Hawaii RPS Study

Executive Summary

Hawaii State Capitol, May 2015

GE Energy Consulting, in partnership with and sponsored by the Hawaii Natural Energy Institute

Harjeet Johal, Derek Stenclik, Gene Hinkle, John Cole, Richard Rocheleau

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Study objectives

Identify and evaluate cost-effective pathways that support the growth of renewables on Oahu and Maui, by evaluating

- Different resource mixes (wind, solar) and grid configurations (independent or connected islands)
- Economics of the various options (scenarios)
- Other changes in generation or grid operation to reduce cost of electricity and increase renewable energy
- Grid reliability levels as existing generation is retired (and new generation is added)

Hawaii RPS Goals:

- 10% renewable energy by 2010
- 15% renewable energy by 2015*
- 25% renewable energy by 2020
- 40% renewable energy by 2030

***In 2013, 18.2% of electricity was generated from renewable sources**

Project tasks and analysis flowchart

Analyze candidate renewable growth scenarios → Analyze use of LNG for power generation → Assess the value of modification in operating practices → Establish generation resource adequacy → Evaluation of additional scenarios as defined in PSIP

Oahu is the major load center of Hawaii

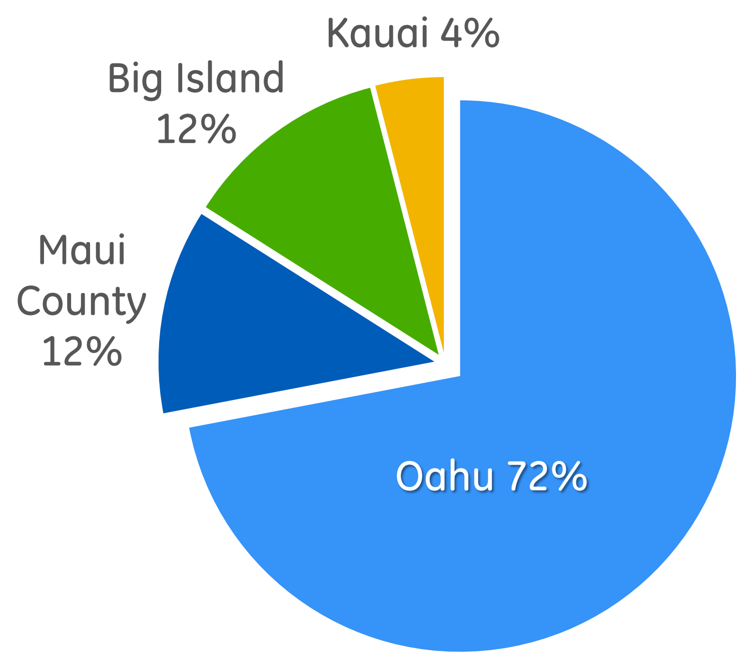
Achieving desired state-wide reductions in fossil fuel usage requires that Oahu RPS goals are met

Options for increased renewable energy on Oahu include:

- Significant growth of Oahu on-island renewable generation
- Growth of Oahu renewable generation AND renewable energy transfer via island interconnect to Oahu

All future scenarios assume modification to increase grid flexibility (lower turn down and cycling capability)

2013 annual load energy

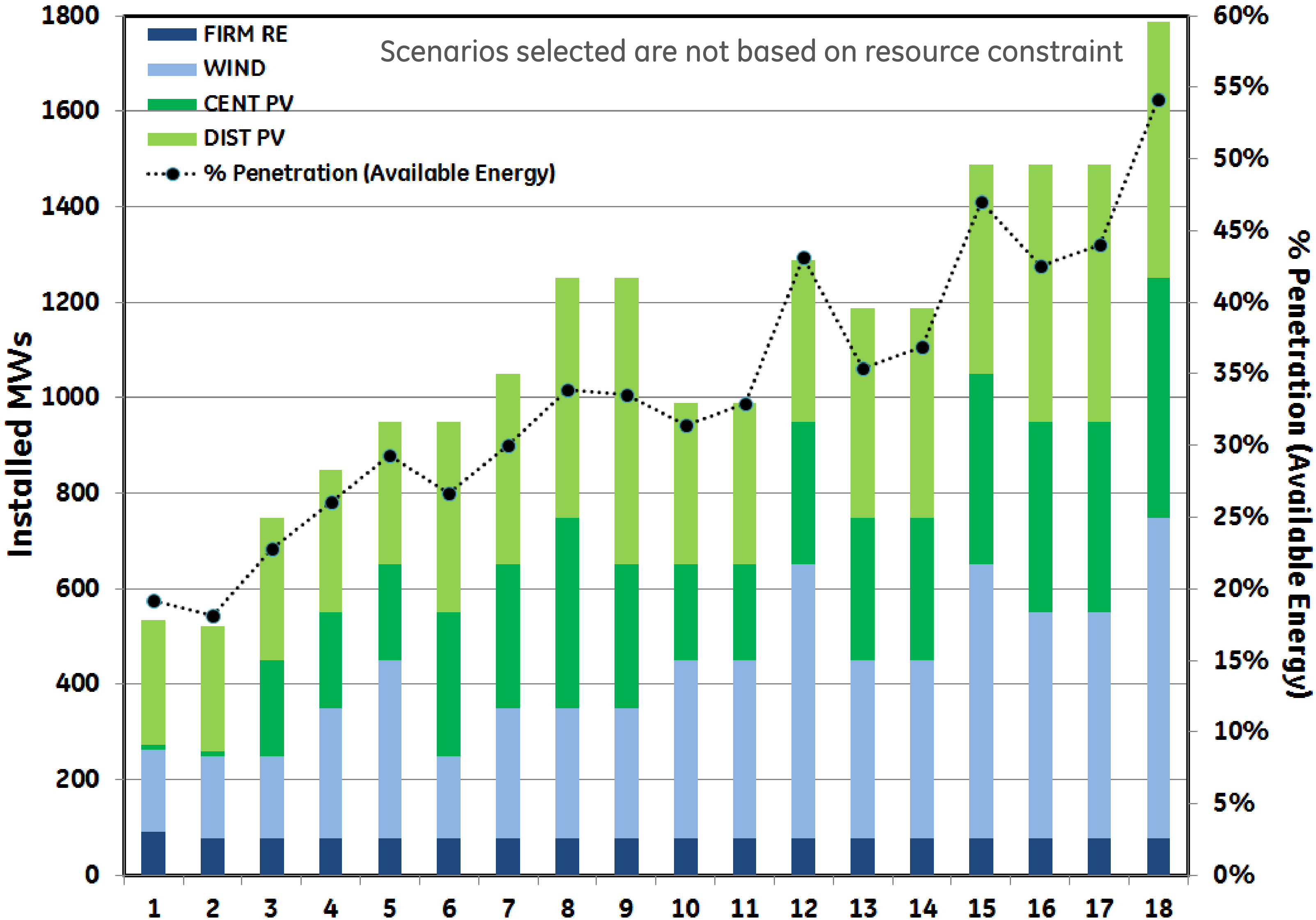


Source: Hawaii Energy Facts & Figures, gnergy.hawaii.gov, November 2014

Nine(9) scenarios analyzed assuming differing amounts of wind, solar (distributed and central) and other renewable generation sited on Oahu

Nine (9) scenarios analyzed including off-island gen-tie, Maui grid-tie, and mixed interconnections assuming differing amounts of renewables on Oahu

