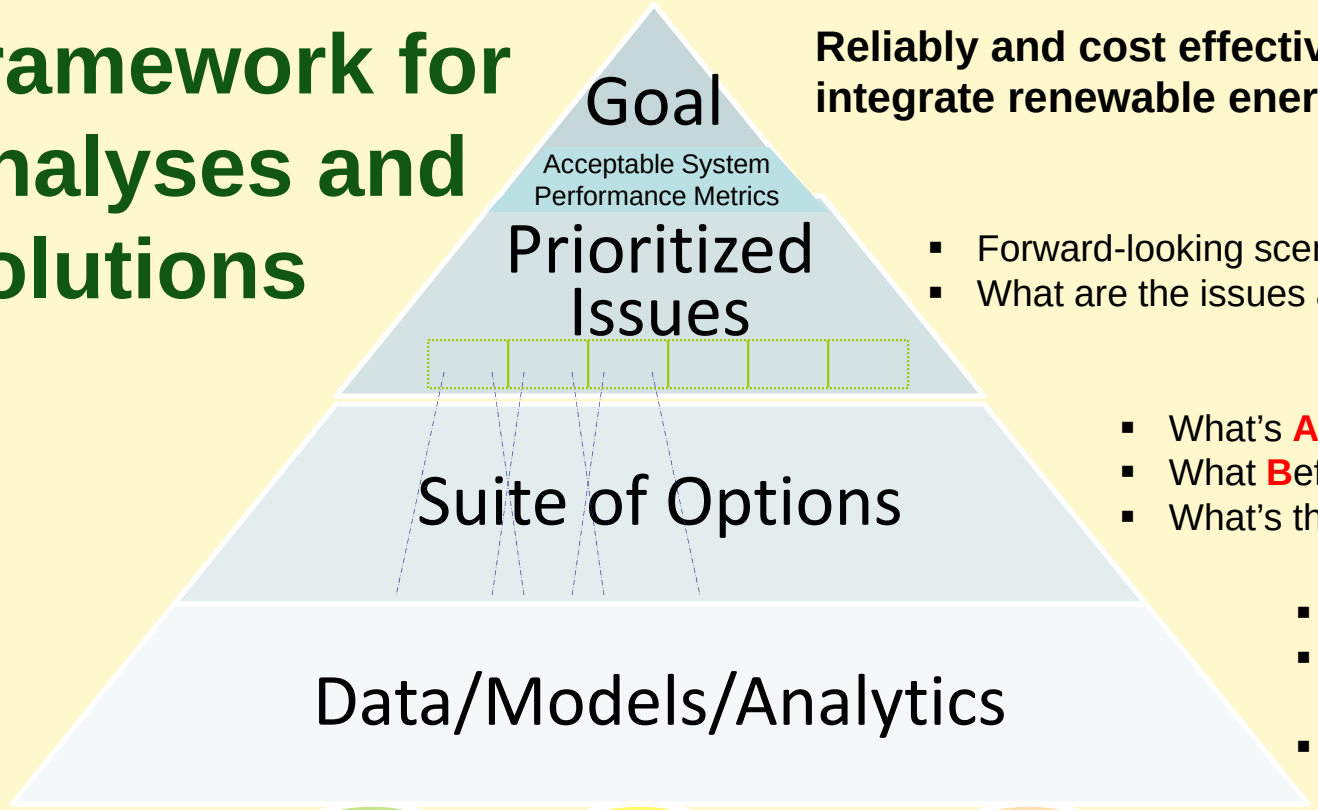
Wind

Solar

How We Can Move Ahead

- **Technical Innovation**
  - Renewable resource technology deployment
  - Grid transformation and systems integration
  - Inter-island connections
  - Liquid fuels substitute

