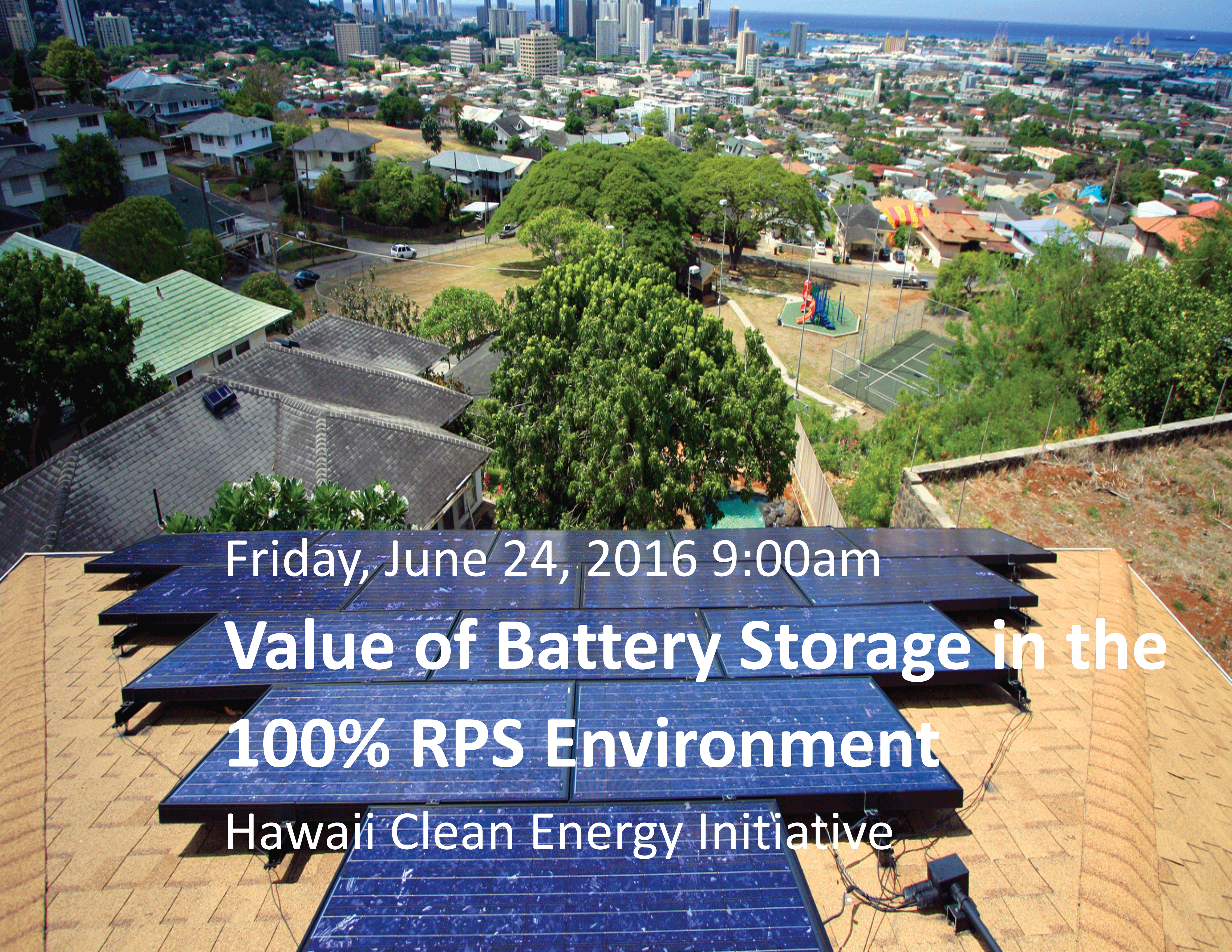


Friday, June 24, 2016 9:00am

Value of Battery Storage in the 100% RPS Environment

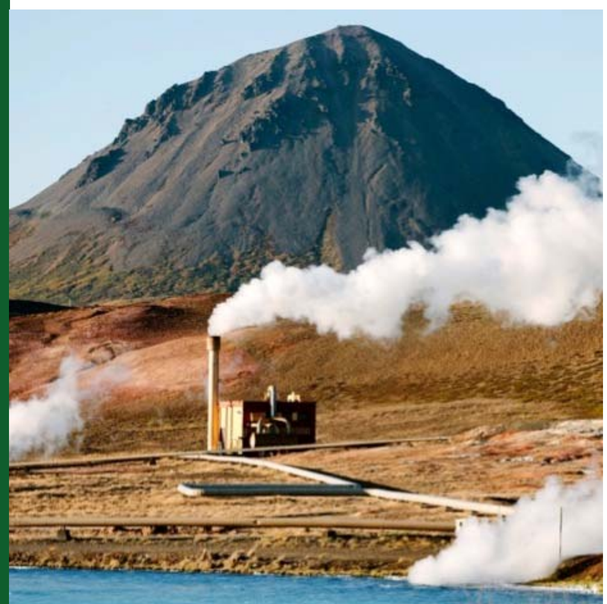
Hawaii Clean Energy Initiative

ENERGY TRANSITION INITIATIVE

Hawaii's Leadership in the Clean Energy Economy

Updates on DOE Energy Storage Work & Other Updates

June 2016



Energy Transition Initiative: Islands

The *Energy Transition Initiative: Islands* is an opportunity for insular areas to define and realize their own vision for a clean energy economy

Our Goal/Mission:

- Accelerate commercial opportunities to transition island economies off imported fossil fuels by focusing on local resources

Anticipated Outcomes:

- Eliminate the dependence of island economies on imported fuels
- Replicable solutions for others around the world

Islands Can Be Deployment Leaders

Jurisdiction

	Island	**City**	**City with Municipal Utility***	**State with Regulated Monopoly**	**State with Generation Separated**	**Federal (Non-PMA)**	**RTO/ISO**
Central Power Stations	✓	Siting*	✓	✓ (IPPs get special treatment)		Hydro only (IPP PURPA?)	Limited
Distributed Generation	✓	Siting*	✓	✓		PURPA?	Limited
Capacity Requirements	✓		✓(Can be shared with Regional Interconnect)	Can be shared with Regional Interconnect (not MISO)		Limited	✓, Can be shared
Reserve Margins / Reliability							
Interconnection	✓		✓	✓		Interstate wires / Bulk Power System	Interstate wires / Bulk Power System
DG Compensation	✓		✓	✓		PURPA	Wholesale participation
DG Financial Incentives	✓	✓	✓	✓		✓	
Environmental Requirements for Energy Infrastructure	✓	Some, in construction or delegated from state		Delegated authority from Fed		✓	
Transmission	Sometimes / Rarely Shared	Siting*	Shared with State	Shared with Federal		Shared with States	
Distribution	✓	Siting*	Shared with State	Shared with Federal			
Utility-Led Energy Efficiency	✓		✓	✓			
Energy Efficiency Financial Incentives	✓	✓	✓	✓		Some	
Building Energy Codes	✓*			Shared with Federal		Shared with States	
Public Transportation	✓	Shared with State and Fed		Shared with Cities & Fed		Shared with States & Cities	
Alternative Fuel Vehicle Incentives	✓	✓	✓	✓		✓	
Alternative Fuel Infrastructure	✓	Some	Some	✓		Shared with States	

NB: U.S. Focus.

*Siting authority of local governments varies under state law

Current ETI Decision Support Resources

- **State and Local Energy Data Tool.** SLED helps state and local governments develop long-term energy plans by analyzing and sorting data in real-time, www.eere.energy.gov/sled.
- **Energy Scenario Modeling Tool.** Based on user-defined energy information, the scenario tool provides the basis for data-driven discussions on transition pathways and investment priorities, all focused on reaching a user-defined clean energy goal (e.g., 32% by 2030). By modelling the costs of different fuel mixes over time, communities can quickly analyze different pathways to realizing their own clean energy goals.
- **In-Person Training.**
  - *Utility Renewable Energy Integration Information and Support Training*: For utility leadership and engineers interested in successful programmatic and technical integration of distributed generation, including microgrid design.
  - *Policymaker & Program Manager Electric Grid and Renewable Energy Support Training*: For policy and program decision makers interested in baseline technical grid, renewable energy, and program best practices.

ETI: Islands Playbook

“The Islands Playbook (the Playbook) provides an action-oriented guide to successfully initiating, ***planning and completing a transition to an energy system that primarily relies on local resources to eliminate a dependence on one or two imported fuels.***

It is intended to serve as a readily available framework that any community can adapt to organize its own energy transition effort.”

Islands Playbook Content

- **Highlights the process - the *how* - of organizing an energy transition and implementing projects**
  - Eliminating a dependence on imported fuels requires iteration
- **Lessons learned from islands work to date**
  - USVI and Hawaii
  - Aruba, Barbados, Canary Islands
- **Downloadable worksheets and templates**
  - Community organizing tools, such as stakeholder and donor coordination matrices
  - Project management tools, such as a Risk Register and Strengths-Weaknesses-Opportunities-Threats matrix

www.energy.gov/islandsplaybook

Playbook Themes

- **Focus on people**
  - Engaging stakeholders proactively
  - Empowering the community to set vision
    - Not just the government and not just the utility
  - Developing human capital
    - Effort not dependent on one administration or one person
- **Focus on projects**
  - Identifying near-term actions that support long-term goals
  - Tracking progress to maintain momentum
  - Improving execution for the next project(s)

Based on experience of USVI and Hawaii

- **Hawaii Energy Goal from 2009:** 70% clean energy goal by 2030, with 40% renewable and 30% efficiency
  → Recently increased to 100% by 2045

- **Hawaii Success Indicators:**
  - Met its 2015 renewable electricity target two years early
  - 226 MW oil-fired generation is scheduled for retirement by 2016
  - Doubled the percentage of electricity supplied from renewable resources

For more background info:
http://www.hawaiicleanenergyinitiative.org

Hawaii Energy Leadership

Google

postcard from the future energy

Web | Images | Videos | Shopping | News | More | Search tools

About 932,000 results (0.53 seconds)

A Postcard from the Future? | EnergyBiz
www.energybiz.com/magazine/article/404561/postcard-future
HAWAII IS UNDERGOING an **energy** transformation that has been described as a **postcard from the future**, and many people are working hard to ensure that the ...

NEWS: Hawaii's Advanced Energy "Postcard From the Future"
blog.aee.net/news-hawaiis-advanced-energy-postcard-from-the-future
May 1, 2015 - his week, let Advanced **Energy** Perspectives take you on a Hawaiian vacation… or, well, we'll discuss the changes in Hawaii's **energy** mix and ...

