MAUI ENERGY
Conference + Exhibition

100% Renewable Energy in Hawaii:
It's No Longer A Matter of When

March 16 - 18, 2016 | Maui Arts & Cultural Center

Presented By:

MAYOR'S OFFICE OF ECONOMIC DEVELOPMENT MAUI COUNTY

INTEGRATION OF DISTRIBUTED ENERGY RESOURCES

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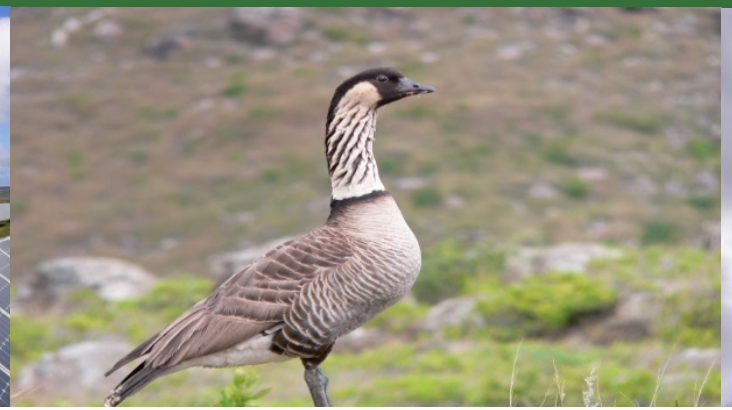
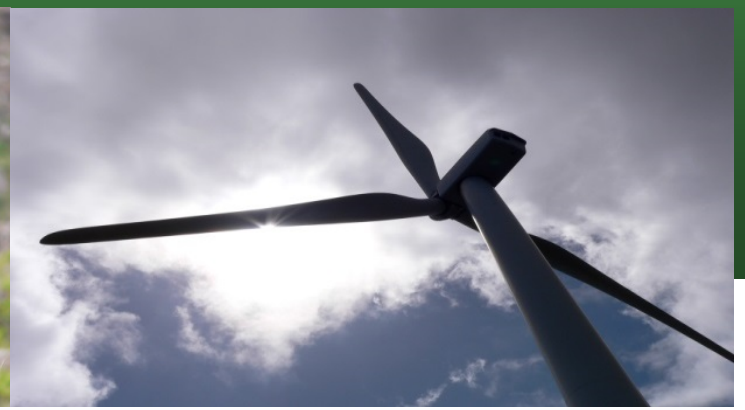

Integration of Distributed Energy Resources

Maui Energy Conference
March 17, 2016

HNEI
Hawai'i Natural Energy Institute
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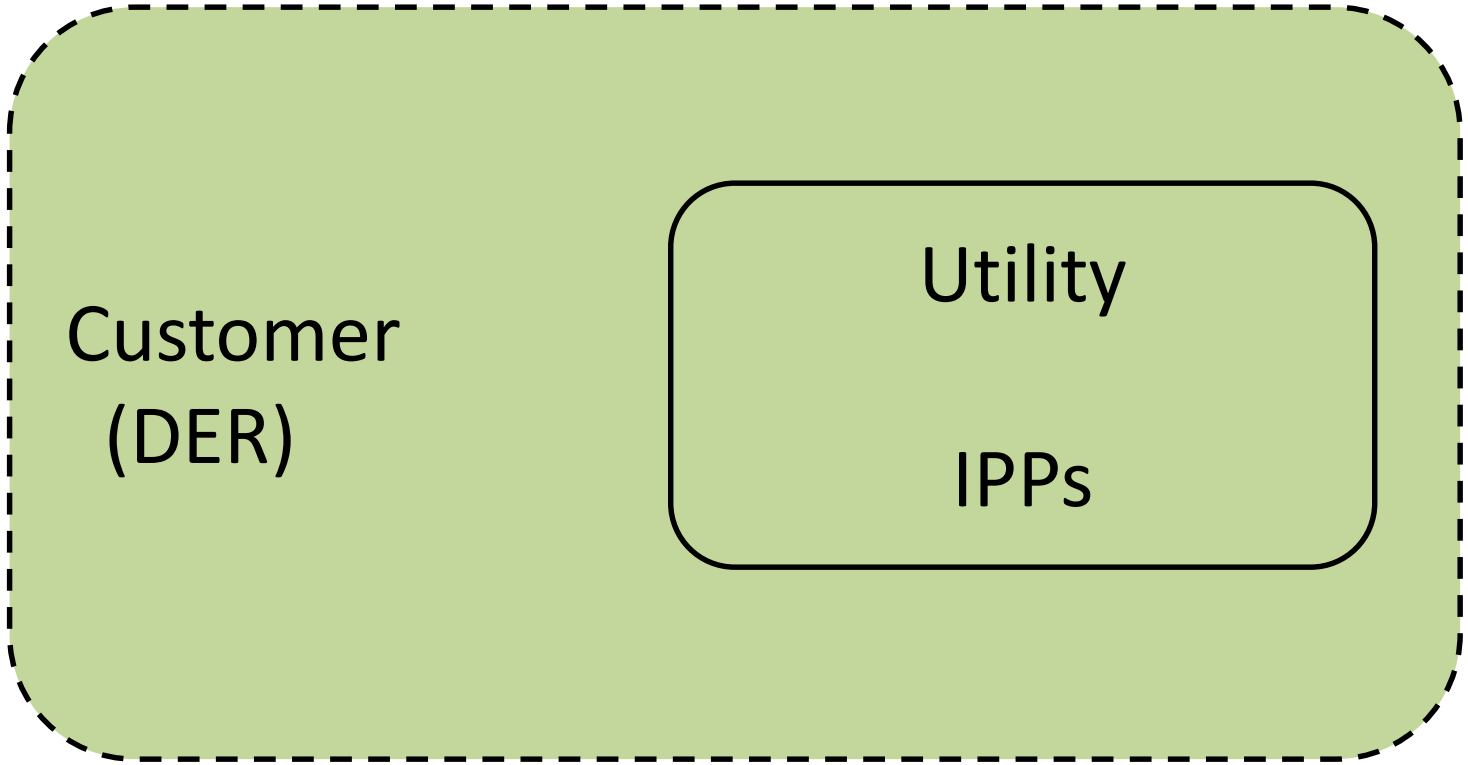
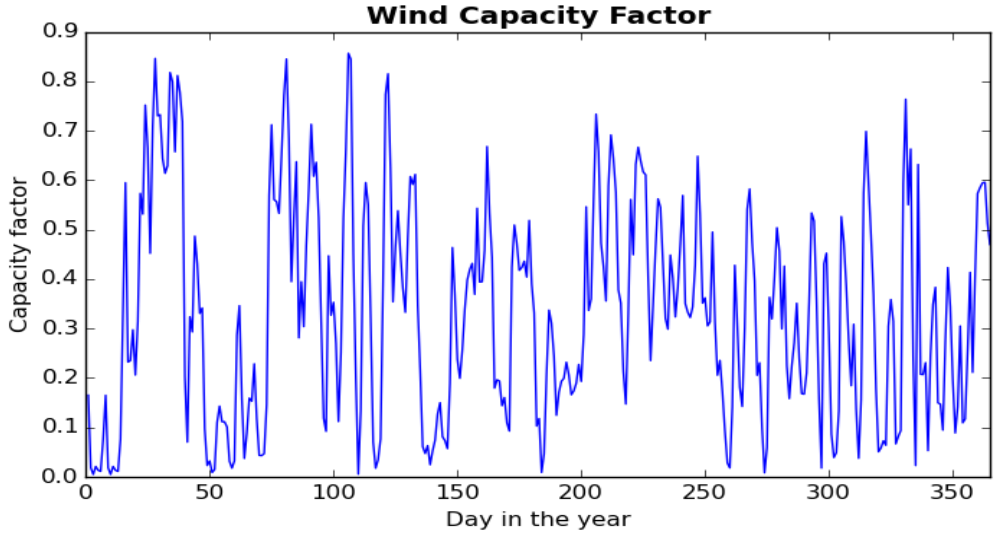
Optimization