Framework for Analyses and Solutions

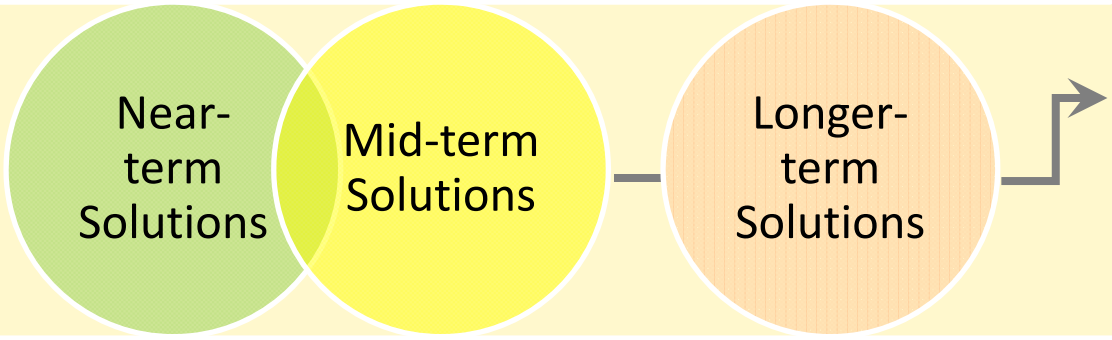


Reliably and cost effectively integrate renewable energy

- Forward-looking scenario of high penetration RE
- What are the issues and quantify magnitude

- What's **A**vailable?
- What **B**efits the System?
- What's the **C**ost to Customers?

- Timing of Solutions?
- Value Benefit vs. Costs/Risks?
- Near and Long-term Impacts?



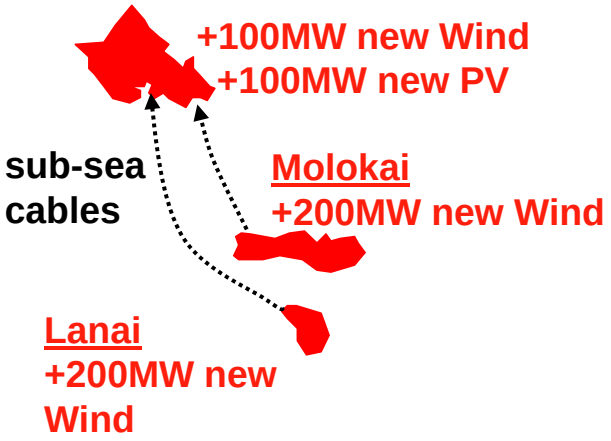
Resource Planning

Informed Recommendations → HPUC

Tailored analytical roadmap needed for each island grid

O‘ahu Wind Integration Study (OWITS)
Focus on High Penetration Wind Scenarios

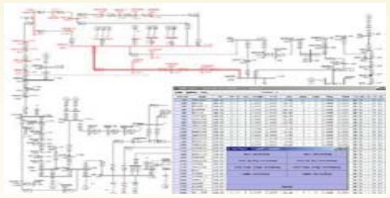
Scenario	Title	Wind			Solar PV
		Oahu	Lanai	Molokai	Oahu
Baseline	2014 Baseline	-	-	-	-
Scenario #1	Oahu only	100MW	-	-	100MW
Scenario #2	Oahu + Lanai only	100MW	400MW	-	100MW
Scenario #3	Oahu + Lanai + Molokai	100MW	200MW	200MW	100MW



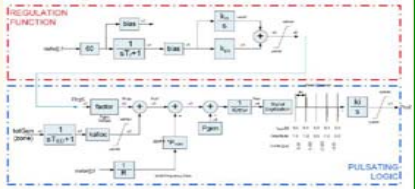
These 3 scenarios were analyzed to determine the commitment/dispatch, identify new operating characteristics, and establish a new baseline to assess strategies to enhance operation with high penetrations of renewables

Modeling Across All Timescales

Positive Sequence Load Flow (GE PSLF™)



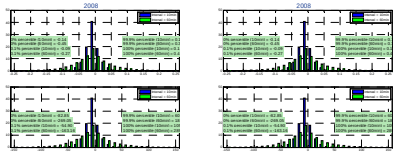
Long-term Dynamic Simulations (AGC)™



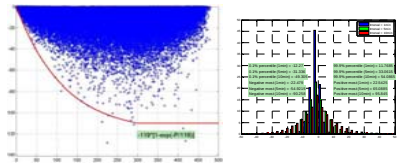
1 sec | 1 min | 10 min | 1 hr | 1 day | 1 wk