What comes after net metering: Hawaii's latest postcard from ...
www.utilitydive.com/news/what...postcard-from-the-future/407753/
Oct 22, 2015 - The Hawaii Public Utilities Commission closed retail rate net **energy** ... to as **postcards from the future** because the high penetration of solar on ...

Postcard from the future: 122% wind power in Denmark ...
www.aweablog.org/postcard-from-the-future-122-wind-power-in-denma...
To champions of renewables, this is validation that a clean **energy future** is possible and that the transition is already underway. These regions also give insight ...

Renewable Energy Future Postcard | Energy
energy.agwired.com/2015/10/07/renewable-energy-future-postcard/
Oct 7, 2015 - The Institute for Local Self-Reliance (ILSR) has released a new paper, "Hawai'i at the **Energy** Crossroads". The report highlights the fight in ...

Hawaii's latest postcard from the future : energy - Reddit
https://www.reddit.com/.../energy/.../hawaiis_latest_postcard_from... Reddi
Oct 24, 2015 - discussions in /r/**energy**. <>. X. 10 points. Chinese ... Hawaii's latest **postcard from the future** (utilitydive.com). submitted 22 hours ago by zipzag.

Postcard from the Future: Hawaii | America's Power Plan
americaspowerplan.com/2013/08/hawaii/
But its island environment — from sunny days to active volcanoes — also holds the keys to a **future** powered by renewable **energy**. Oil powers all of Hawaii's ...

Utility DIVE | TOPICS | FEATURES

What comes after net metering: Hawaii's latest postcard from the future

Hawaii regulators offered two new remuneration schemes for rooftop solar in a landmark decision last week

By Herman K. Trabish | October 22, 2015 print

Images for postcard from the future energy | Report images

Hawaii Postcards

Recent Islanded System Work

“Advanced Grid-Friendly Controls Demonstration Project for Utility-Scale PV”

- National Renewable Energy Laboratory
- Funded by Solar Energy Technologies Office
- Conclusion: AES Ilumina PV (Guayama) plant can provide Automatic Generation Control, frequency response *faster than synchronous generators*, and voltage droop support to PREPA’s grid, with existing hardware and proper communication protocols
- http://www.nrel.gov/docs/fy16osti/65368.pdf

Advanced Grid-Friendly Controls Demonstration Project for Utility-Scale PV

Figure 32. Snapshot of PREPA's AGC units—no conventional units are selected.
Image from PREPA

During a significant amount of the test period over a few days, AES PV was the only plant participating in AGC

Recent Islanded System Work

“Optimization of a Virtual Power Plant to Provide Frequency Support”

- Sandia National Laboratory
- Funded by Solar Energy Technology Office
- Conclusion: **Solar PV can reduce cost of grid operations** by reducing O&M of synchronous generators, even when compensating for curtailment ($20k/day savings using PV as reserves for FW22 on Lanai, Hawaii)
- **http://prod.sandia.gov/techlib/access-control.cgi/2015/1511070r.pdf**

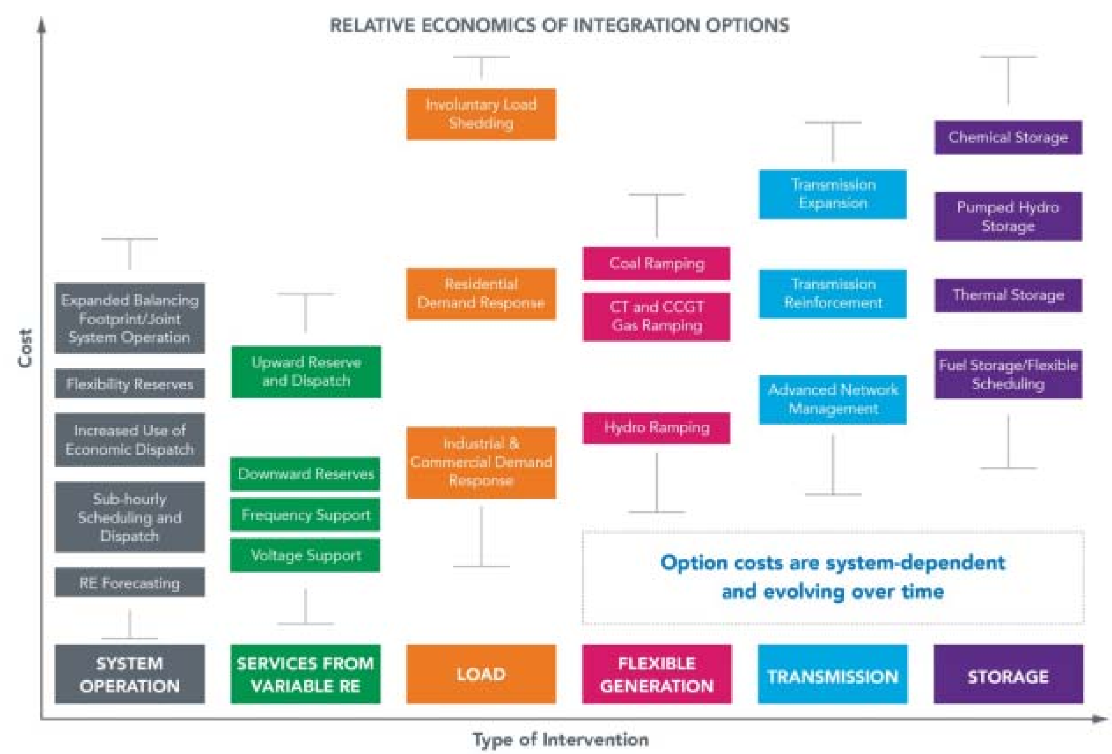
Recent Mainland System Analysis

“Do We Really Need Storage…?”

- **NREL PPT**

Short answer: Yes

Flexibility Supply Curve Concept

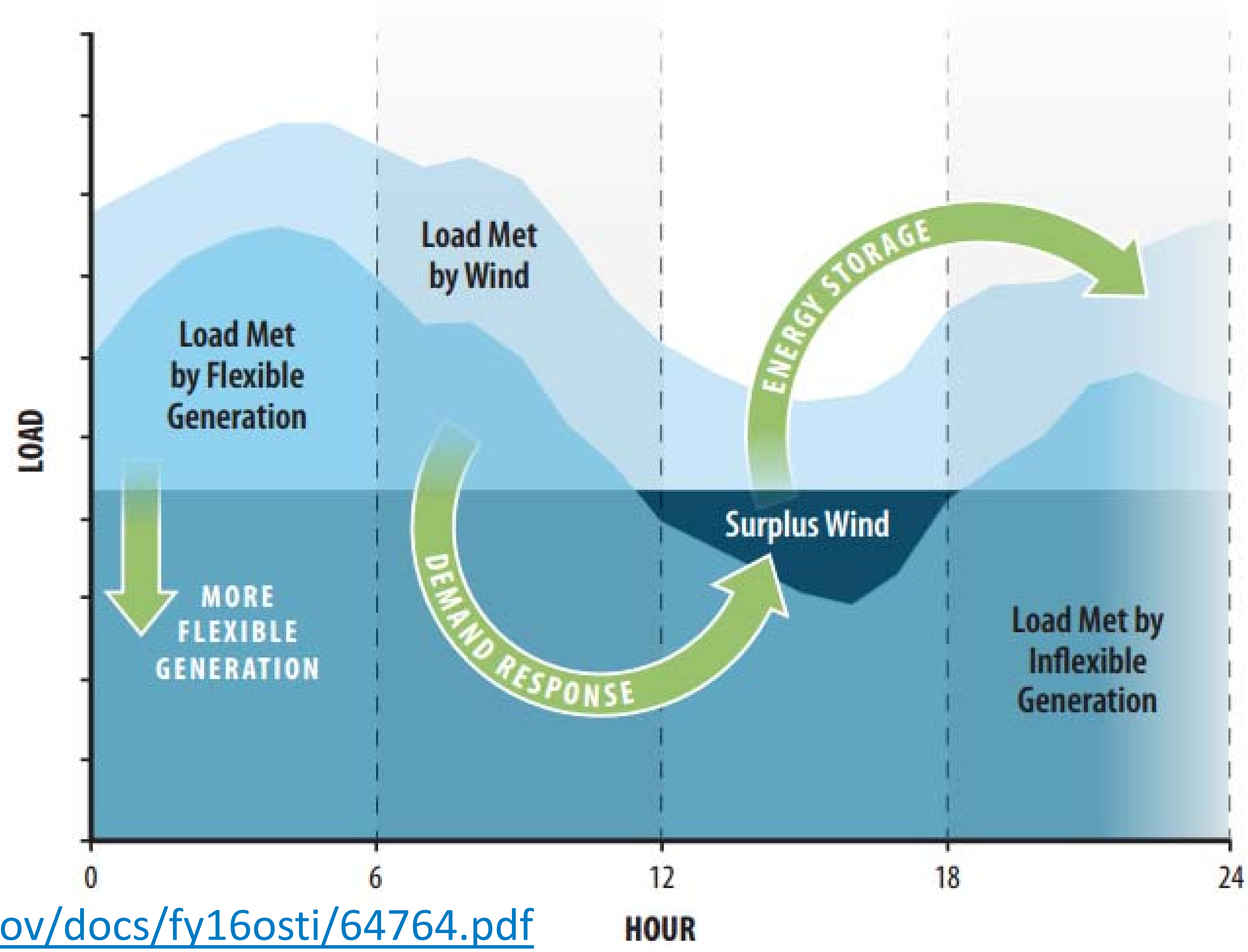


http://www.nrel.gov/docs/fy16osti/66104.pdf

Recent Mainland System Analysis

“Energy Storage Analysis Insights”

- **NREL**



http://www.nrel.gov/docs/fy16osti/64764.pdf

Recent Mainland System Analysis

“Operational Benefits of Meeting California’s Energy Storage Targets”

- NREL
- “Overall, the mandated storage requirement of 1,325 MW was estimated to reduce the total cost of production by up to $78 million per year in the base 33% scenario and $144 million per year in the base 40% scenario.”
- “Between 29% and 67% of these avoided costs in the base cases are due to avoided generator startup costs.”
- “Storage value is contingent on components of electric power markets that are relatively small contributors to aggregate market costs”
- **Higher penetrations of solar increased value of storage – By 2X**
- http://www.nrel.gov/docs/fy16osti/65061.pdf

Recent Storage Market Barriers Work

"DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA"

- Sandia National Lab, EPRI, NRECA
- How-to guide for electric systems engineers/planners, vendors, and investors to aid in the selection, procurement, installation, and/or operation of stationary energy storage systems.
- Relied on input from a variety of stakeholders to ensure different aspects of storage could be presented to different stakeholders: generators and system operators, load-serving entities (LSEs), and customers
- http://prod.sandia.gov/techlib/access-control.cgi/2015/151002.pdf