Renewable Capacity by Scenario



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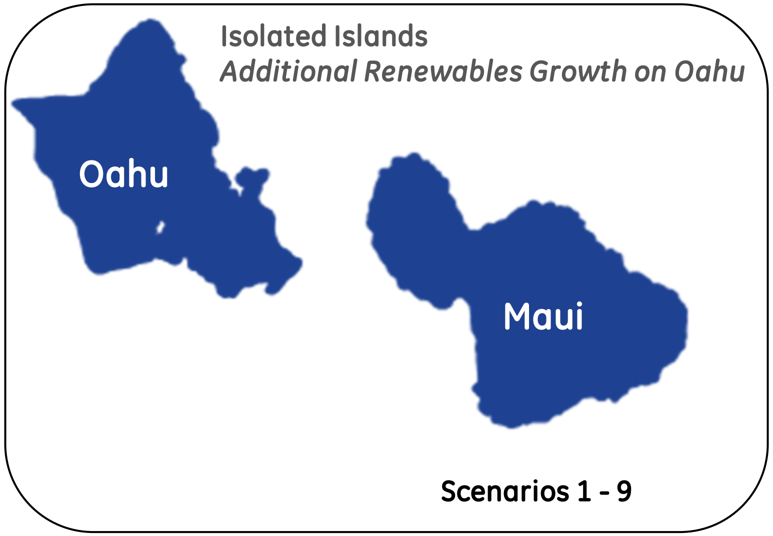
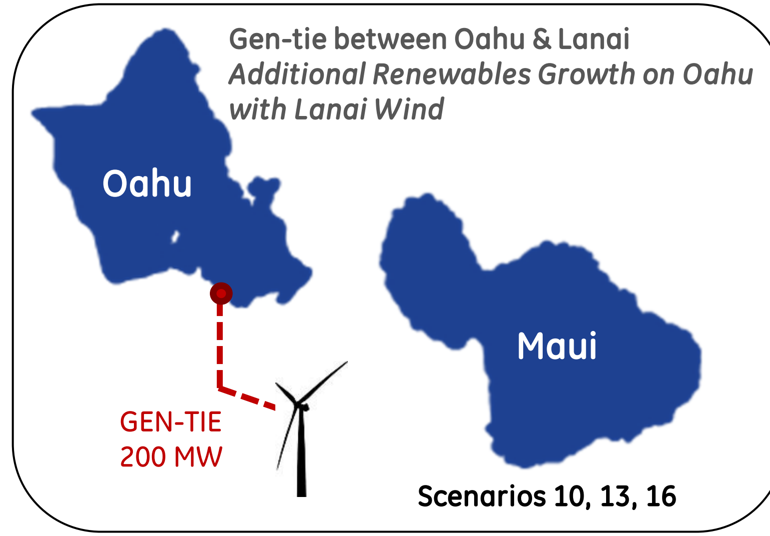
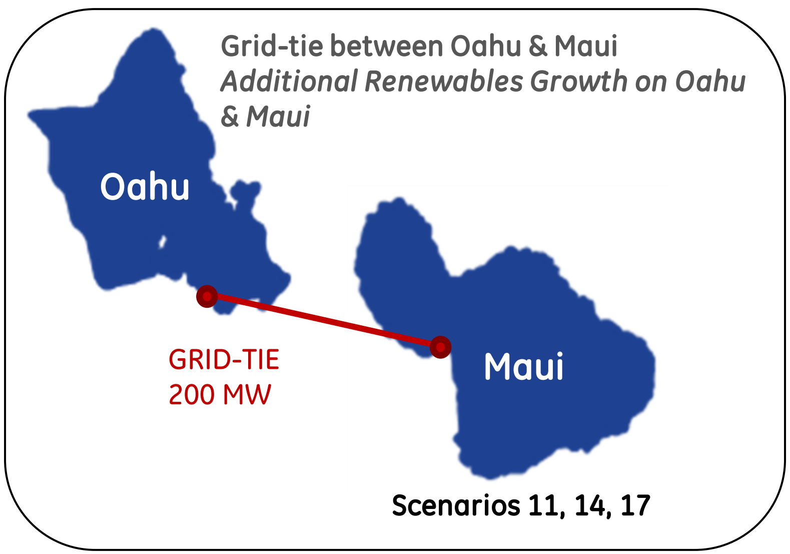
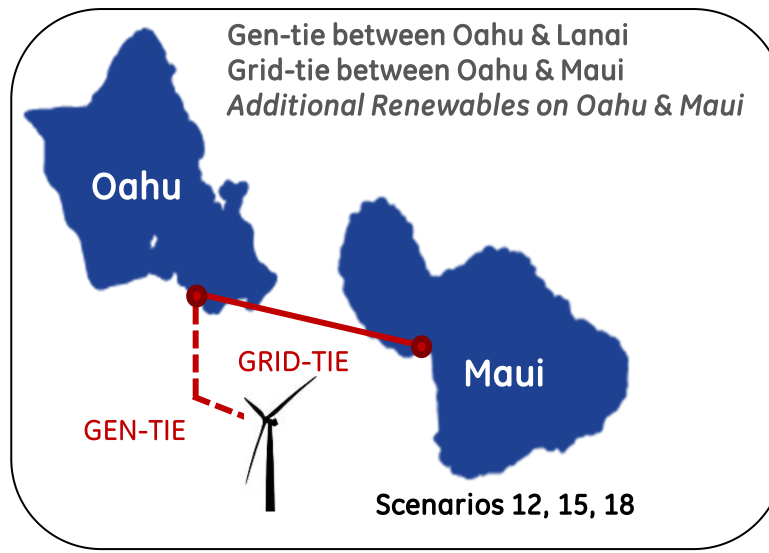
Grid Topology by Scenario









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How do the island grids operate?

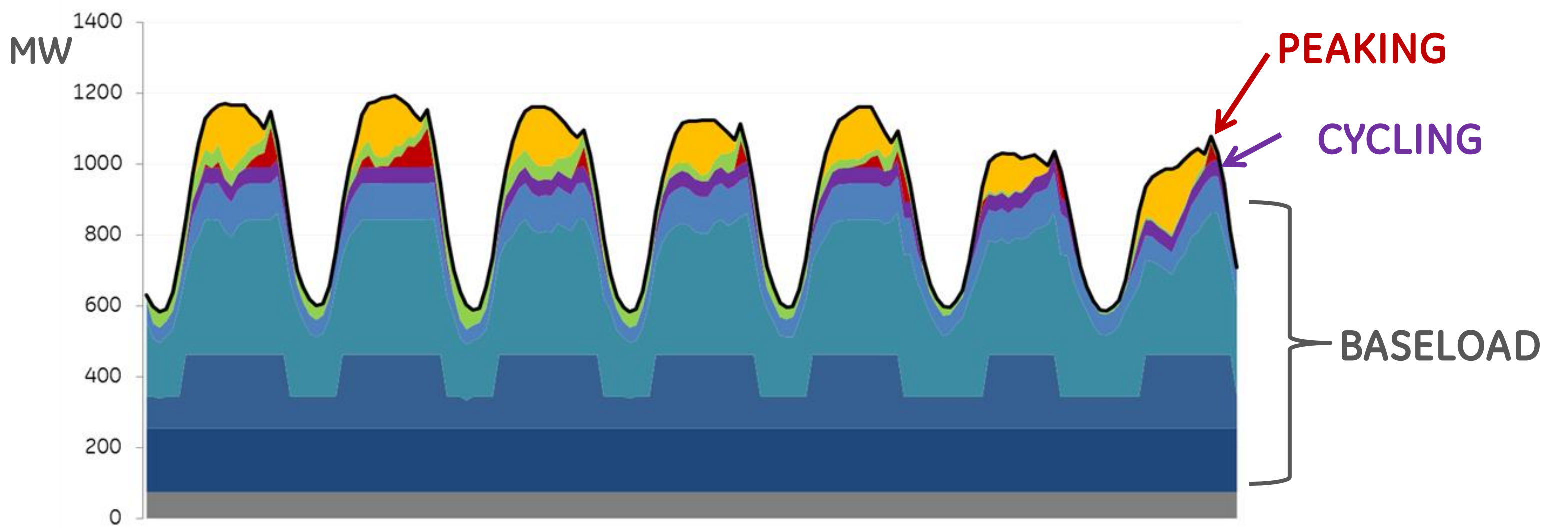
Thermal unit characterization

BASELOAD
- Usually the most economic
- Fixed operating schedules
- **Oahu:** AES, Kalaeloa, Kahe 1-6, Waiau 7-8, H-Power, Honua
- **Maui:** Maalaea CC, Kahului 1-4*

CYCLING
- Cycled on and off as necessary
- Must be committed in advance
- **Oahu:** Honolulu 8-9*, Waiau 3-6
- **Maui:** Maalaea 5, 7 – 13,