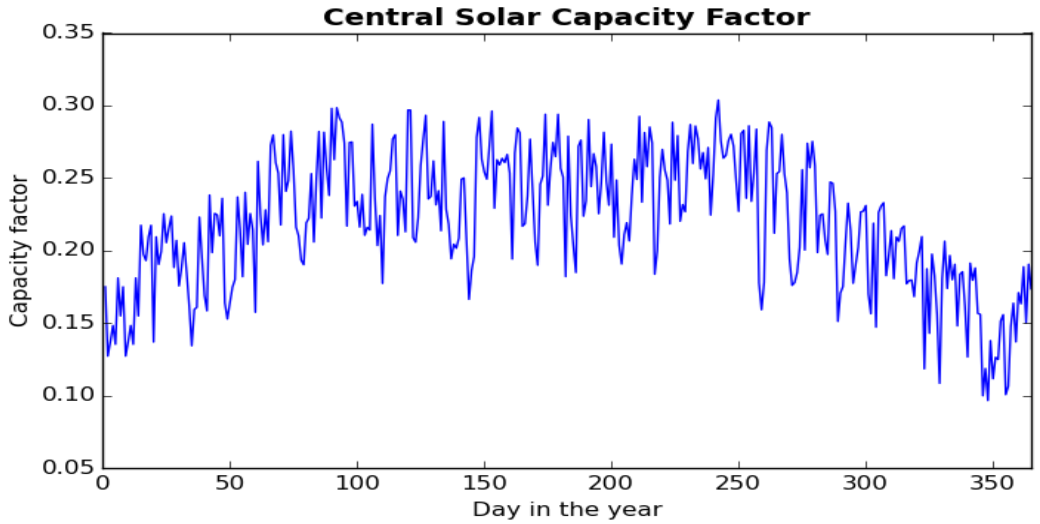


Wind and Solar Optimization
High Level Preliminary Analysis

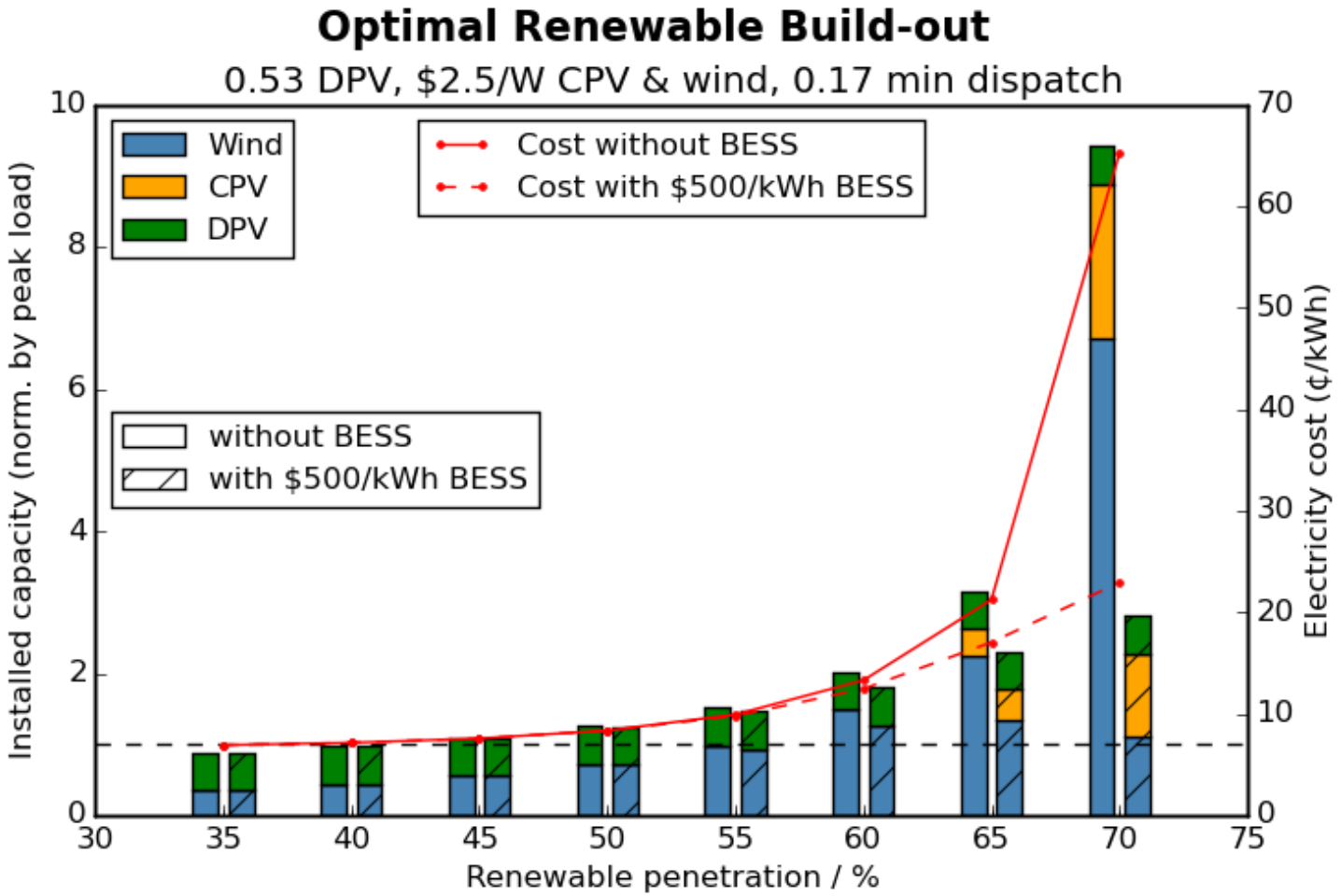
- High penetration scenarios (40 – 70%)
- Hourly production cost over a year
  - "Realistic" cost assumptions for storage, W&S
  - Simplified assumptions for thermal mins & DR
  - Cost sensitivities evaluated
- Optimize wind, solar & storage mix for different percentages delivered