Recent Storage Tech Work

"Demonstration of Isothermal Compressed Air Energy Storage to Support Renewable Energy Production"

- National Energy Technology Lab
- 1.5MW ICAES Commercial-scale prototype using foam-based heat transfer, operational since Sept. 2013. Relied on mostly commercially-available parts to achieve relatively low CLOE (under $0.02/kWh), high cycle efficiency (>50%). Standby to full power response is 10 seconds, can applied in both generation and transmission.
- http://www.osti.gov/scitech/servlets/purl/1178542

Recent Storage Modelling Work

"Technoeconomic Modeling of Battery Energy Storage in SAM"

- NREL
- Lead-acid and lithium-ion battery models added to the free, publically available System Advisor Model, which focuses on PV systems.
- http://www.nrel.gov/docs/fy15osti/64641.pdf

"Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems"

- PNNL & SNL
- Provides basis for assessing how an ESS will perform with respect to key performance attributes relevant to different applications.
- It is intended to provide a valid and accurate basis for the comparison of different ESSs.
- http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22010Rev2.pdf

Questions and Discussion

Islands Playbook Website:
www.energy.gov/islandsplaybook

ETI web-site: energy.gov/eere/technology-to-market/energy-transition-initiative

Island Energy Snapshots:

energy.gov/eere/about-us/island-energy-snapshots

Stephen Walls

Stephen.Walls@ee.doe.gov

Supporting Hawaii's Clean Energy Transformation

Chris Yunker

Energy Systems & Planning Branch Manager
Hawaii State Energy Office
Department of Business, Economic Development, and Tourism

HCEI Public Stakeholder Meeting

Jun 24, 2016

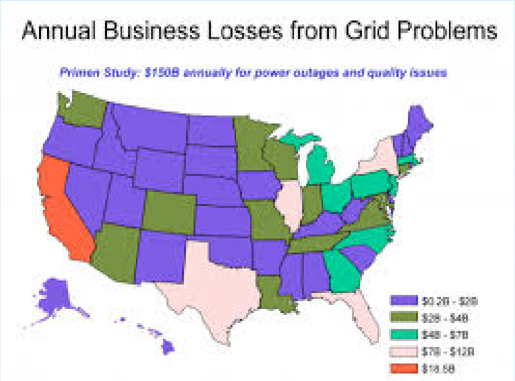
Pricing Implications of (DER) Battery Storage

- DER technology has effectively unbundled the services that utility provide
- However, energy pricing has not kept up with technological innovation
- Pricing reform needs to accelerate such that technology will be deployed and utilized to lower total costs for all customers

Utility Services

- Energy
  - To power your appliances

- Reliability
  - There when you need it
  - Balancing energy supply and demand



- Power Quality
  - So your equipment won't fry

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HAWAII STATE Energy Office

The Fixed Costs of Reliability and Power Quality

- Generation Capacity
  - The physical asset that generates electricity

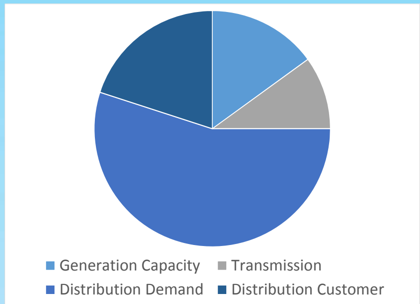
- Transmission
  - Bulk power movement

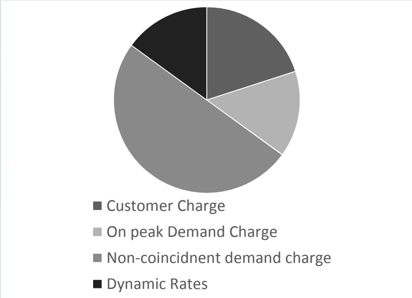
- Distribution Demand
  - Local delivery network

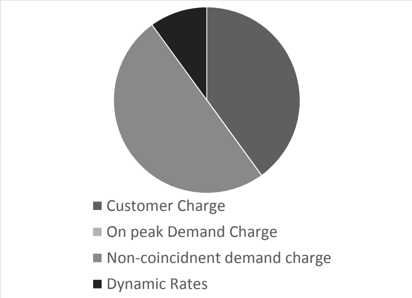
- Distribution Customer Costs
  - The last mile of delivery, meters, call centers, etc.

Fixed Cost Recovery Alternatives

- Customer Charge ($)
  - $/month (a per customer charge)
  - Minimum Bill (bill price floor)
- Demand Charges ($/kW)
  - On peak (i.e. 4 p.m. to 9 p.m.)
  - Non-coincident (your personal peak demand)
  - Ratchets (minimum level of demand charged based on historical usage)
- Dynamic Pricing ($/kWh)
  - System (price adders for times when the system peaks)
  - Distribution (price adders for times when circuits or feeders peak
  - Oversupply (price discounts during periods of oversupply/curtailment)







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Encouraging Efficient Utilization of DER

<u>Avoiding Future Infrastructure Investments</u>

1. Create Market Opportunity
   - Develop and Deploy Pricing
2. Market Deployment
   - Suppliers create value proposition for customers and move product
3. Load Modification Reflected in Forecast
   - Either through change in customer historical use or forecast of product adoption
4. Investments are Deferred or Avoided
   - RFPs reflects reduced capacity or avoided altogether

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Managing Complexity with Customer Choice

- Fully Bundled Customers
  - Option available for a fully bundled rate

- Customers Self Providing Services

Option of sophisticated rate to maximize the realization of value from their DER by themselves or technology supplier

<u>A Question in front of PUC in DER Docket</u>

What is the level of pricing sophistication necessary for customers who self provide a portion of their own energy service needs to enable efficient DER adoption while ensuring equity in customer cost responsibility?

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Creating the Market Opportunity

Enablement of Price Signals

- Developing Price Signals
  - Data to assign costs to a rate component
- Sending Price Signals
  - Providing the price information to customers
- Billing Price Signals
  - Collecting customer usage data
  - Back office accounting to create a customer bill

Mahalo

Chris Yunker

HAWAII STATE
Energy Office

energy.hawaii.gov

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STATE OF HAWAII • DEPARTMENT OF BUSINESS, ECONOMIC DEVELOPMENT & TOURISM
HAWAII STATE
Energy Office

Hawaii Natural Energy Institute

School of Ocean and Earth Science and Technology
University of Hawaii at Manoa
Rick Rocheleau, Director