PEAKING
- Most expensive units
- Quick response to generation shortfall
- **Oahu:** Waiau 9 and 10, CIP CT1, Airport DG, Schofield Barracks
- **Maui:** X1 and X2, Maalaea 1 – 4, 6, ICE Additions 1 and 2

*Unit retirements



A WEEK OF OPERATION

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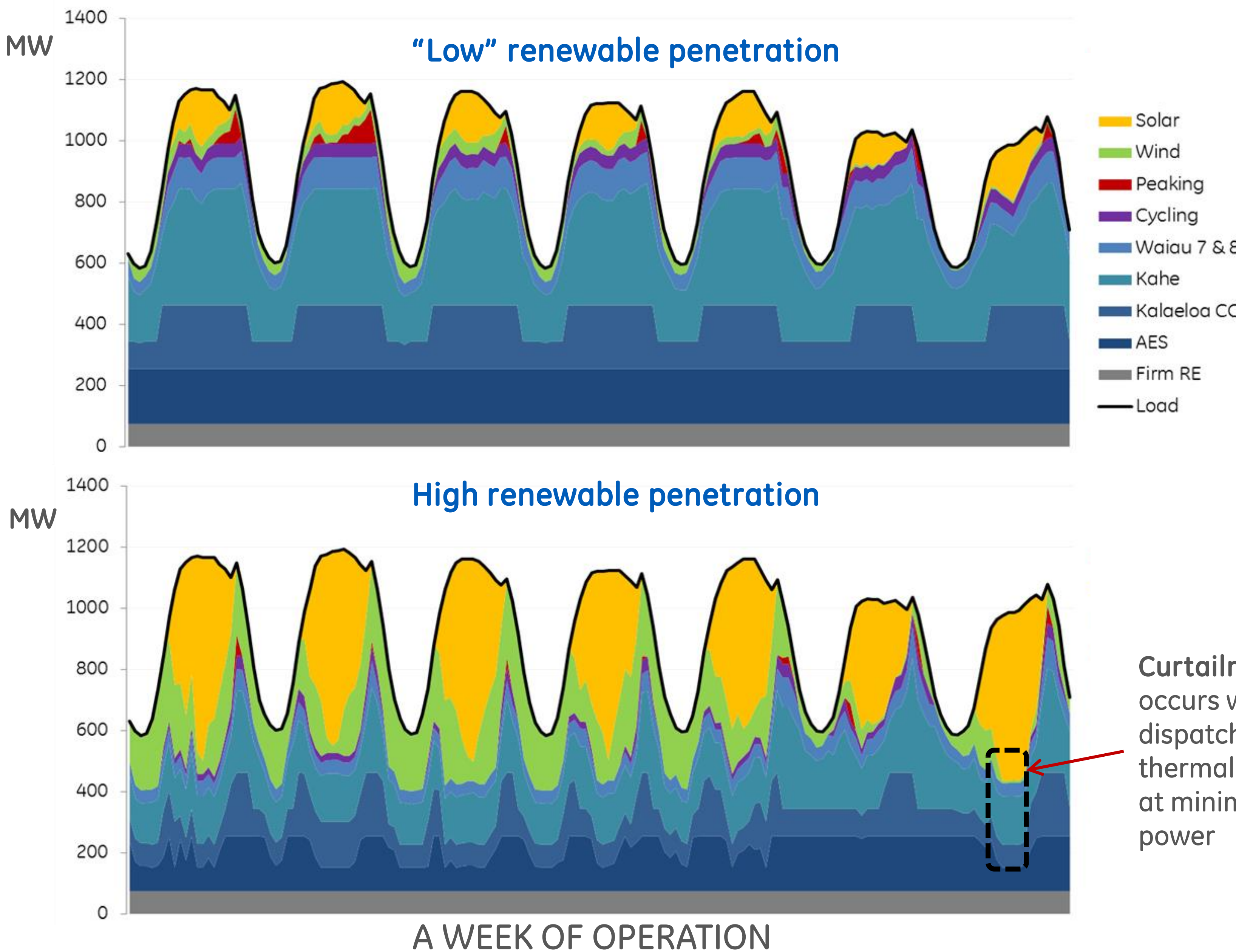
Dispatch to meet load and accept renewables



Curtailment occurs when all dispatched thermal units are at minimum power

Operating Cost of the System Quantifies the Benefits of Renewable Resources

Annual Production Cost

- Captures fuel, O&M, start-up/shut-down cost of thermal fleet

Annual PPA Costs of Existing Renewables

- Captures existing contractual agreements with IPPs (Wind and Firm RE)

Cost of New Renewables/Equipment/Grid Upgrades

- Captures annualized cost using a Fixed Charge Rate (FCR)

Annual Operating Cost = Production Cost + PPA Cost + New Capex

Lower annual operating cost results in lower cost to serve load. The magnitudes are highly dependent upon the type of resource mix

All costs are in 2013 $
Fuel costs are based on HECO IRP (e.g. LSFO - $ 18.64/MMBTU)

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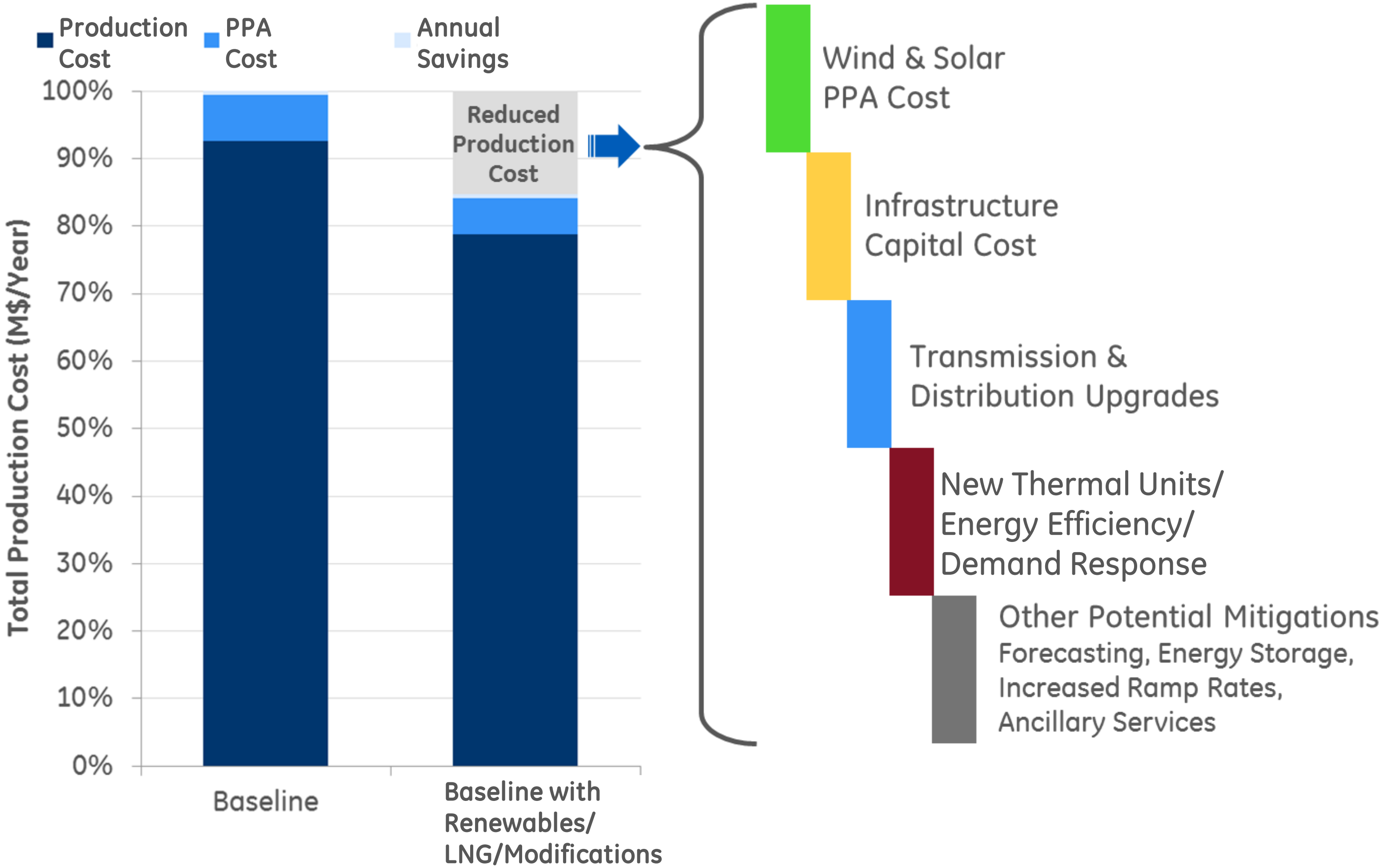
Cost/Benefit Analysis