- Voltage Support
- Inertia
- Governor Response
- AGC Regulation
- Economic Dispatch
- Planning

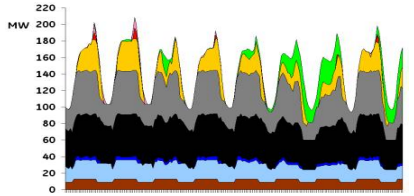
Statistical Wind Power Variability Assessments



Interhour Renewables Variability Analysis™



Multi-Area Production Simulation (GE MAPS™)



Transitioning to High Renewable Energy

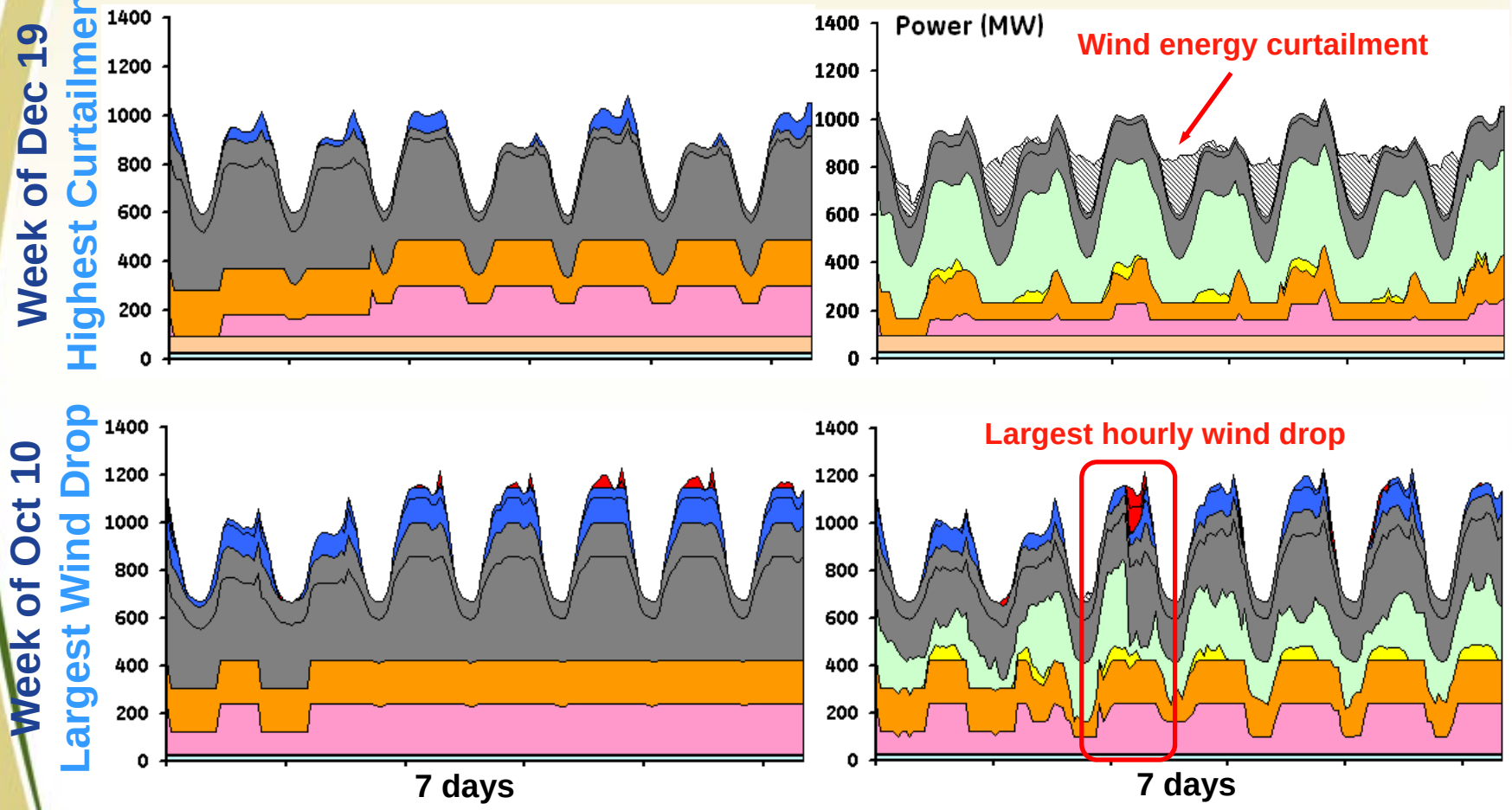
50% of Peak Load met by Renewables (25% annual energy)