Day-to-day Wind and Solar Variability



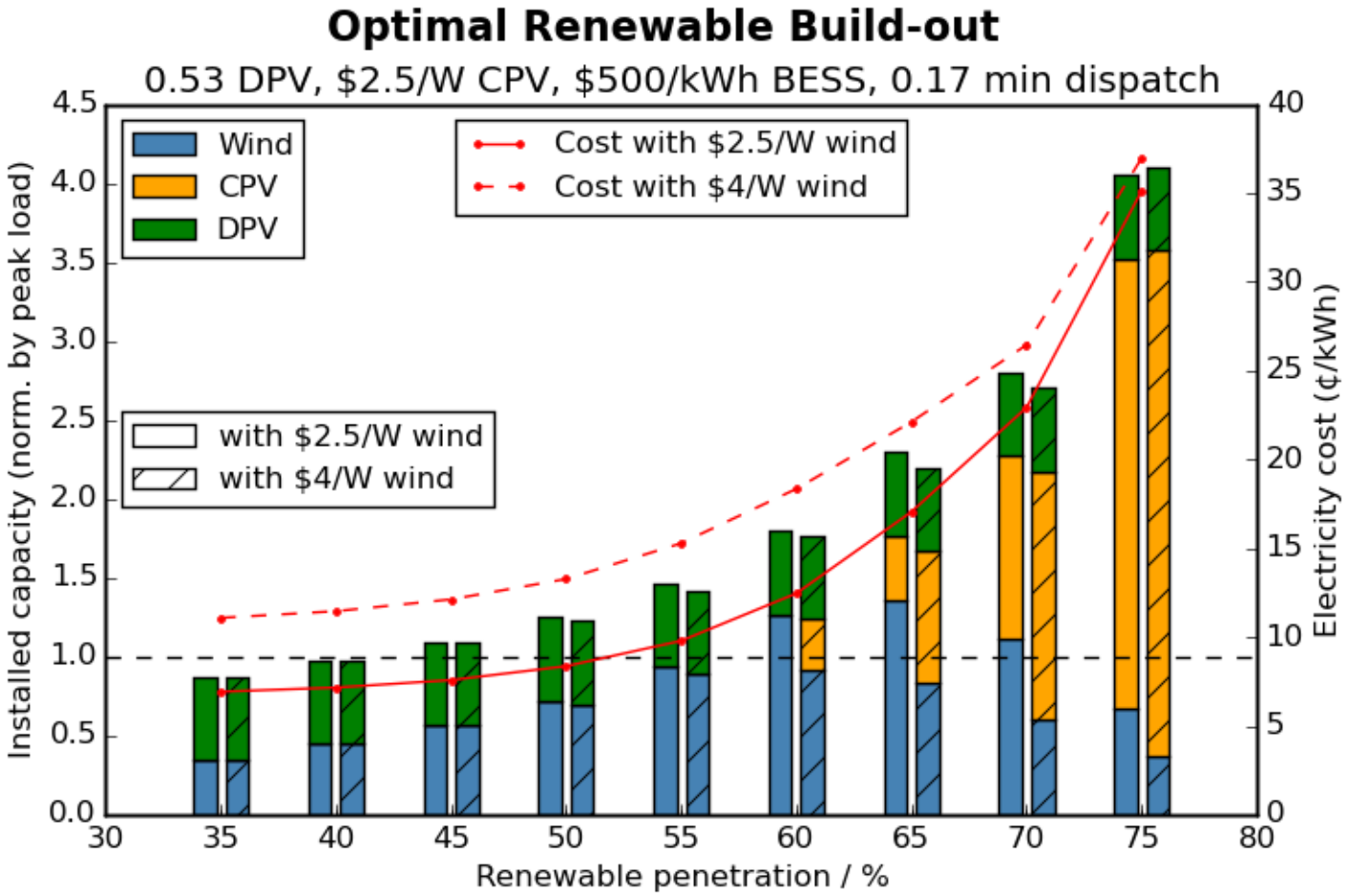


- Temporal differences occur at many different time scales - seconds to hours to days and even inter-annual
- Dispatchable resources (or load) must compensate for variability
- Day-to-day variability can be more difficult to manage than shorter periods



Identified trends applicable all islands

- Storage does little to address day-to-day wind variability
- Wind more cost effective at low to intermediate penetrations (0-60%)
- Solar with storage becomes more cost effective at higher penetrations



<u>Higher cost wind</u> – i.e offshore

Other sensitivities: storage cost, min. dispatch, with/without DPV, etc.