The annual savings must offset the cost of renewables/modifications/grid upgrades for a net benefit to the grid

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Key takeaways and conclusions

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Oahu & Maui can surpass the RPS goals and reduce operational costs, provided the following measures are implemented …

Operational flexibility

- Increased turn-down capability of existing thermal units
- Optimally commit units to optimize reserves and energy
- Utilize ancillary services from wind and controllable solar plants

Infrastructure for reliability

- Wind and solar have limited ability to maintain/improve reliability levels
- New thermal units, energy efficiency, and demand response are key

Generation resource mix

- Pursue a balanced renewable resource mix (wind vs. solar, central PV vs. distributed PV)
- Procure units that can start quickly and ramp faster, turn down lower

LNG as the primary fuel

- LNG on Oahu alone can help to achieve significant cost savings
- LNG consumption will decrease as renewables increase; suitable contract should be secured

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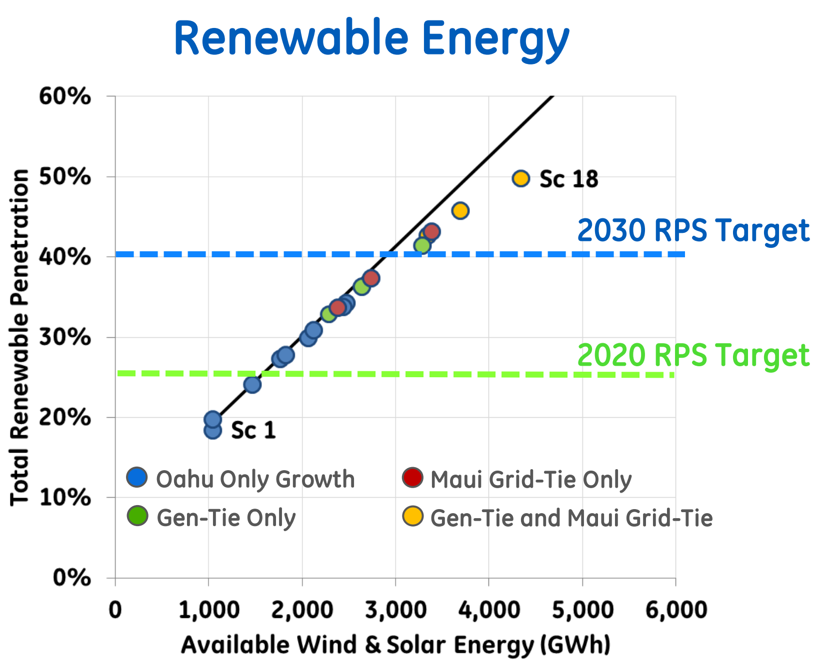
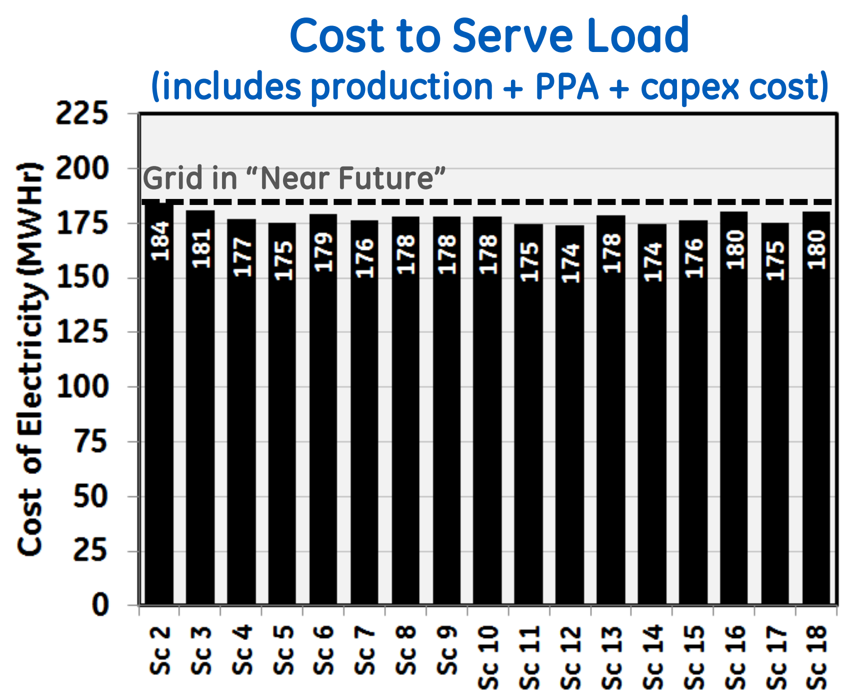
Cost of electricity with growth of wind and solar

- Islands can achieve significant renewable energy penetration without an interconnection
  - Cost of electricity can be reduced by up to 3% with renewable energy levels reaching 30% and beyond

- Higher renewable energy penetration and increased savings is possible with interconnections
  - Cost of electricity can be reduced by up to 5.4% with renewable energy levels reaching 40% and beyond





Assumes low cost of capital – FCR 10%

Cost of electricity will increase as the cost of capital increases

This does not represent retail cost of electricity

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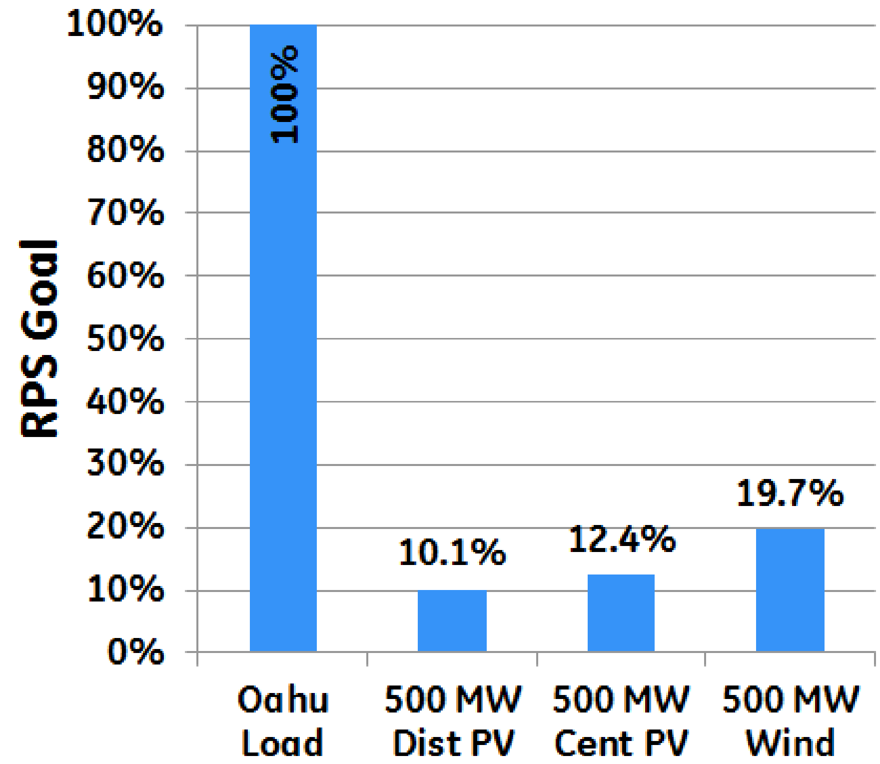
Fast Growth of Distributed PV can Challenge System Operations