Baseline

No Wind or Solar

High Renewables

500MW Wind & 100 MW Solar

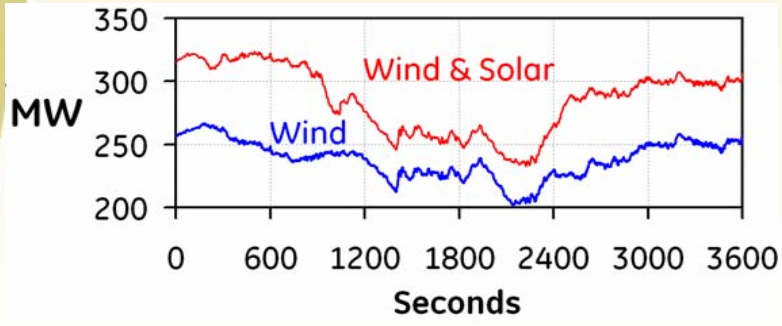


Thermal units are backed down, wind energy is *sometimes* curtailed at light load, and wind power changes are managed by ramping the thermal units.

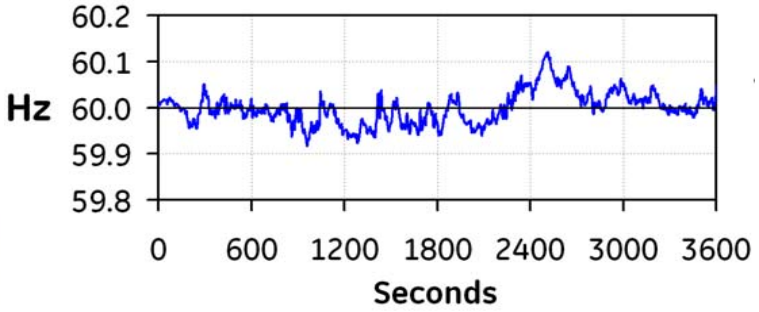
Frequency Maintained During Wind Events

Fast Wind Power Variability

Aug 30th 10am (995MW Load)



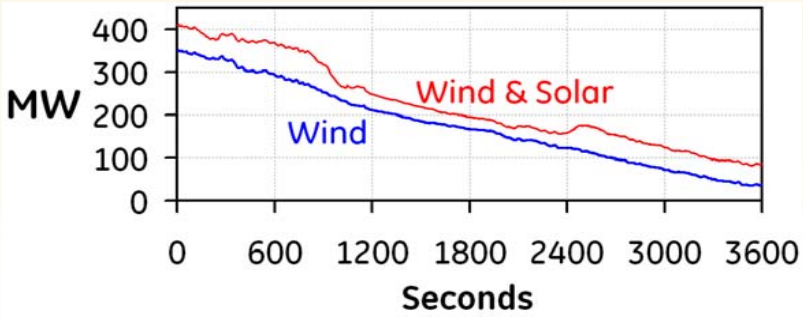
Large and fast wind power variability over the 5-10min timeframe in both directions



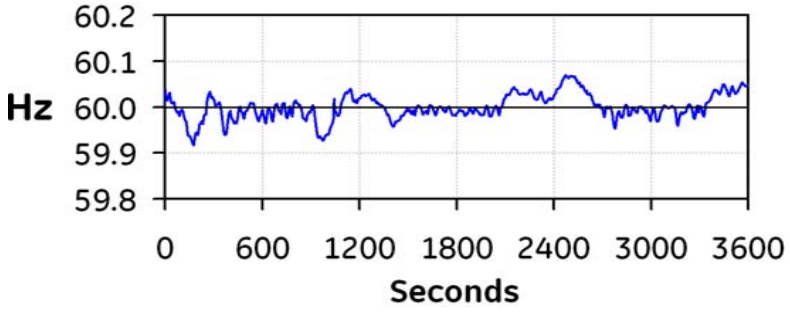
System frequency over fast wind variability events