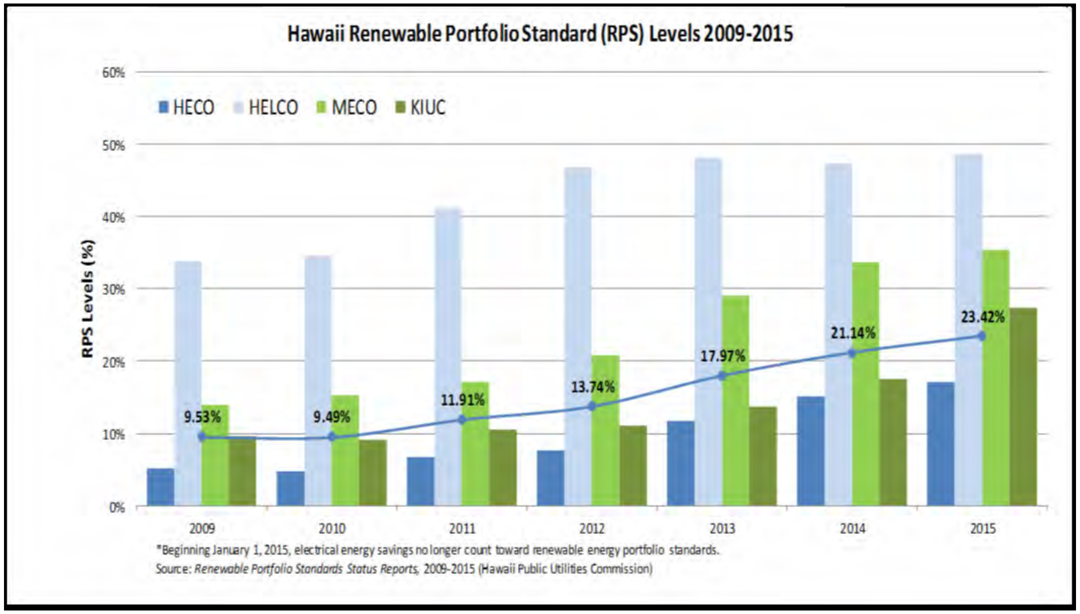


HCEI Public Stakeholder Meeting
Energy Storage
June 24, 2016

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

Hawaii Renewable Portfolio Standard

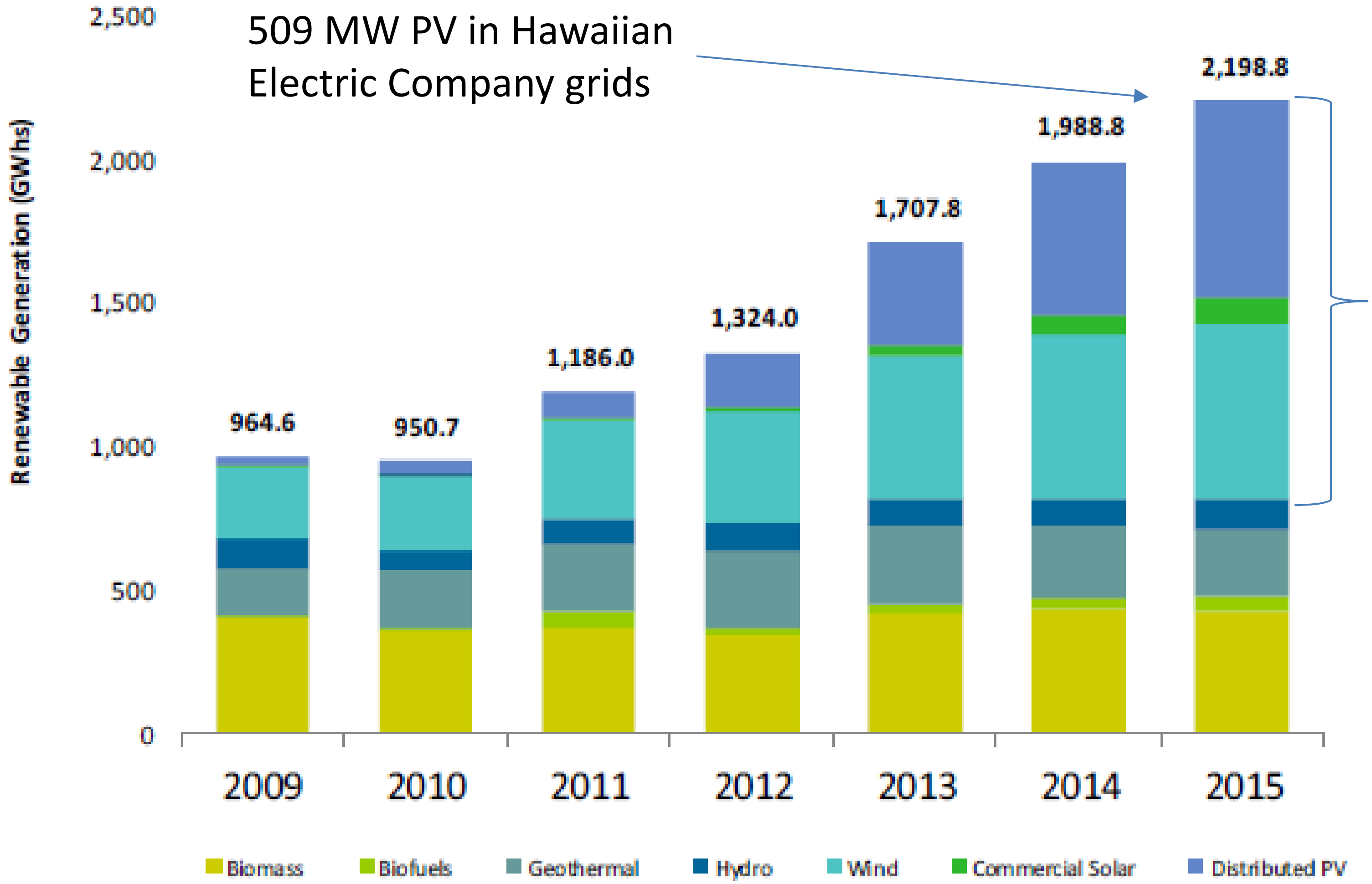
30% by 2020 → 40% by 2030 → 70% by 2040 → 100% by 2045



Hawaii Energy Efficiency Portfolio Standard

- 4,300 GWh of electricity savings by 2030
- PUC set interim standards, for 2015, 2020, and 2025
- 2015 standard: 1,375 GWh in savings was exceeded

Renewable Energy Generation by Resource



Source: *Renewable Portfolio Standards Status Reports*, 2009-2015 (Hawaii Public Utilities Commission)

DBEDT Hawaii State Energy Office |Hawaii Energy Facts & Figures, May 2016

Great Progress But a Long Way to Go (Oahu)

Near Future (Oahu Only)

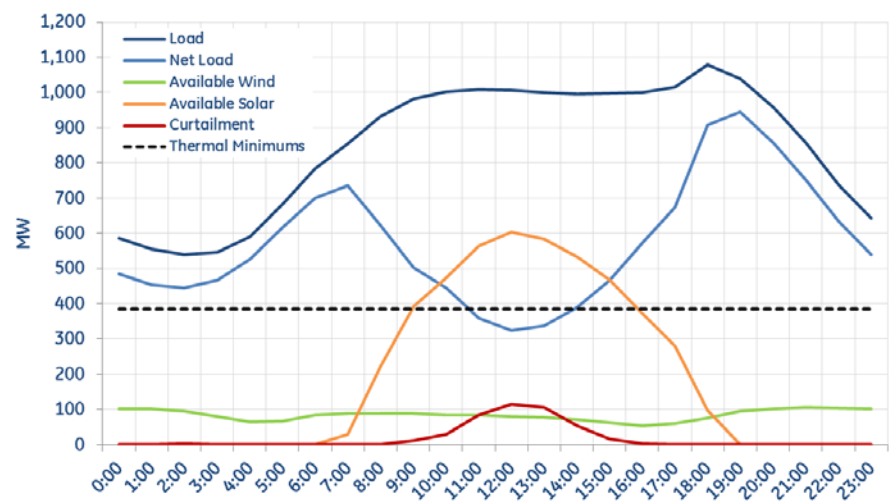
125 MW Wind (+25)	~383 GWh (~4.9%)
375 MW DPV (+20)	~591 GWh (~7.6%)
152 MW CPV (+137)	~293 GWh (~3.8%)
69 MW Waste	~390 GWh (~5.2%)
120 MW Biofuel	~36 GWh (~0.5%)
Total RE	~1696 GWh (~21.8%)

*Assumes no curtailment

375 MW of Distributed PV +152 CPV can be >50% of daytime load but contributes only ~11.5% of annual energy

100% RPS by 2045 will require

- Substantial increased renewable energy
- Very significant grid changes
- Novel operating strategies and mitigations