- ❑ Limited benefits in meeting RPS goals
  - 500 MW of installed rooftop PV will be able to meet only 10% of annual load energy
- ❑ Other grid stability & reliability requirements for Distributed Solar PV
  - Voltage & frequency ride through
  - Enabling curtailment
  - Reactive support
  - Frequency response
  - Other grid strengthening measures



500 MW of Distributed Solar PV can be a reality in the near future

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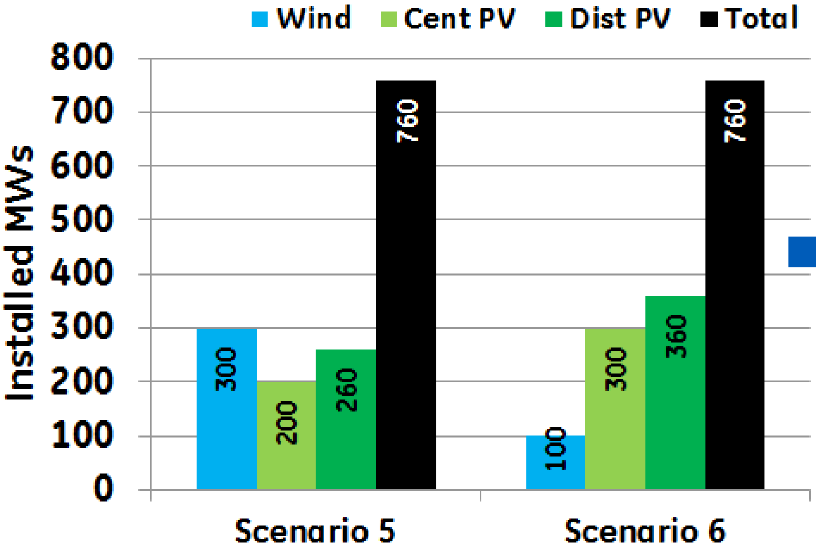
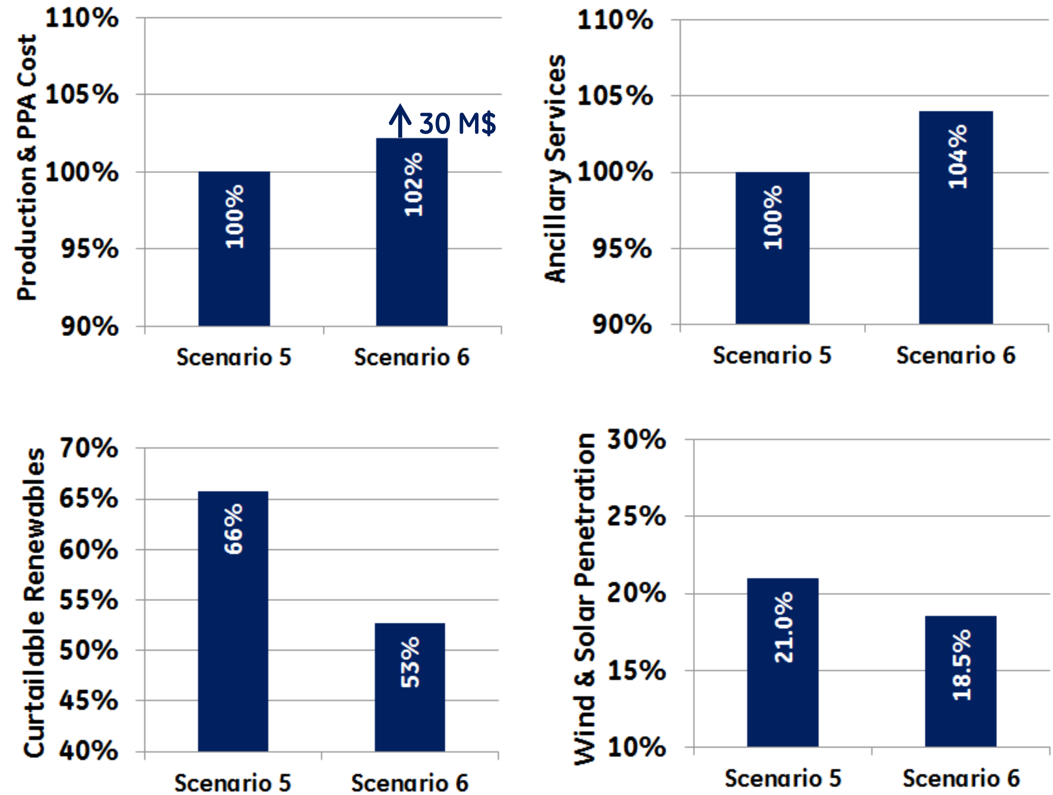
Resource Mix is Important





A balanced growth of resource mix will be more economical to meet RPS goals

- Solar PV: Available only during day-light hours, displaces expensive generation
- Wind: Higher energy density and available throughout the day
- Distributed Generation: Geographical diversity helps to reduce variability

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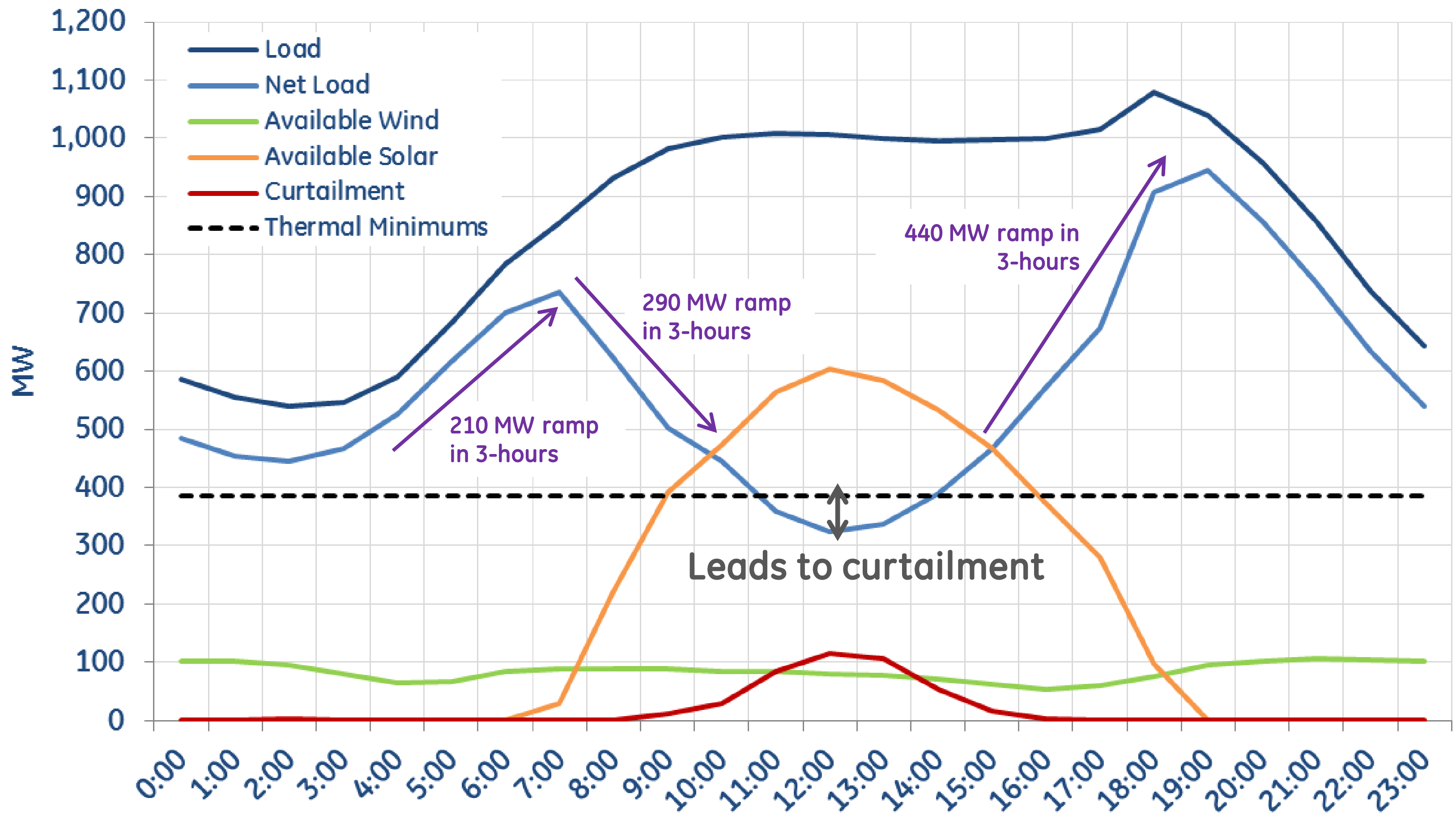
Need for Improved Flexibility