Sustained Wind Power Drop

Oct 12th 2pm (1160MW Load)



Largest wind forecast error. Largest hourly wind drop (311MW; 27% of gen.) All fast-start units dispatched



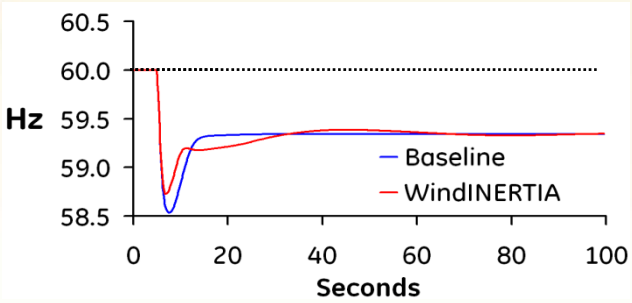
System frequency over large sustained wind drop

Wind Plant Transient Response

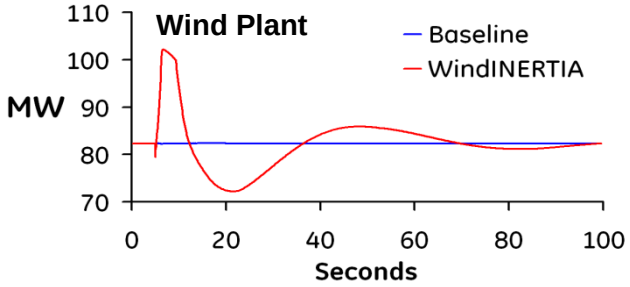
Wind plant controls help respond to system events

Sudden 200MW Cable Trip

Oct 24th 8pm (1020MW Load)



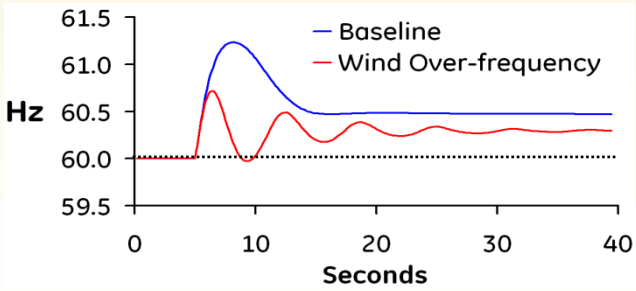
Cable trip caused loss of 200MW of wind power at high wind conditions (363MW) and low up reserve (267MW)



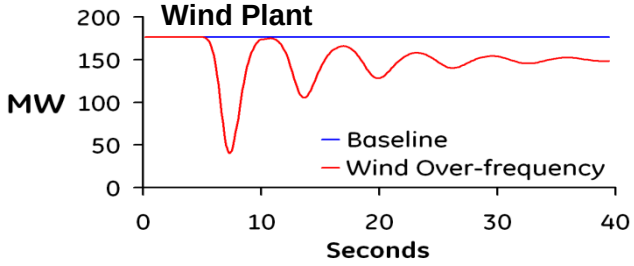
Wind turbine inertial response helped reduce frequency drop

Load Rejection during High Wind

Oct 23rd 12am (720MW Load)



140MW load rejection. Low load and high wind (357MW, 50% load). Thermal units near min power; carrying 89MW of down reserve.