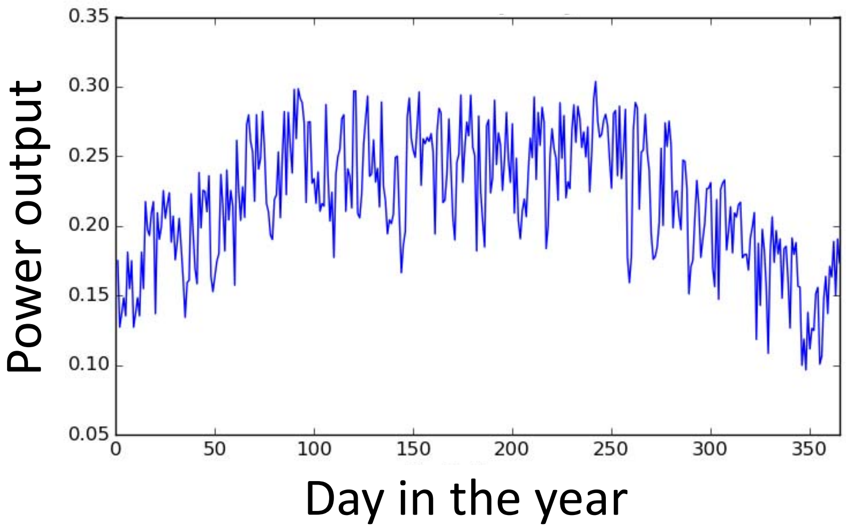


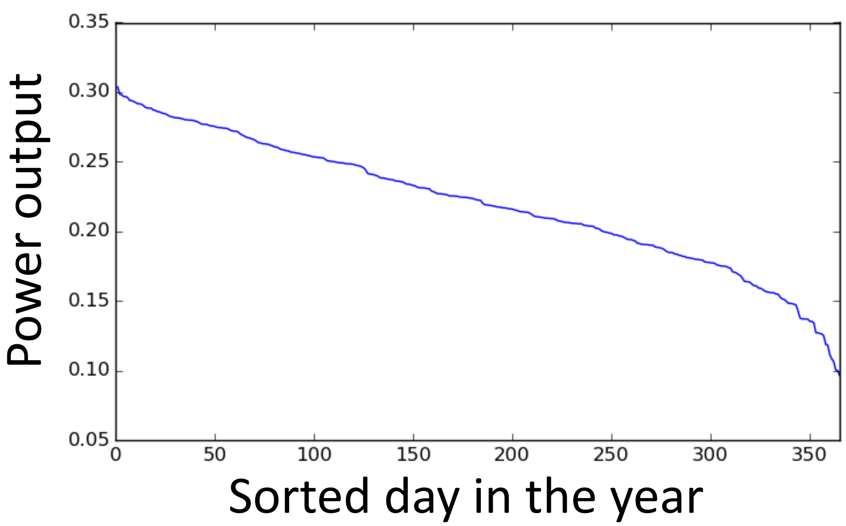
Variability and Curtailment

Wind and Solar Resources

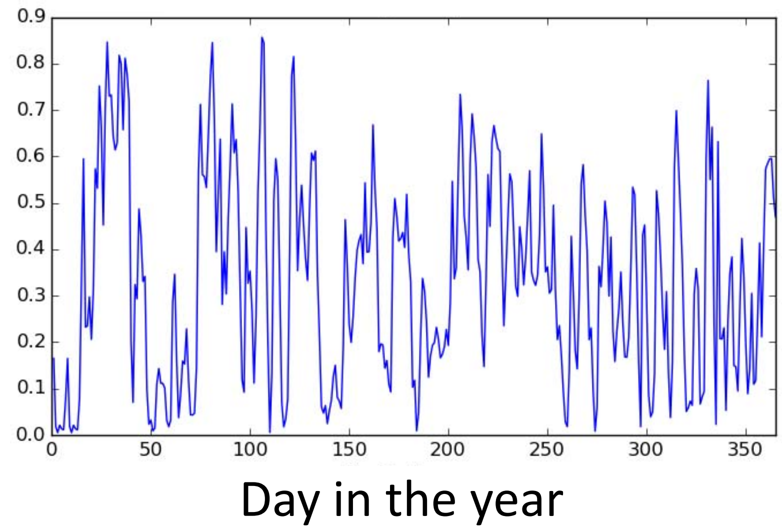
High day-to-day variation

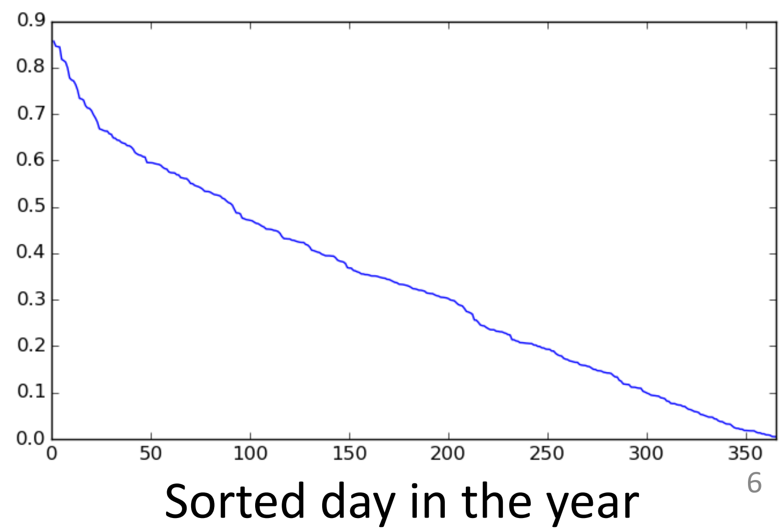
Solar





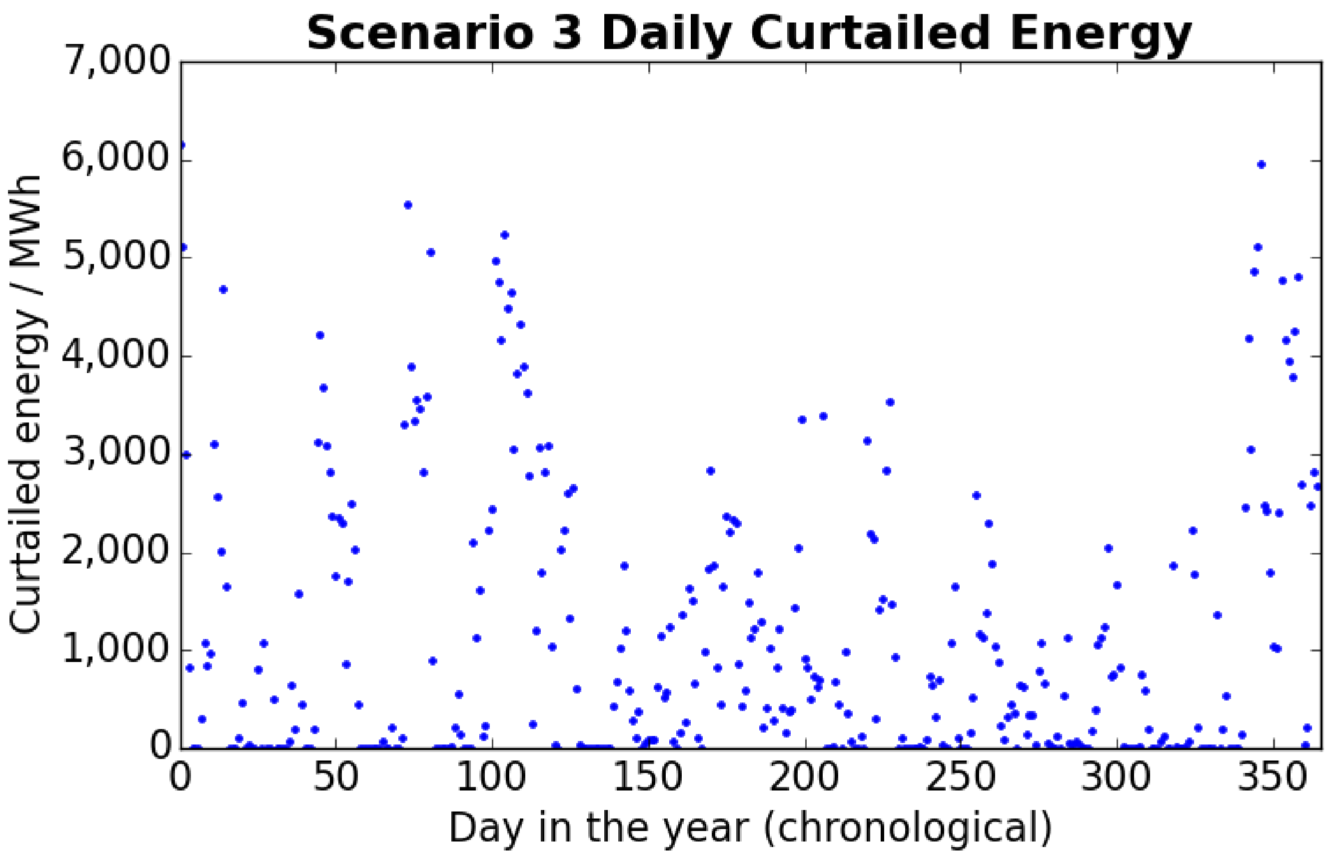
Wind





Curtailment Looks More Variable than Resource

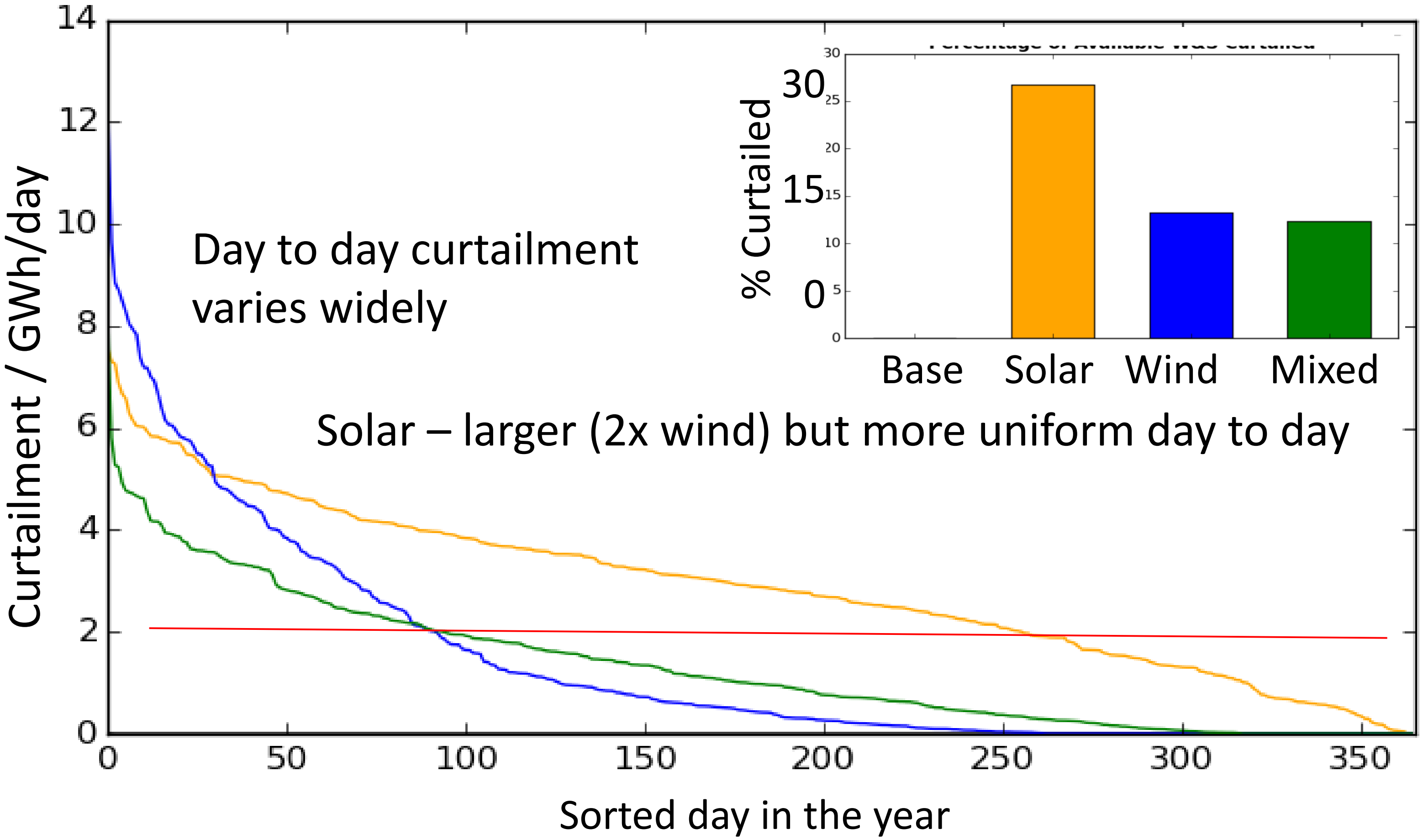
(Storage Needs Highly Variable Day to Day)



Numbers from Oahu model but illustrative only

Curtailment

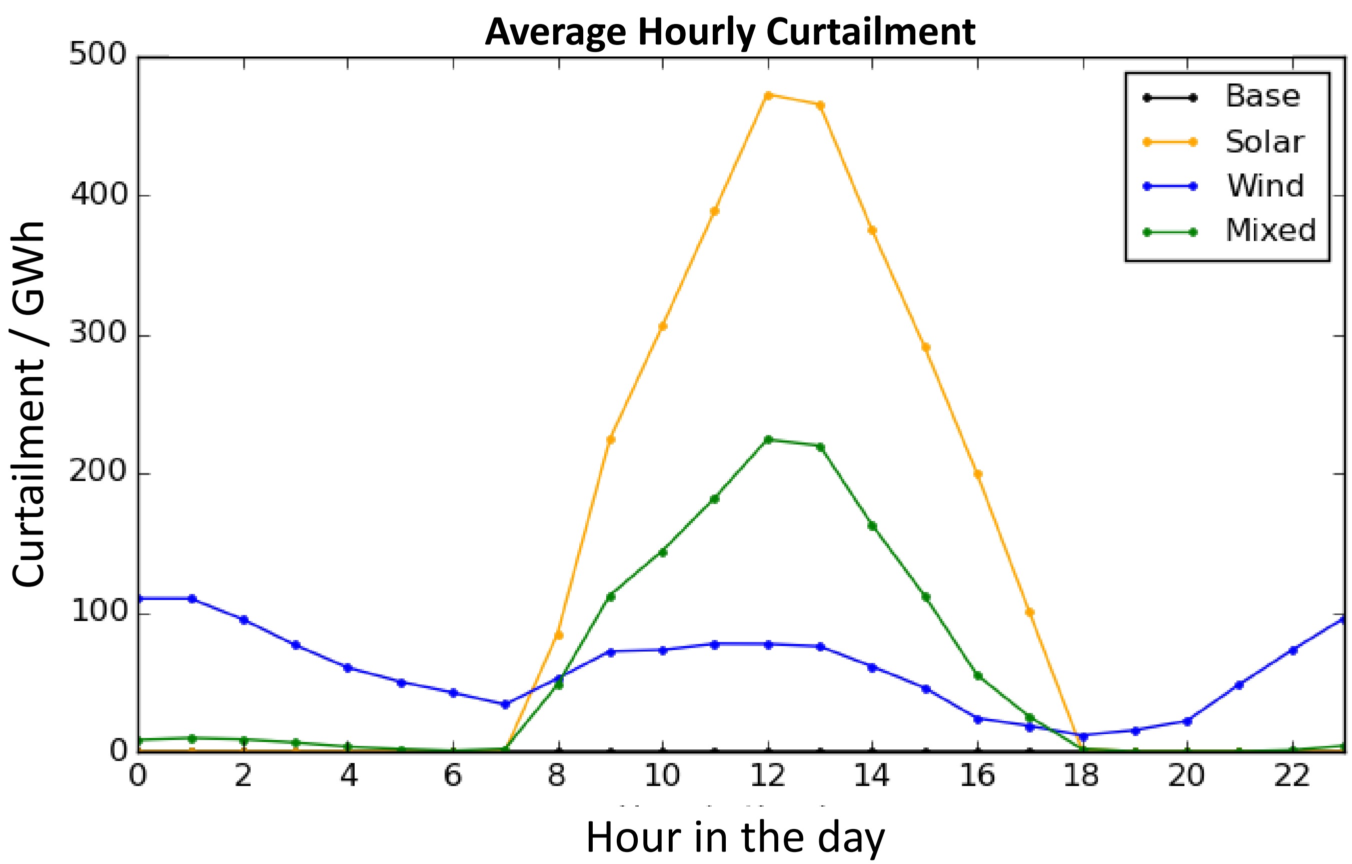
2016 plus wind and/or solar for 50% W&S availability on Oahu