Average day in March: Oahu, scenario 8



The system can accommodate the renewable, provided:

- ✓ Thermal units have the capability to be turned-down lower
- ✓ Thermal units can be cycled up/down
- ✓ Renewables can be curtailed, if needed

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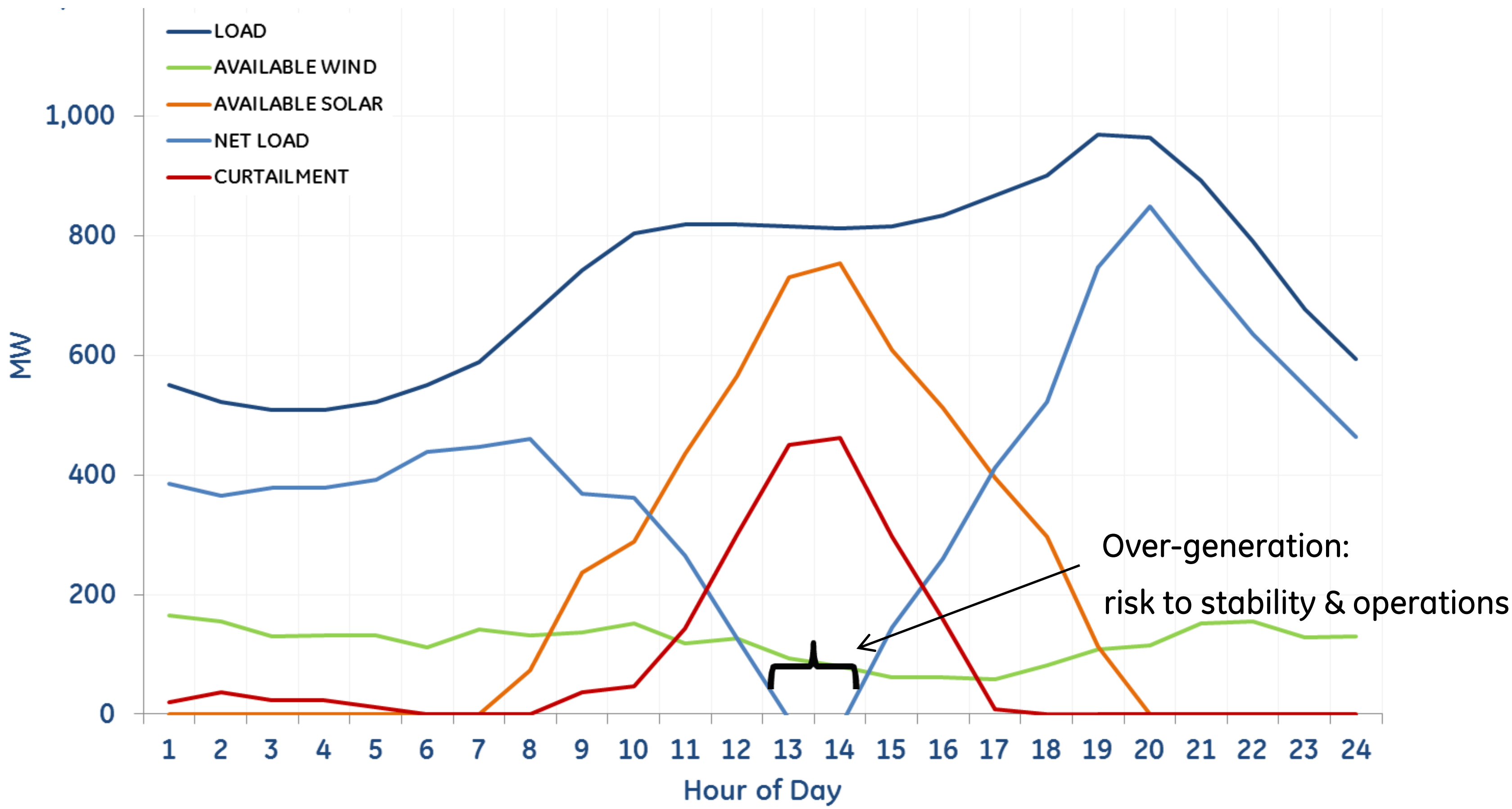
Challenge to System Operation & Stability

Day with High Renewables: Oahu, scenario 8



High penetration of "un-curtailable Distributed Solar PV" can challenge:

- ✓ System operations by requiring faster cycling and unit commitment
- ✓ Grid stability by requiring more frequency responsive ancillary services

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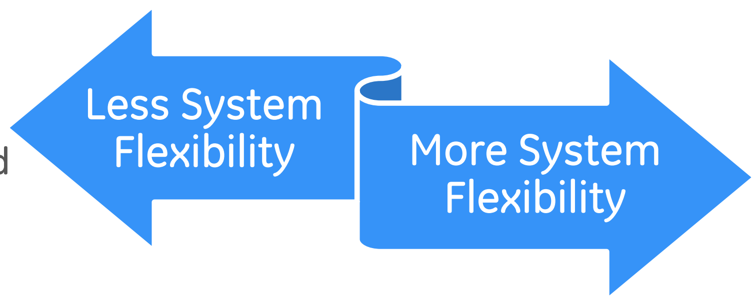
The system operator has options available to increase renewable penetration and reduce operating cost…

- ✓ Reduce minimum operating levels on thermal units
- ✓ Remove must-run constraints and allow cycling of baseload units
- ✓ Allow wind and solar to provide down reserves
- ✓ Make changes to the operating reserve strategies
- ✓ Invest in new resources to provide ancillary services

- Higher Minimums
- Must-Run Constraints
- No ancillary services from RE
- Reserve practices unchanged

✓Higher Curtailment
✓Higher Costs



- Lower Minimums
- Cycling Options
- Renewables provide reserves
- Changes to reserve strategies

✓Lower Curtailment
✓Lower Costs

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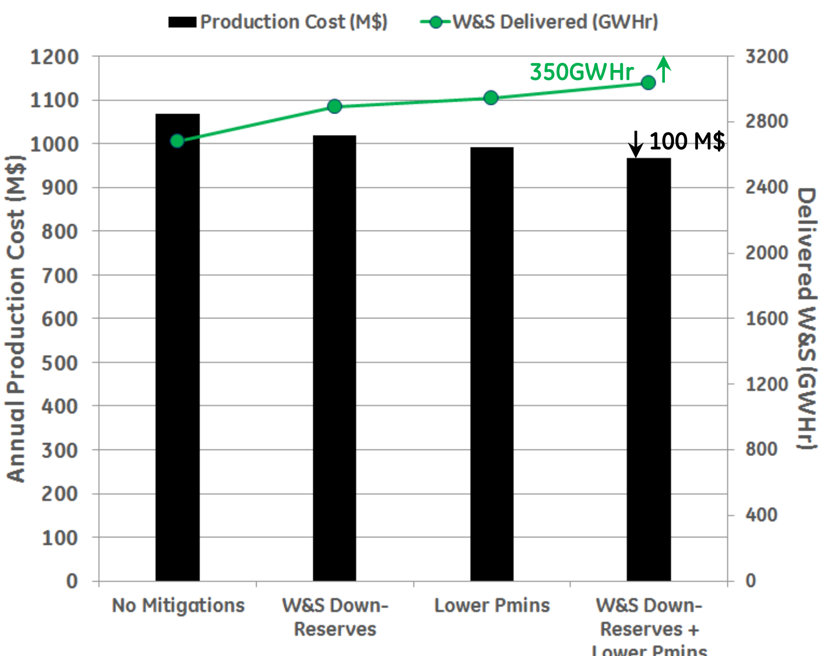
Benefits from Modifications