System Support from DER requires:

- Proper framework
  - Utility must be able to “see” and have some level of control over distributed resources
  - Good rate design would enable markets to help address challenges
- Technologies: develop and make cost effective
  - Storage
  - Smart inverters
  - Smart grid – communication/controls
  - Data and analytics

MAHALO

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INTEGRATION OF DISTRIBUTED RESOURCES

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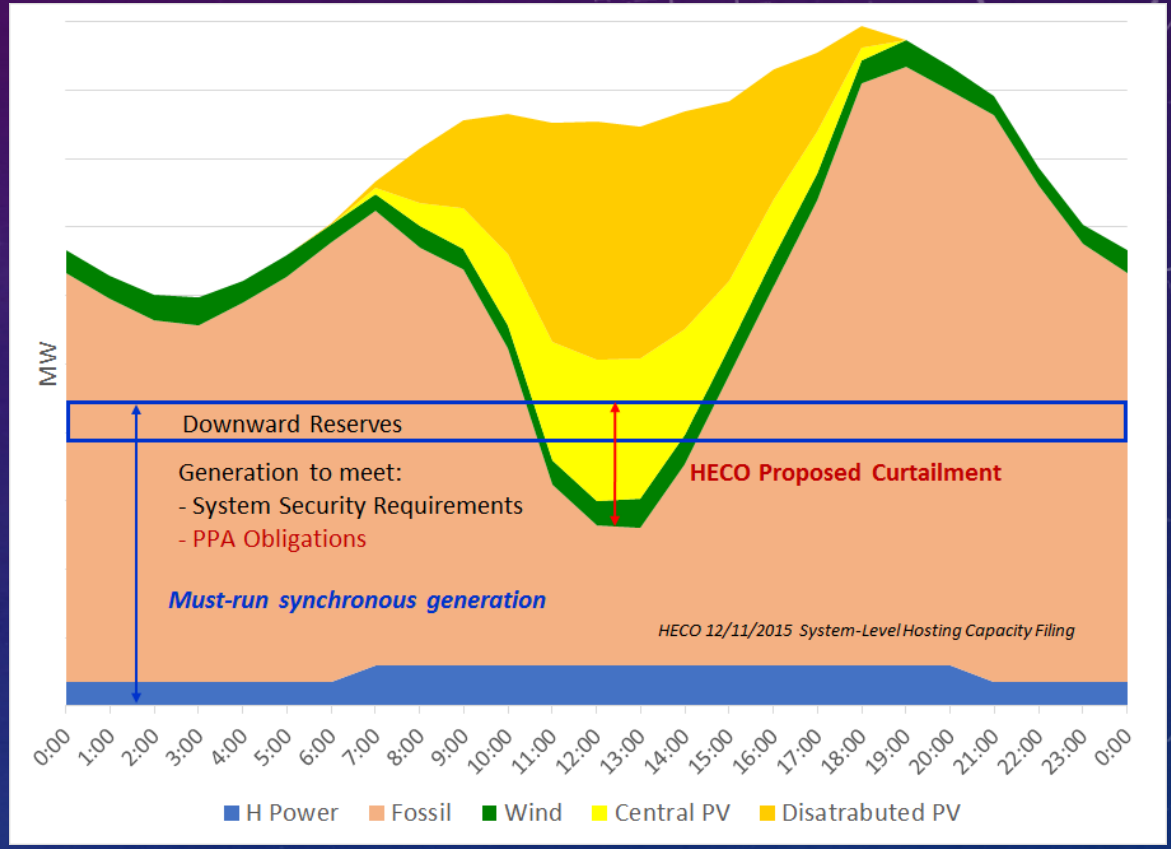
SYSTEM HOSTING CAPACITY IS THE BIG OBSTACLE

- Circuit hosting limits are being systematically identified and addressed through a collaborative effort
- Circuit hosting limits in Hawaii reasonably mirror limits on the mainland
  - *Individual circuit* DG-PV penetrations *can* be high for any utility anywhere
- System hosting limits have only recently gotten attention in Hawaii
- Hawaii will likely reach system hosting limits sooner than most mainland utilities
  - *Interconnection-wide* variable renewables penetration is the critical parameter and this will remain relatively low for WECC, the Eastern Interconnection, and Quebec for many years
  - ERCOT already successfully deals with 45% instantaneous wind penetration and days with 40% wind energy penetration – and is preparing for more

SYSTEM HOSTING LIMIT DRIVERS & POTENTIAL SOLUTIONS

- Reduce must-run generation requirements
  - Distinguish between must-run for system security and must-run for the generator or operator convenience
  - Reserves from wind and utility scale PV
  - *Up* & down frequency response capability from new DG-PV
    - Self-supply will be curtailed at times and have frequency response capacity available: *Require* up frequency response capability – *do not block it*
  - Reserves from Demand Response as well as energy shifting
- Increase generation flexibility
  - Lower minimum loads
  - On/off cycling ability – especially fast-start generation
  - Increased ramp rates
  - Convert to synchronous condensers for voltage and short circuit
  - Do not build or contract with new "base load" inflexible generation