Curtailment ranges from 0 to almost 10 GWh in any day

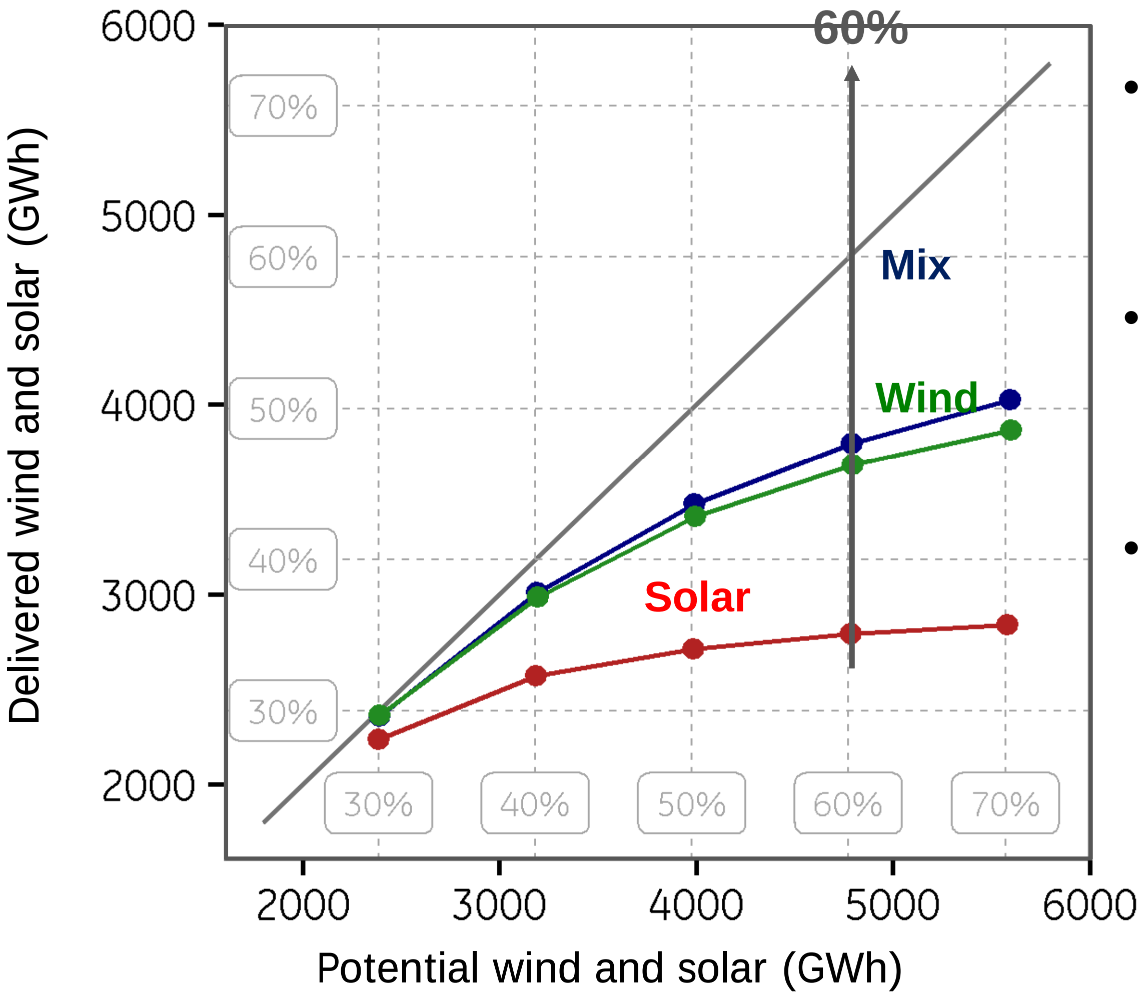
Curtailment by Hour of Day (ave)

- Solar: Large mid-day peak, none beyond midday
- Wind: Curtailment can occur at any and all hours
- Wind: Curtailment can continue for days or even weeks
- Mixed: Reduced daytime peak, nighttime curtailment reduced



Storage for Different Scenarios

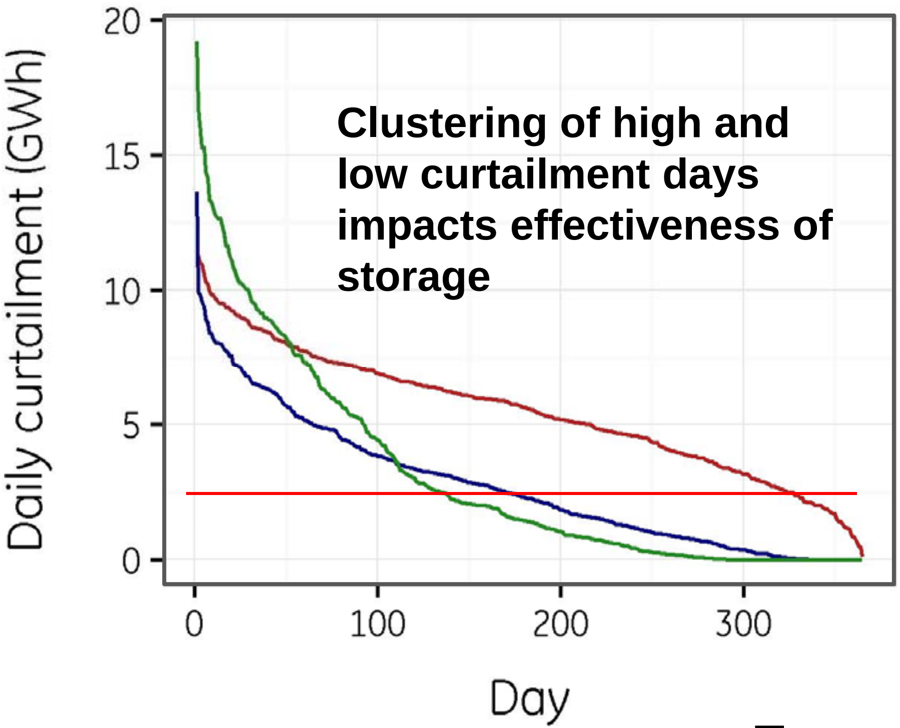
Curtailment at High Penetrations wo Storage (Oahu only)

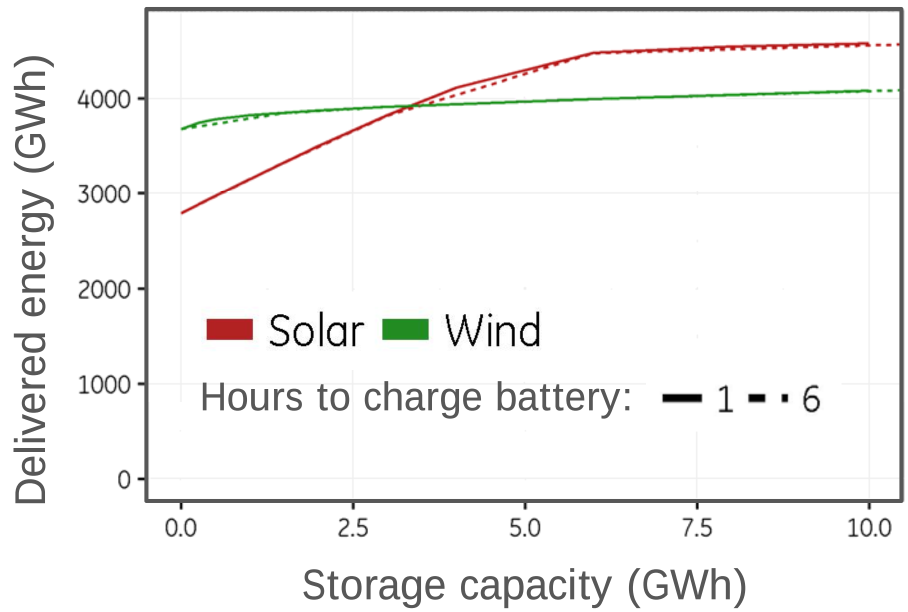


- **Curtailment a strong function of resource used**
- **Incremental curtailment increases significantly as penetration increases**
- **Incremental curtailment of solar approaches 100% at <40% penetration**

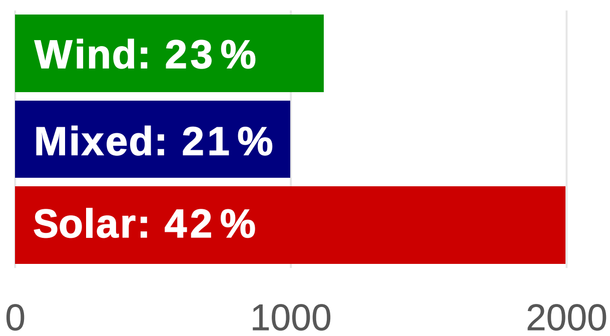
Effect of Storage on Curtailment

Advanced grid, 60% W&S penetration





Annual Curtailment (GWh):



- **<u>Energy</u> storage not effective for shifting curtailed wind**
- **Storage more effective for solar but more needed earlier**
- **Clustering of wind days has big effect**

Battery Energy Storage System Costs (partial)

Interconnection studies
Engineering and design
Battery
Battery system (incl inverter and controls)
Permitting
Site preparation
Installation/construction
Insurance
Warranties and service
Decommissioning
Recycle

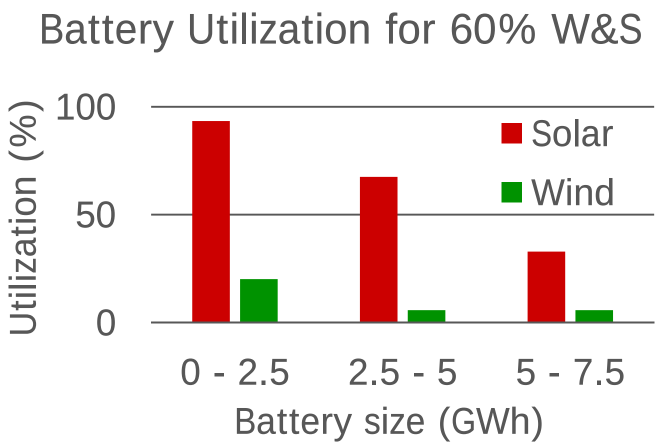
Cost of Captured Curtailment

- **Idealized curtailment capture/cost estimate**
  - Assume battery is cycled once per day at full capacity – a 1GWh battery would reduce annual curtailment by 365 GWh per year.
  - Assume 10% annual full cost recovery (cost of capital, lifetime)
  - 100% round trip efficiency