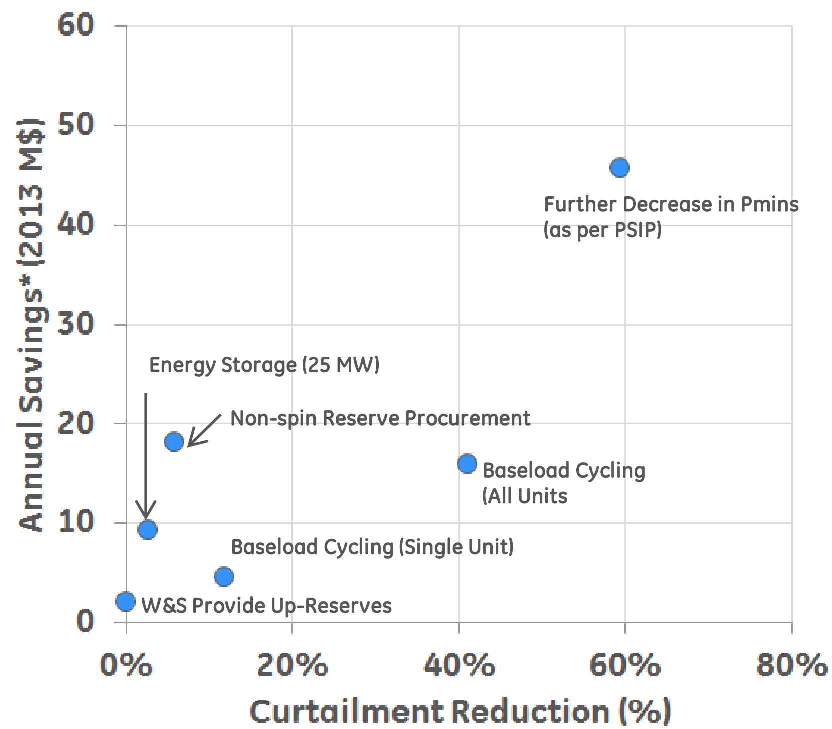
- The following modified practices are recommended moving forward
  - Reduced Pmin of thermal units
  - Down-reserves from wind and solar plants

Strategies that provide the biggest benefits



- Additional strategies are recommended that can provide benefits as renewable penetration further increases

Strategies that provide additional benefits



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Summary of Recommended Modifications

- ✓ Reduced minimums on thermal units is critical for high levels of wind and solar penetration,
- ✓ Removing must-run constraints and allowing baseload unit cycling can increase system flexibility, decrease curtailment, and lower system costs,
- ✓ Removing must-run constraints does NOT increase cycling of baseload units dramatically. In general, no more than 2-3 baseload units are cycled,
- ✓ Changes to current operating practices of Kalaeloa CC and Kahe 6 will provide the largest benefits in a high renewables scenario,
- ✓ Adjustments to procurement strategy of operating reserve can reduce system cost and increase renewable penetration,
- ✓ Ancillary services from wind and solar plants can provide significant production cost savings to the system.

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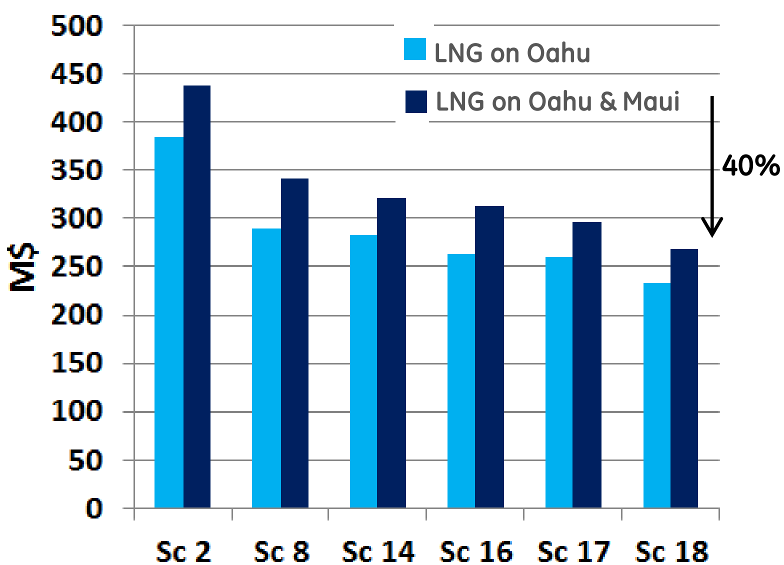
LNG – An Attractive Fuel Mix

- Savings in system production cost depends on renewables penetration
  - Savings decrease by 40% in Scenario 18

Annual savings in operations

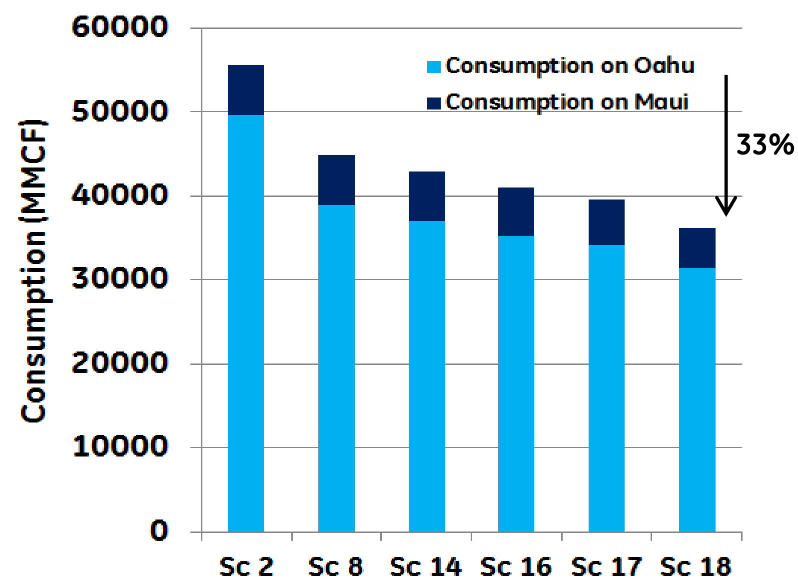


Assumes LNG contract price of 15.5 $/MMBTU on Oahu
Assumes LNG contract price of 17.05 $/MMBTU on Maui

Savings are highly dependent on the underlying fuel cost

- Contract price is the key…
  - Consumption of LNG decreases by 33% in Scenario 18