Wind turbine over-frequency control helped reduce over-frequency event

Key OWITS Conclusions

O‘ahu can reliably accept 25% of its energy from 500 MW Wind (and 100 MW of PV) provided the following system modifications are considered:

- Incorporate wind power forecasting
- Refine reserve requirement (function of wind power forecast)
- Incorporate other off-line resources for reserves (load control, fast-start units)
- Reduce minimum power of thermal units
- Increase ramp rates and modify droop characteristics of thermal units
- Apply advanced wind turbine capabilities (inertia, frequency response, curtailment)

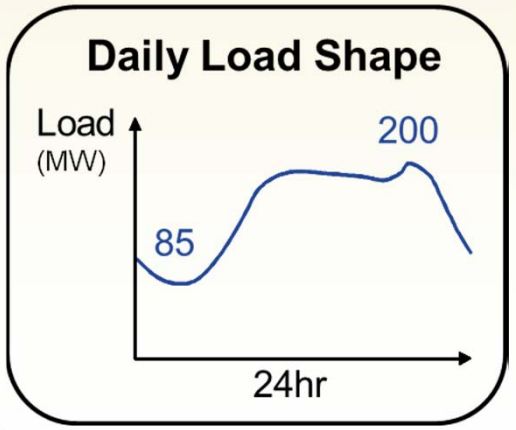
Hawaii Solar Integration Study (HSIS)

- **Study is underway**
  - Build upon OWITS work product
  - Target completion by Oct. 2012
- **Key study outcomes**
  - Examine operating characteristics across all timescales and the key challenges with high levels of solar (and wind) power on the O‘ahu and Maui grids
  - Assess and quantify the value of alternative solutions to enable high penetrations of solar (and wind) power
  - Recommend strategies to enable high levels of solar (and wind) power on the O‘ahu and Maui grids