Installed cost of storage ($/kWh)	**$ 250**	**$ 500**	**$ 1000**
Additional cost of captured curtailed energy ($/kWh)	**0.07**	**0.14**	**0.28**

Other factors may increase cost significantly

- Lifetime < 20 years
- Storage "utilization" – resource and size dependent
- Round trip efficiency
  - H2: 30-40%
  - Pumped hydro: 60-75%
  - Chemical storage: 80-90%



HNEI Storage Projects

Grid Scale BESS Projects (HNEI)

Optimize BESS value to grid while maximizing battery lifetime

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

- Frequency regulation and wind smoothing

Molokai Secure Renewable Microgrid (2MW)

- Operating reserves, (fault management), frequency regulation, power smoothing, and peak shifting
- <50ms response

Campbell Park industrial feeder with high penetration (1MW)

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

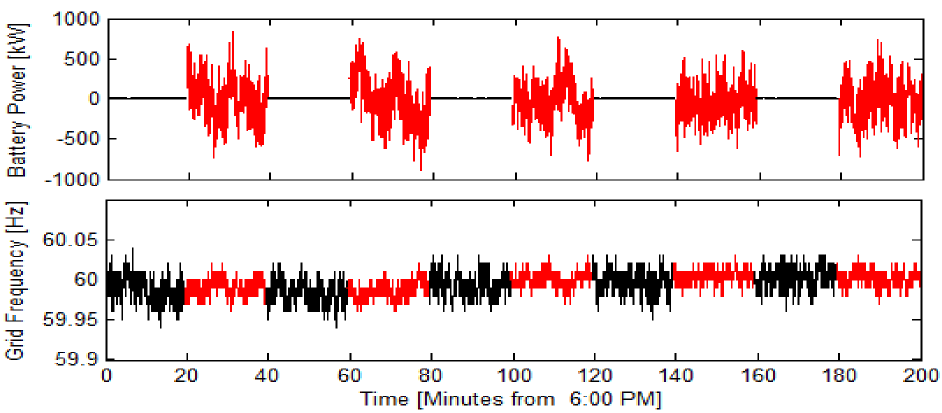
photos courtesy of Altairnano

HNEI is testing cells in the laboratory to determine expected lifetime under real world conditions

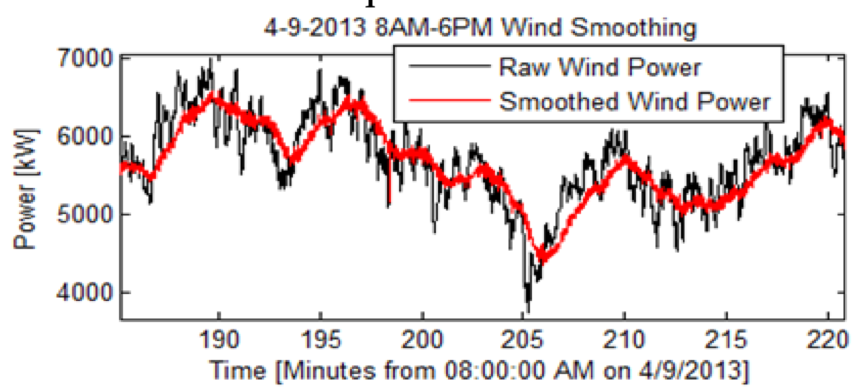
Hawaii Island BESS

- Fast response 1MW, 250kW-hr, nanostructed lithium titanate BESS
- System comprised of 2,688 Li-ion titanate 50 A-Hr cells
- 3 years of operation; >6000 full cycles
- Data collected over wide range of grid conditions with different operating algorithms

Reduces BI frequency variability by up to 40%



Wind smoothing helps meet PPA requirements



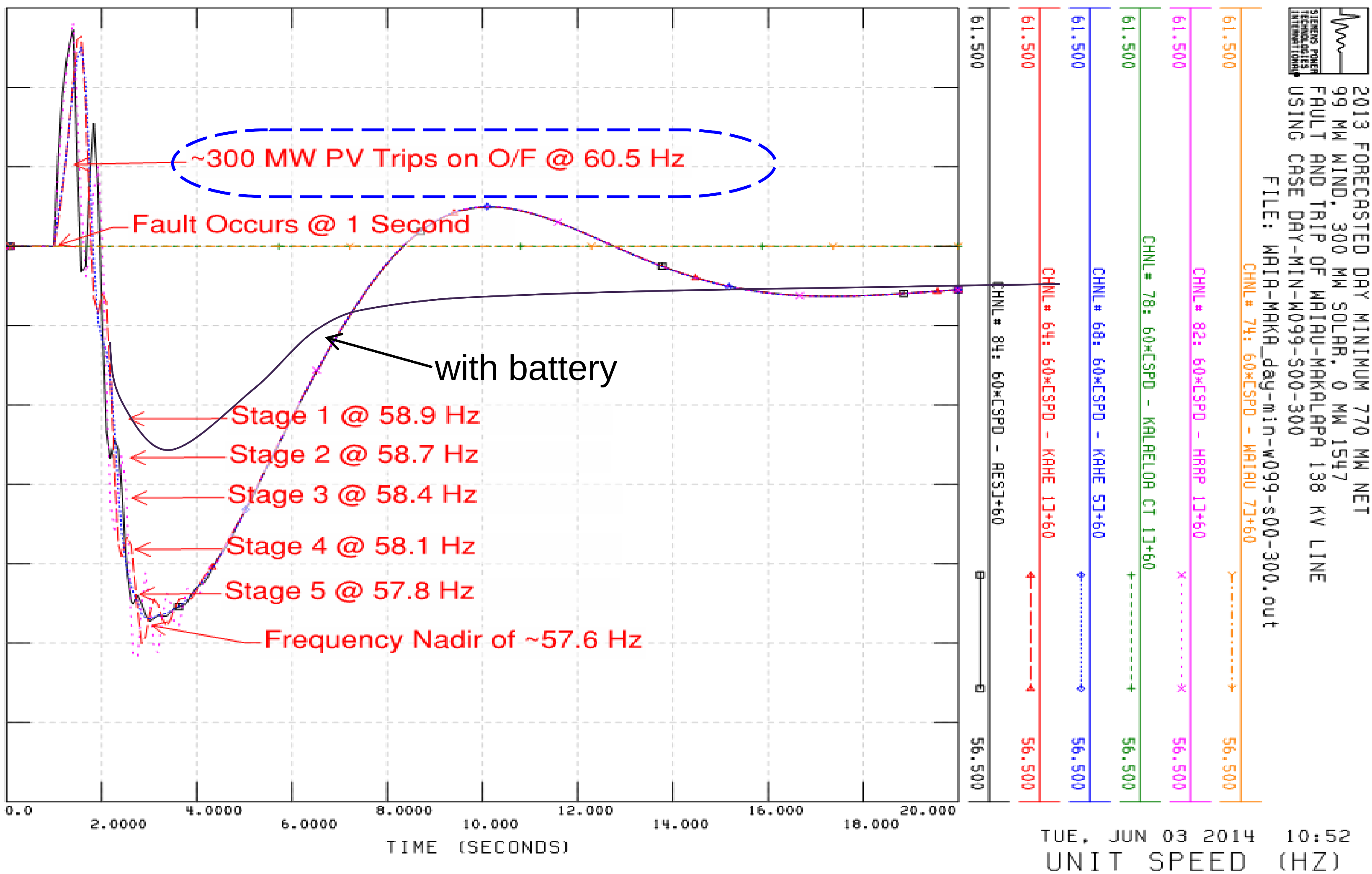
Gaining valuable understanding of grid impacts and lifetime

HNEI Hawai'i Natural Energy Institute

Hawaii Clean Energy Initiative Public Stakeholder Meeting

June 24, 2016

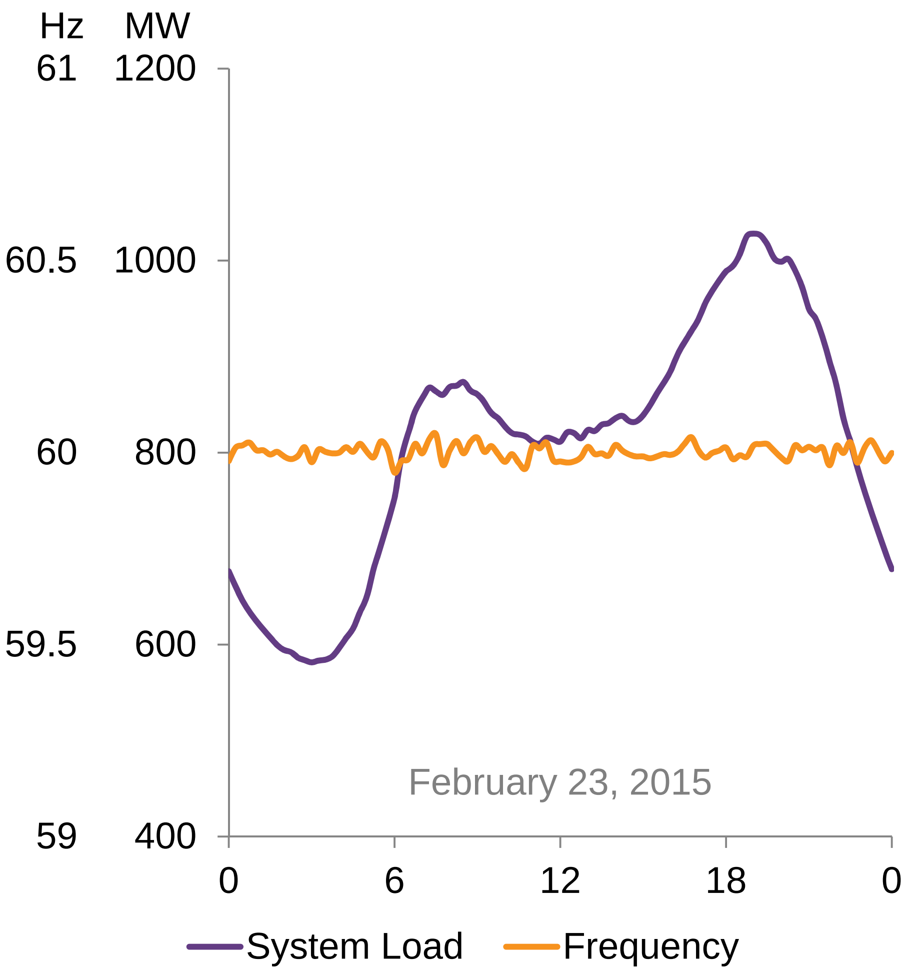
Battery energy storage can restore grid stability in a more renewable-based system