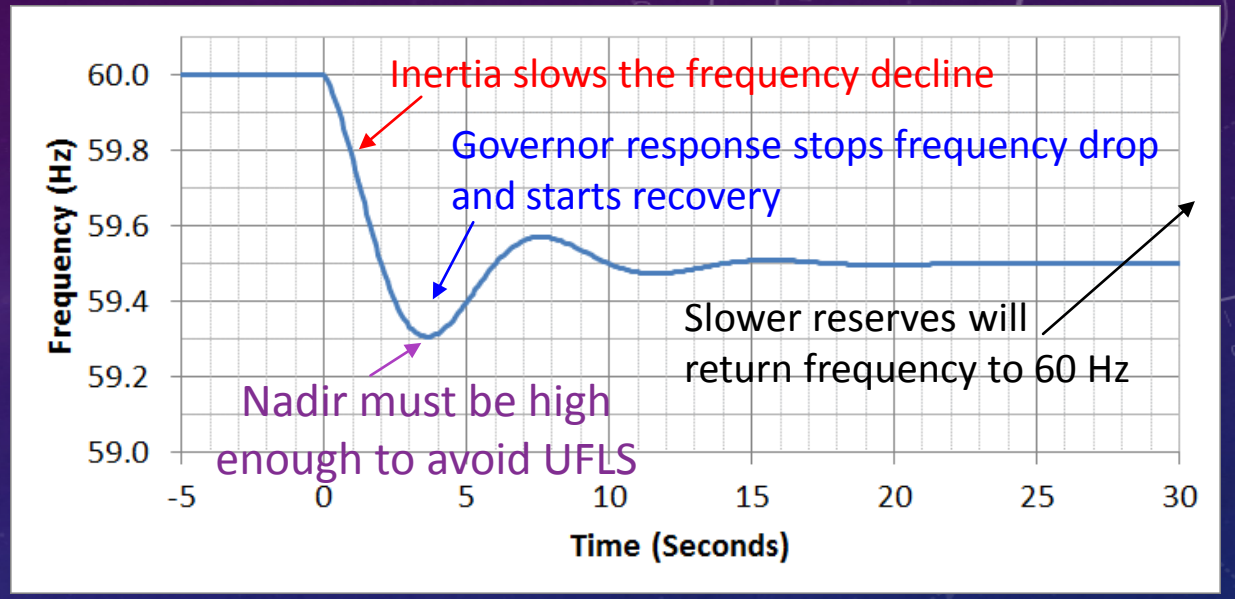


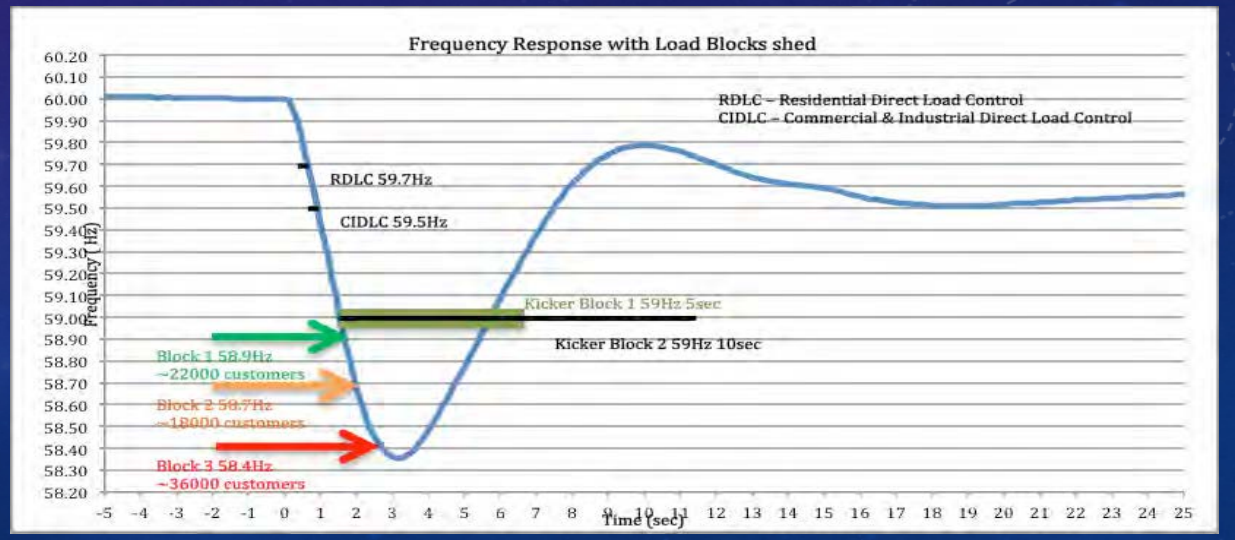
(Re)negotiate contracts and operate the power system based on economic principles and societal benefits

- All existing capital costs are sunk – wind & PV marginal costs are zero

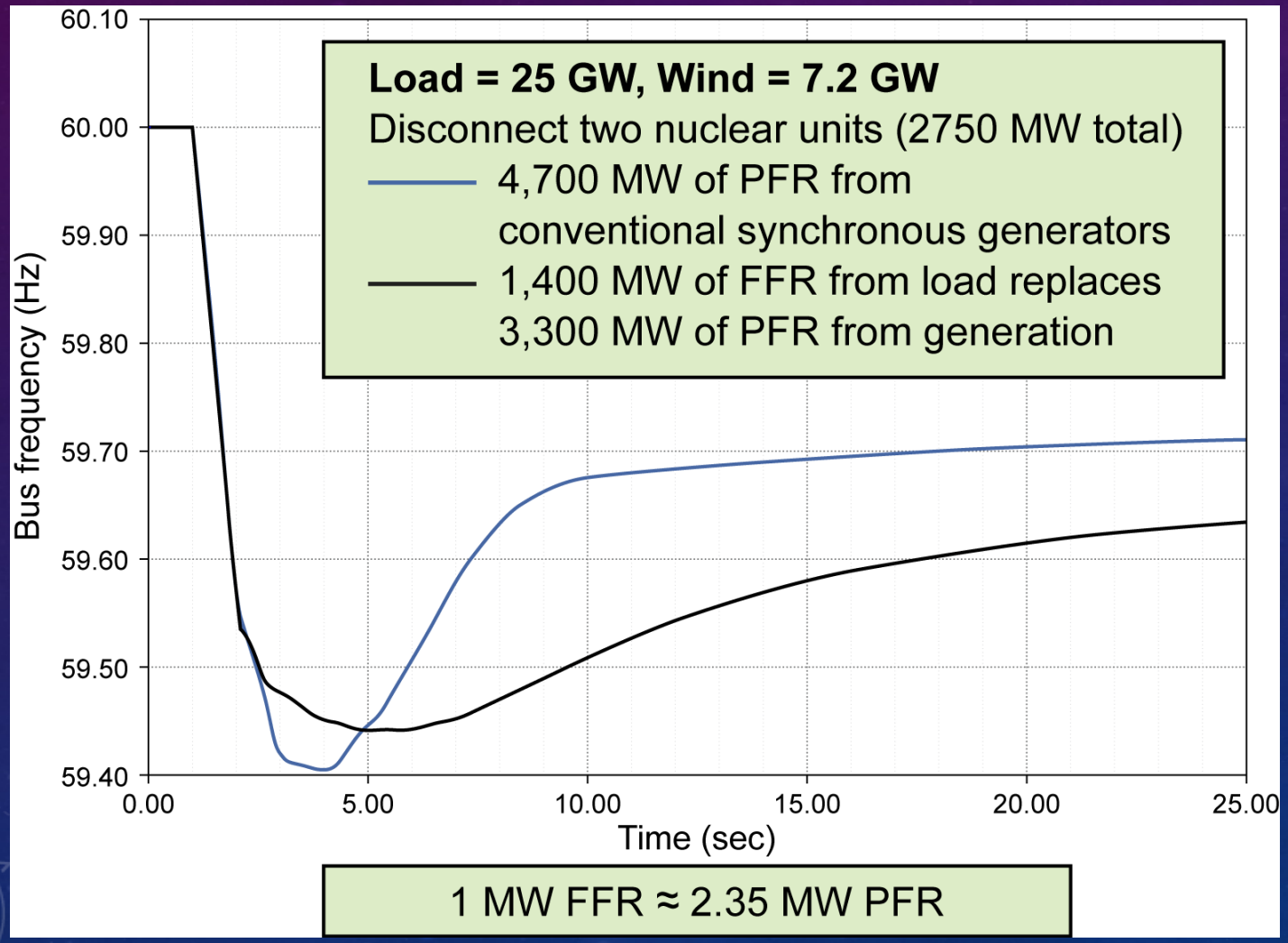
GENERATORS CAUSE AND RESPOND TO CONTINGENCIES