The Maui island Experience

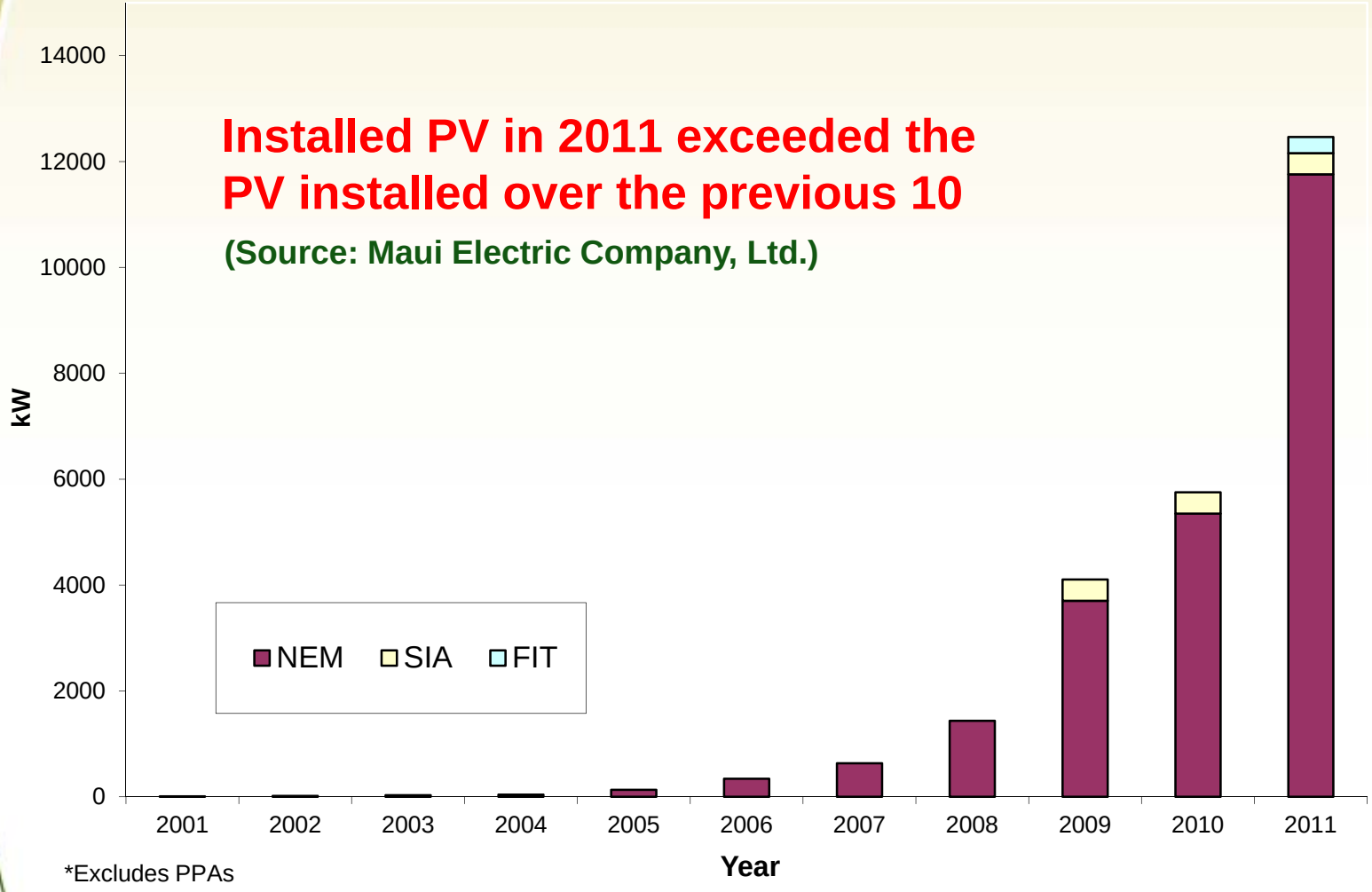
72 MW of Wind Power

63,000 Customers



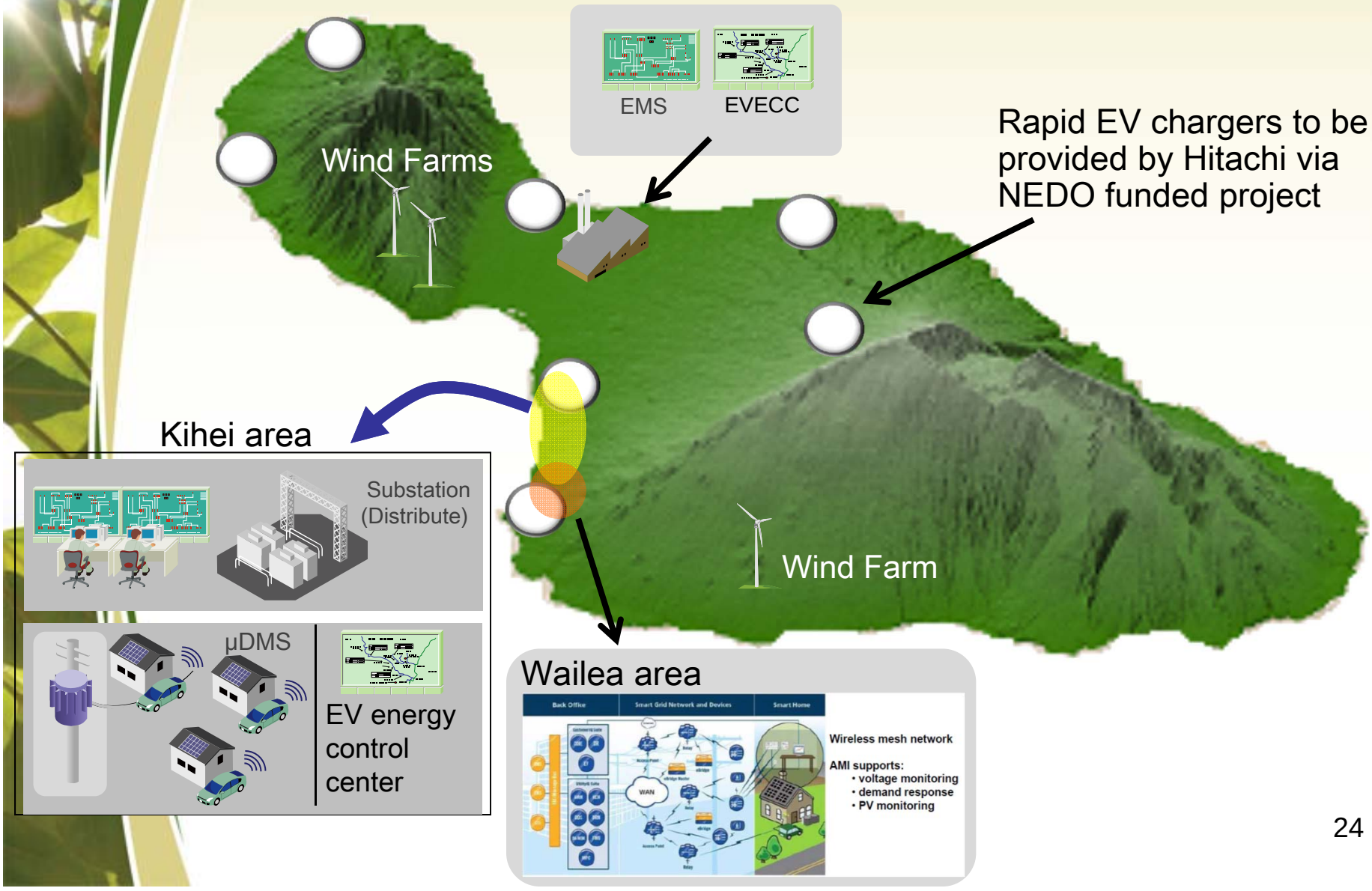
Rapid PV Market Growth

Island of Maui



*Excludes PPAs

Integrate Renewables and Transform the Maui Grid

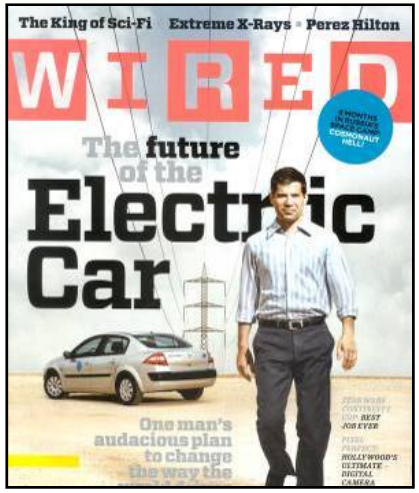


Electrify Transportation

- 1/3 of oil imported for ground transportation
- Driving electric vehicles are …
  - a good fit for Hawaii
  - cleaner (less CO2)
  - cheaper
    - Mitsubishi “i” @ 9 cents/mile (30 cents/KWh electricity)
    - Avg. Gas Car @ 20 cents/mile ($4/gal gas; 20 mi/gal)

OKINAWA
EV Charging spot


Star Bulletin
IT'S ELECTRIC!
A California firm proposes to jump-start electric car use in Hawaii
WHERE'S LINGLE?


The King of Sci-Fi Extreme X-Rays Perez Hilton
WIRED
The future of the Electric Car
One man's audacious plan to change the way the

Hawaii-Okinawa Clean Energy Collaboration

The Molokai Opportunity

- **Partners**