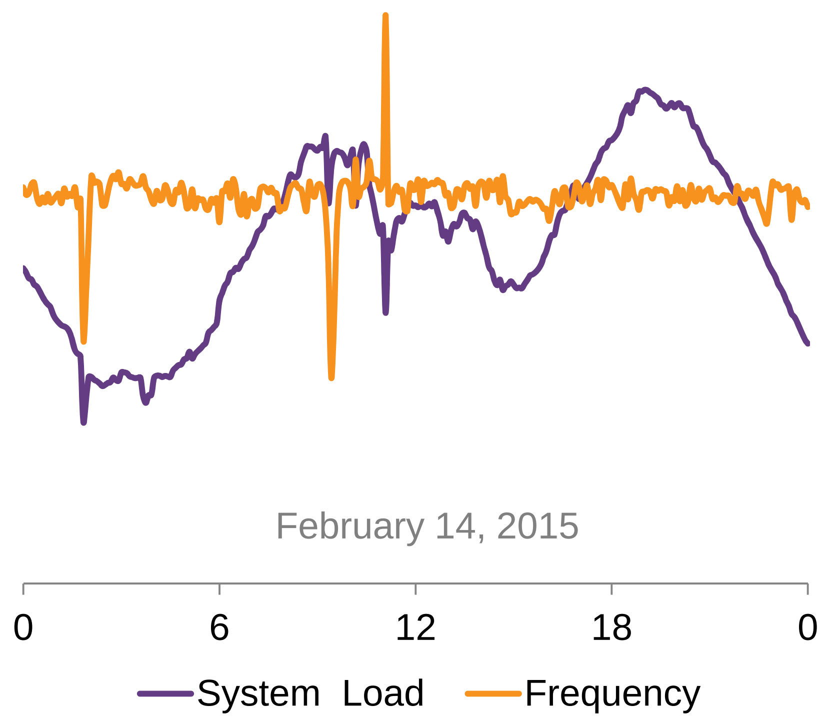
Hawaiian Electric
Maui Electric
Hawai‘i Electric Light

System loads are less predictable and more variable – another role for storage

O’ahu System – Typical Day



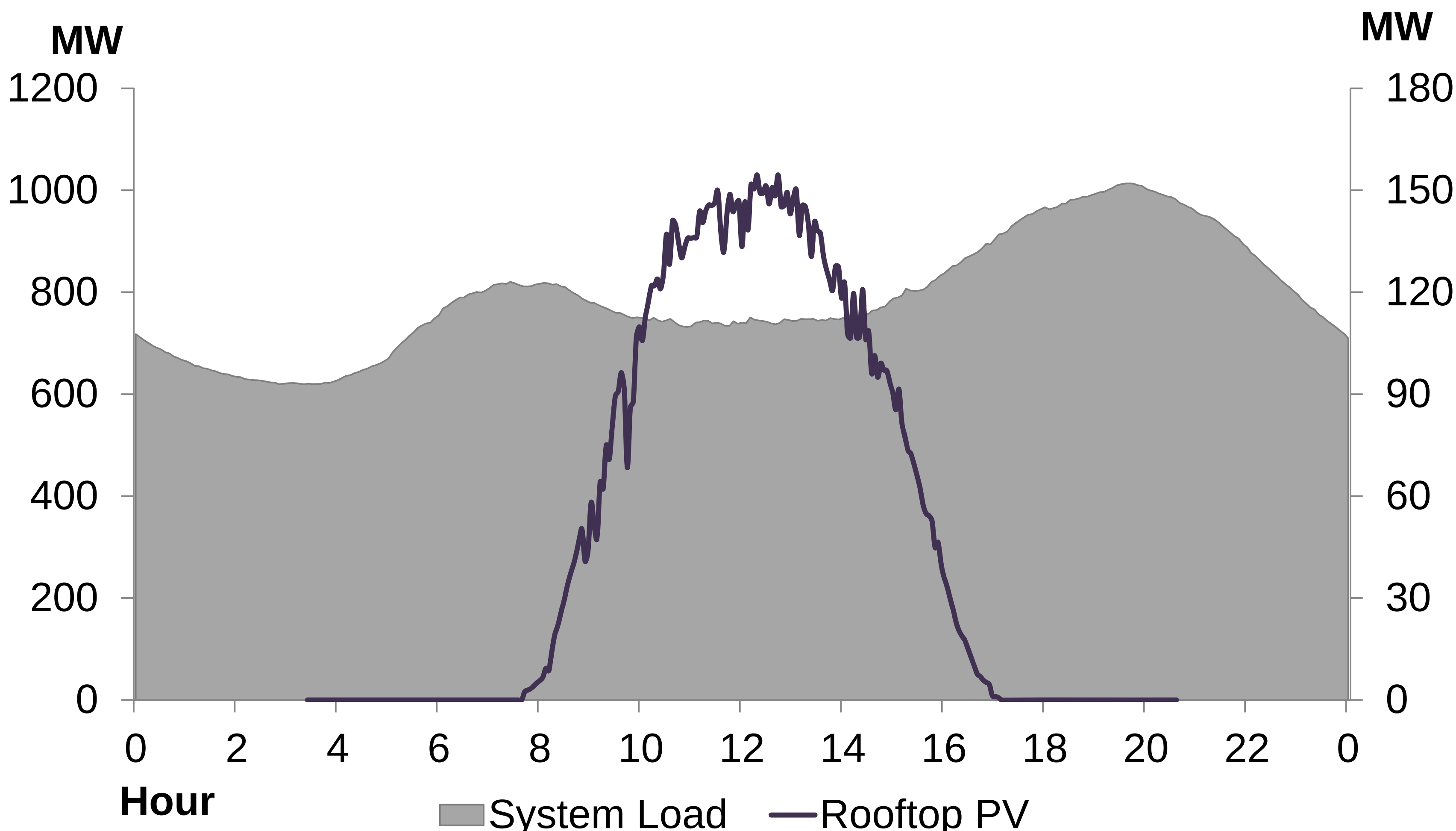
O’ahu System – Bad Day



Hawaiian Electric
Maui Electric
Hawai‘i Electric Light

x

Typical system load and solar profile – energy and load are not time-matched



June 7, 2016

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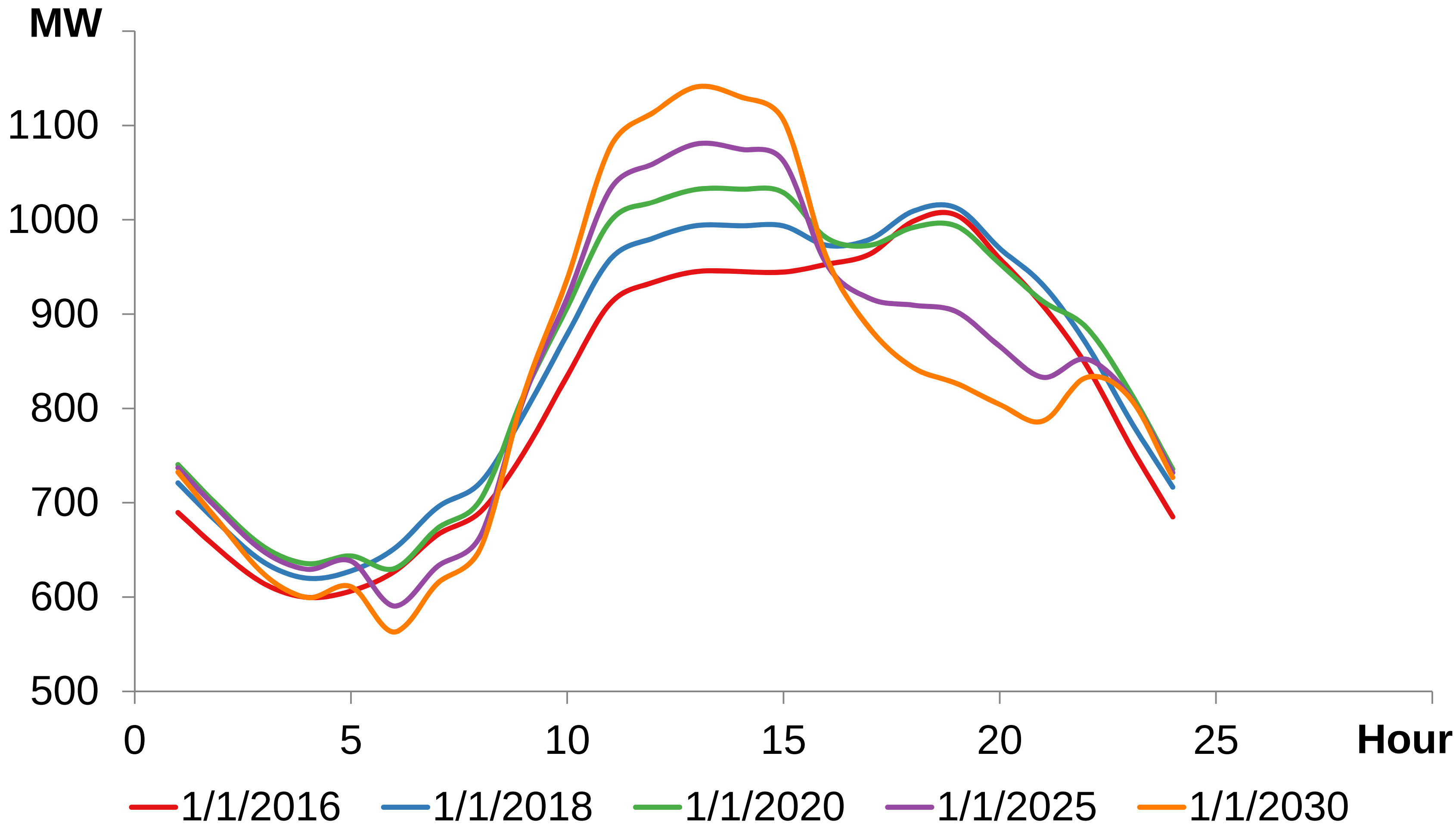
TOU rates and demand response can better align demand and PV production



Mahalo!


MAHALO
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