- Not new technology – always understood
  - Historically there was inherently typically enough inertia and governor response from online synchronous generators
  - Spinning reserve from synchronous generators inherently includes governor response and a specific amount of inertia (fortunately typically enough)
- Changing conditions with high penetrations of PV and wind
  - Minimum net-load becoming a concern as inverter coupled PV and wind displace fossil fueled synchronous generators
  - Solar and wind typically dispatched at full output because of zero marginal energy cost so have no governor response room to increase output
- Now important to separate the components
  - Solar and wind have no inherent inertia but wind can have deliberately designed synthetic inertia and both can have governor response
  - New resources: DR (and storage) can be designed to provide specific inertia and governor response





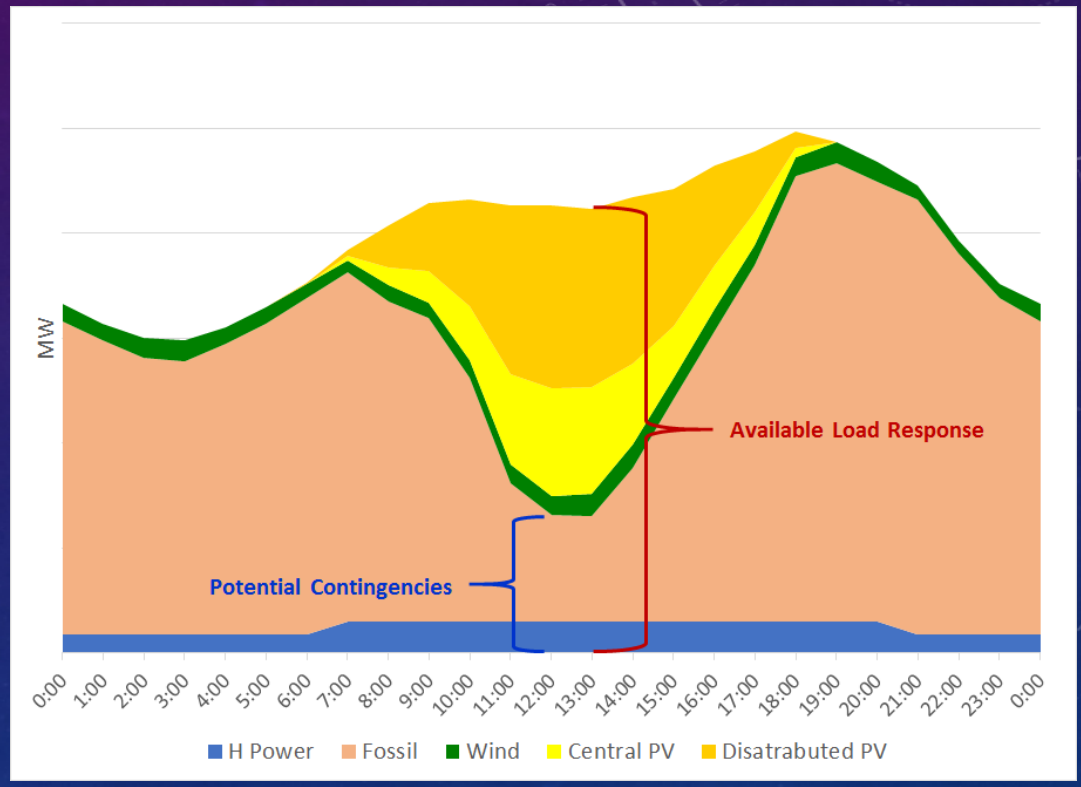
ERCOT SHUTS DOWN ADDITIONAL SYNCHRONOUS GENERATION AND RELIES ON FAST DEMAND RESPONSE AT MINIMUM LOAD



- ERCOT monitors on-line inertia and governor response (df/dt)
- Fast Frequency Response (FFR from DR) and Primary Frequency Response (PFR governor response from synchronous generators) are analyzed hourly
- The system operator calculates the substitutability ratio hourly
- DR paid the generator prices times the multiplier

UNDER FREQUENCY LOAD SHEDDING NEEDS TO CHANGE

- UFLS degradation because feeders have generation as well as load is a serious and inevitable problem
- UFLS is a crude tool coming to the end of its useful life
- The solution is to trip individual loads, not feeders
- Similar technologies exist: millions of cheap GFIs sense milliamps of differential current and trip in cycles – the equivalent of sensing and tripping on ±0.02 hz frequency deviation



Change the power system thinking now, don't allow this as an excuse to limit renewable generation

RECOGNIZE AND ADDRESS SYSTEM LEVEL HOSTING LIMITATIONS

- As utility engineers we (wisely) like to be first to be second
- Hawaii may not want to hold back PV and wind integration until mainland *interconnections* reach the same penetrations Hawaii is experiencing and anticipating
- Study all of the potential resources (generation flexibility, wind & PV response, DR, storage) for each reliability requirement and select the most truly economic solutions
    - Hawaii is somewhat uniquely positioned in system size and PV penetration – It may be wise to be the first to implement some solutions

Hawaii's DERs Market Since the October 12th DERs Decision

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March 17, 2015

Mark Duda, President
Hawaii PV Coalition

PUC DERs Decision Overview

- NEM ended with immediate effect

- Established Transitional Customer Grid Supply Program
  - Program caps: 25 MW for HECO, 5 MW each for HELCO and MECO
  - Exports compensated at lower rate (~ $0.15 for HECO/HELCO; ~ $0.17 Maui) set only for two years
  - Monthly rather than annual true-up

- Established Customer Self-Supply Program (CSS) – 100 kW or less
  - Raises minimum bill to $25 for CSS customers
  - Expedited review (approval period reduced to 15 days) but ability to providing grid services is quid pro quo for expedited interconnection (leaves door open for compensation but does not establish any)
  - Identifies various measures to ensure non-export

- Time-of-Use (TOU)
  - Rejects HECO Companies' proposal noting "apparent ambivalence" toward TOU
  - Identifies three periods (system peak/mid-day/off-peak)
  - Rates for peak set by "combining fixed generation, transmission, and distribution costs")
  - Mid-day rates set marginal cost of generation during the mid-day period
  - Requires HECO Companies' resubmission in 30 days