  - Hawaiian Electric / Maui Electric
  - Hawaii Natural Energy Institute, Univ. of Hawaii
  - Okinawa Enetech

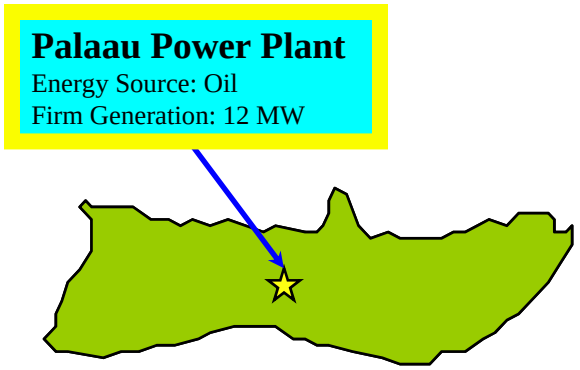
Phase 1

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

Phase 2

- Expand energy production from local renewable resources
- Reduce/stabilize energy costs for residents
- Create green job opportunities

- 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



MOLOKAI

Bottom Line

- Paradigm shift - energy insecurity ⇨ energy security
- Total energy cost (electricity & transportation) lowered and stabilized using renewable energy in place of oil
- Hawaii is an ideal working 'lab' to prove concepts and learn lessons about advanced energy technologies
- Hawaii as an island leader is well on its way
  - Increasing energy independence
  - Reducing fossil-fuel use
  - Limiting greenhouse gases



Mahalo

(Thank you)

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