Annual consumption of LNG



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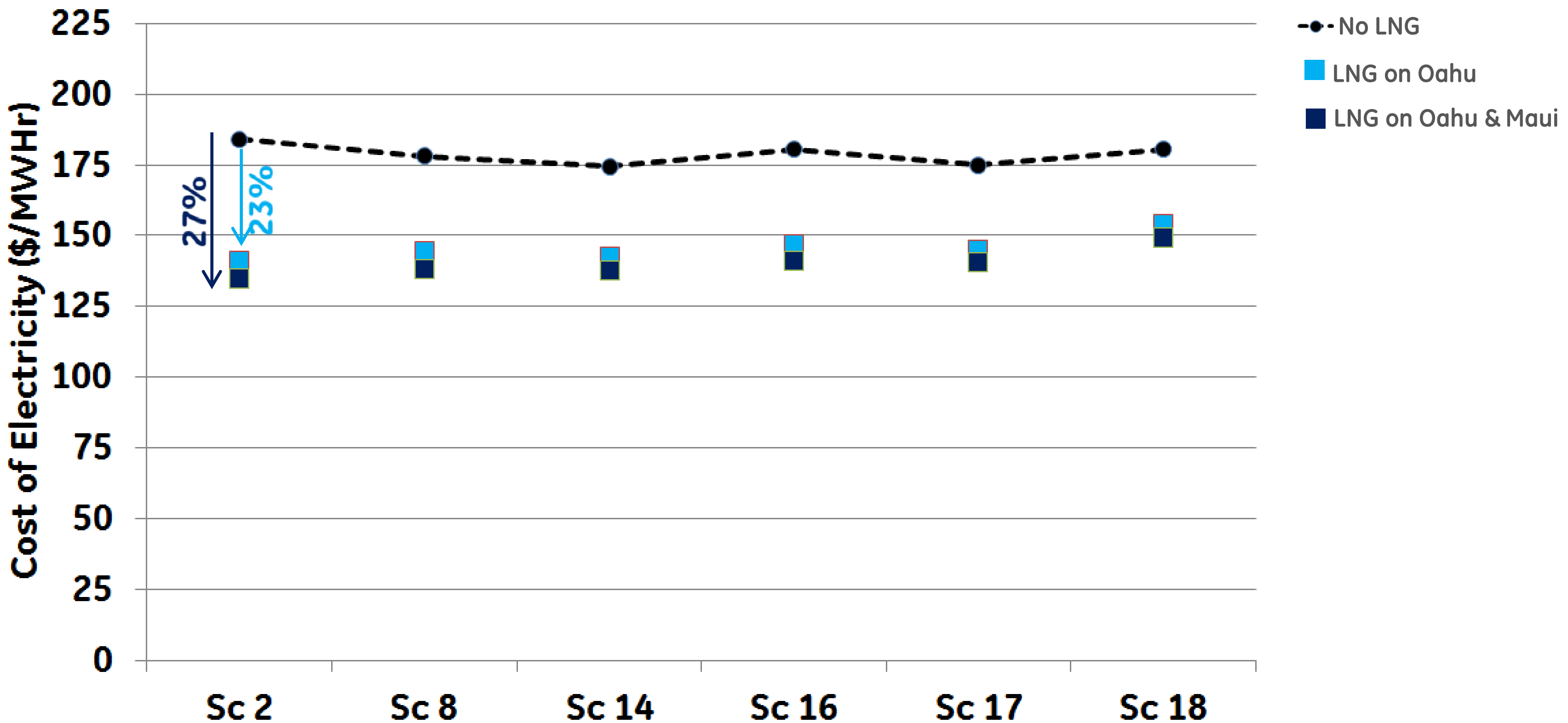
Lower Cost of Electricity with LNG



Assumes low cost of capital – FCR 10%

- With LNG as the primary fuel on Oahu only, a reduction of up to 23% in the electricity price can be achieved
- With LNG as the main fuel on Oahu & Maui, a reduction of up to 27% in the price of electricity can be achieved

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Need for Investment to Improve Grid Reliability

- ✓ Prior to any retirements, Oahu & Maui have acceptable levels of grid security & reliability
- ✓ Proposed retirements of cycling units will challenge the Oahu grid generation adequacy. Reliability levels are not secured even after proposed unit additions.
- ✓ Grid-tie between Oahu and Maui can maintain the reliability to acceptable levels after the proposed unit retirements
- ✓ Energy efficiency and demand response are key to maintaining and improving the ability to serve load at all times
- ✓ Wind and solar have limited ability to contribute to generation adequacy.

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Grid Reliability == Adequate Generation

- Definition: Grid Reliability is defined as the adequacy in generation to serve load at all times
- How is it measured: Generation Adequacy is determined as Loss of Load Probability (LOLP) and is expressed in years/day.
- LOLP is a statistical measure of the frequency of failure to meet load
  - For example, an LOLP value of 1 indicates that the generation fleet would be unable to serve all of the system load for a total of 1 day in a year
  - North American utilities have traditionally based the grid planning on a LOLE of 10 years/day
  - HECO has proposed a baseline level of 4.5-6 years/day

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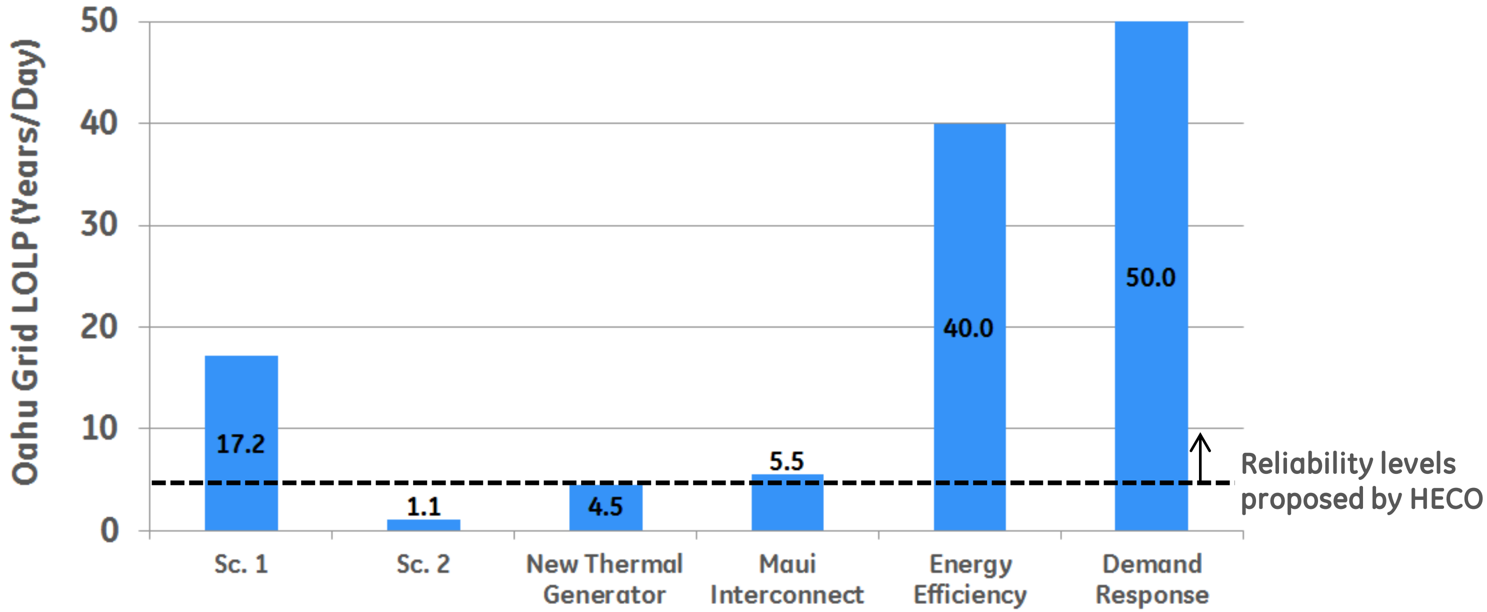
Investments to improve grid reliability

- Prior to any retirements, Oahu and Maui have acceptable levels of grid security and reliability
- Proposed retirements of cycling units will challenge the **Oahu** grid generation adequacy

Reliability levels are not secured with addition of Schoffield Barracks

– Additional thermal units, energy efficiency, demand response are key. Wind and solar have limited ability to contribute to grid reliability



New Thermal Generator: 78 MW of new combustion turbines
Energy efficiency: 2020 target approved by PUC - 2350 GWHr of potential for Hawaiian Islands
Demand Response: ASSESSMENT OF DEMAND RESPONSE POTENTIAL FOR HECO, HELCO, AND MECO – Global Energy Partners, LLC

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Future Work – Challenges in the Near Future

The RPS bill SB715, is asking the utility to support up to 100% renewable energy by 2045. This creates new challenges for maintaining the reliability and stability of the power grid. Future study items may include:

- ❑ Where the power grid will be in the next 2-6 years, assuming very fast growth of distributed solar PV:
  - What flexibility plans are needed in addition to the ones proposed?
  - How can distributed storage, including electric vehicles, help?
  - How can smart inverter functionality help?
  - How is the grid stability and reliability impacted?
  - How to value distributed ancillary services?
  - What mitigations are needed for reliable distribution operation?
  - Stochastic multi-year wind and solar data analysis and updated resource potential screening on Oahu?