Empirical Experience to Date

Program Throughput (MW): Systems Approved and Awaiting Installation as of 3/1/16

	CGS	CSS	*NEM*
HECO	1.0	0.0	*80.2*
MECO	0.0	0.0	*27.7*
HELCO	0.3	0.0	*16.0*

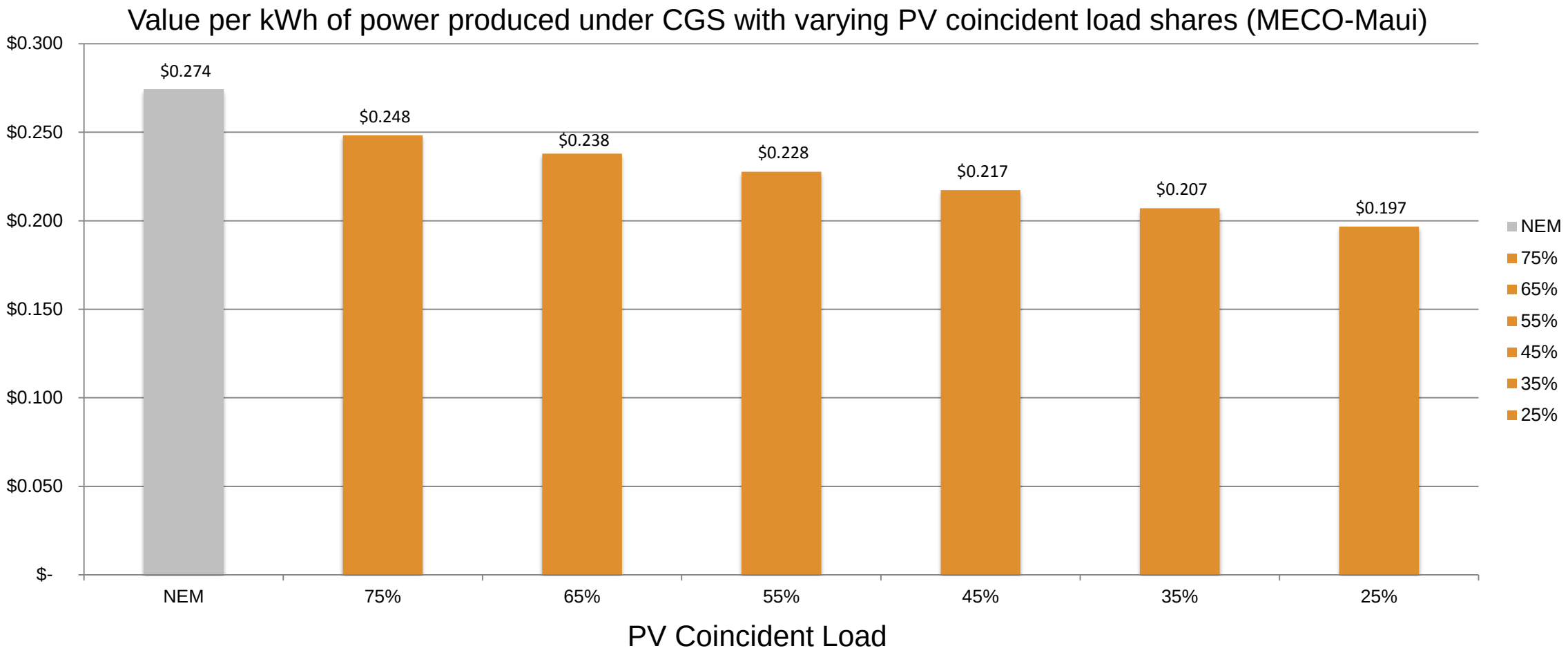
Source: Hawaiian Electric Companies' weekly interconnection queue report.

Some Reasons for Delays

- Significant increase in level of detail required, including repetitive input of the same data point on various pages (e.g., TMK including on pictures)
- Rejection of applications foe technicalities, requirement for resubmission and new wet signature
- New undisclosed requirements (e.g., all blanks be filled in with "n/a" unlike NEM)
- Some contractors told not to submit applications at all until final guidance

NEM vs. CGS

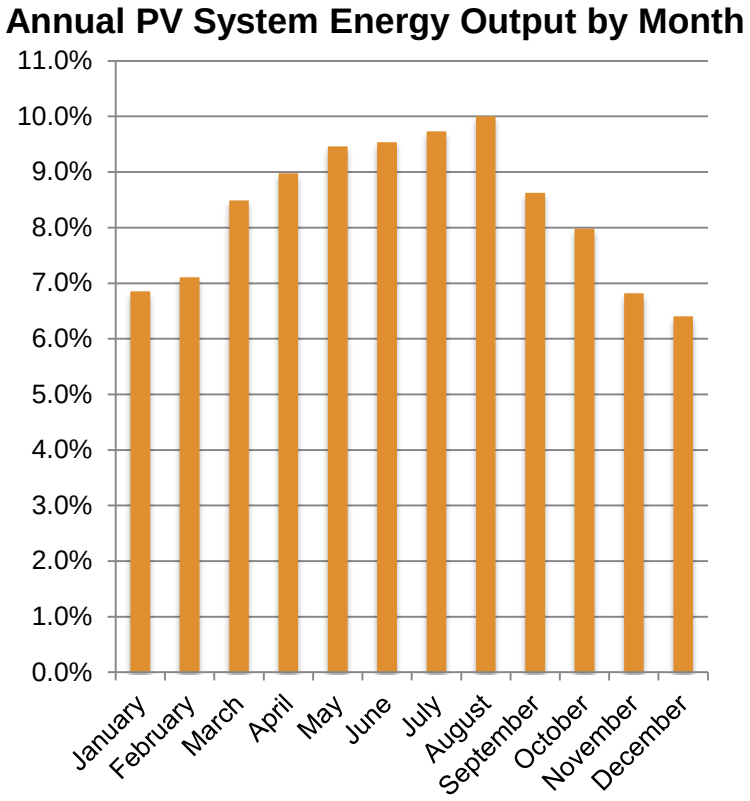
Load Profile Should Influence Investment Behavior

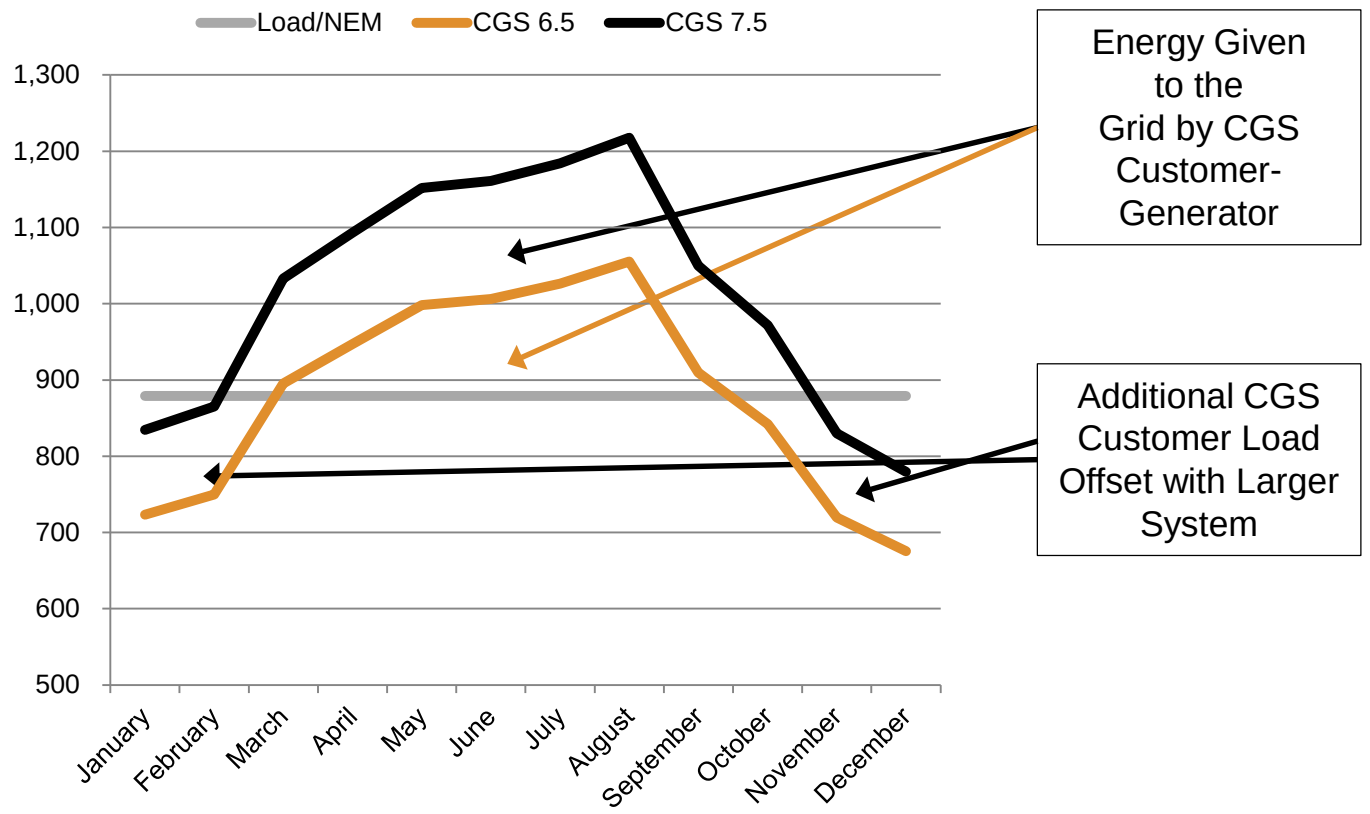


Note: Based on MECO-Maui March 2016 effective rate of $0274/kWh and export value of $0.17 under CGS.

CGS Consumer Behavior

Monthly True-Up Leads to Larger System Sizes All Else Equal





Note: Assumes load is identical in 12 months. System output based on 475 sun zone and NEM DC system capacity of 6.5 or 7.5 kW (STC).

CGS vs. CSS

Are non-export systems compelling yet?

Program	Cost	Energy Bill % Offset
NEM	$24,375	100%
CGS-25% PV Coincident	$24,375	73%
CGS- 50% PV Coincident	$24,375	82%
CGS- 75% PV Coincident	$24,375	91%
CSS-25% PV Coincident	$51,167	100%
CSS-50% PV Coincident	$43,139	100%
CSS-75% PV Coincident	$33,295	100%

Getting Closer, Depends on:

- PV Coincident load
- Storage cost trajectory
- Financing structure
- Installed PV cost
- Solar City & SunRun have residential CSS lease products

Note: Assumes installed cost of PV is $3.75/watt for 6.5 kW system; installed cost of storage $1,000/kWh; round trip efficiency of storage is 90%; ratio of bill offset to for export on CGS is 0.63 (export rate over retail rate for MECO).

Commercial DERs Market

Limited Viability of DG Systems with Storage Component

- Demand charge reduction generally not viable because load profile not available for the vast majority of commercial customers
- No meaningful TOU rate structure → no motivation to shift generation out of the solar window (but even so load profile data gap is a problem, and it's still costly to shift large chunks of energy)
- CSS only available up to 100 kW anyway, so nothing much changed
- Some small NEM systems are now small CGS systems
- Upshot is that the commercial market is basically comprised of non-exporting standard interconnect (SIA) systems (in some cases self-curtailing because it's cheaper than storing power) and some small CGS systems (where self-curtailment isn't worth bothering with because of the opportunity for paid export).

Note: 6.7 kW system equates to 30 kWh/day energy consumption assuming 475 sun zone. Energy charges offset by this system under NEM is $265/month.

DERs Summary

- Commission's attempt to move from NEM to CSS process has been painful/flawed
  - Utility unprepared/obstructionist
  - Utility customers currently enjoying a "discount" due to oil price declines
  - Amount/timing of proposed payments for grid supportive services to defray investment costs are undetermined
  - Integration of new product offerings takes time for solar sales organizations
  - No meaningful TOU option to incentivize behavioral changes/investments
  - Potential CSS customer-generator can choose between CSS now and CCS later – why not wait?

- CSS program was supposed to help save HECO Companies from themselves by providing customers with microeconomic incentives that discourage grid defection – but once flaws/problems above can be addressed, the thing that will drive customers off grid is hosting capacity

- Hawaii's utilities are the first to face deep, penetrating, and fundamental competition from DERs – utilities are not the least cost power provider for their customers so the fundamental basis of the entire regulatory framework is obsolete

- So it all comes back to the fact that Hawaii has not yet come to terms with the need to comprehensively redesign regulatory incentives – "it's the business model stupid" - to act in a way that encourages customers with cheaper power supply options from defecting