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

To Shift or not to Shift?

An Energy Storage Analysis from Hawaii

May 8, 2018

Tenerife, Spain

Imagination at work

GE's Grid Integration Experience in Hawaii

2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017

- **Evaluation of Sustainable Energy** Options for the Big Island
- **Maui Wind** Integration Study
- **Oahu Wind** Integration and Transmission Study (OWITS)
- **Hawaii Solar** Integration Study (HSIS)
- **Oahu-Maui** Interconnection Study (Stage 2)
- **Hawaii RPS** Study
- **Oahu Distributed PV Grid Stability** Study
- **Hawaii Essential Reliability Services** st

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Study Objectives & Limitations

Limiting the scope of the analysis due to uncertainty in key inputs and assumptions

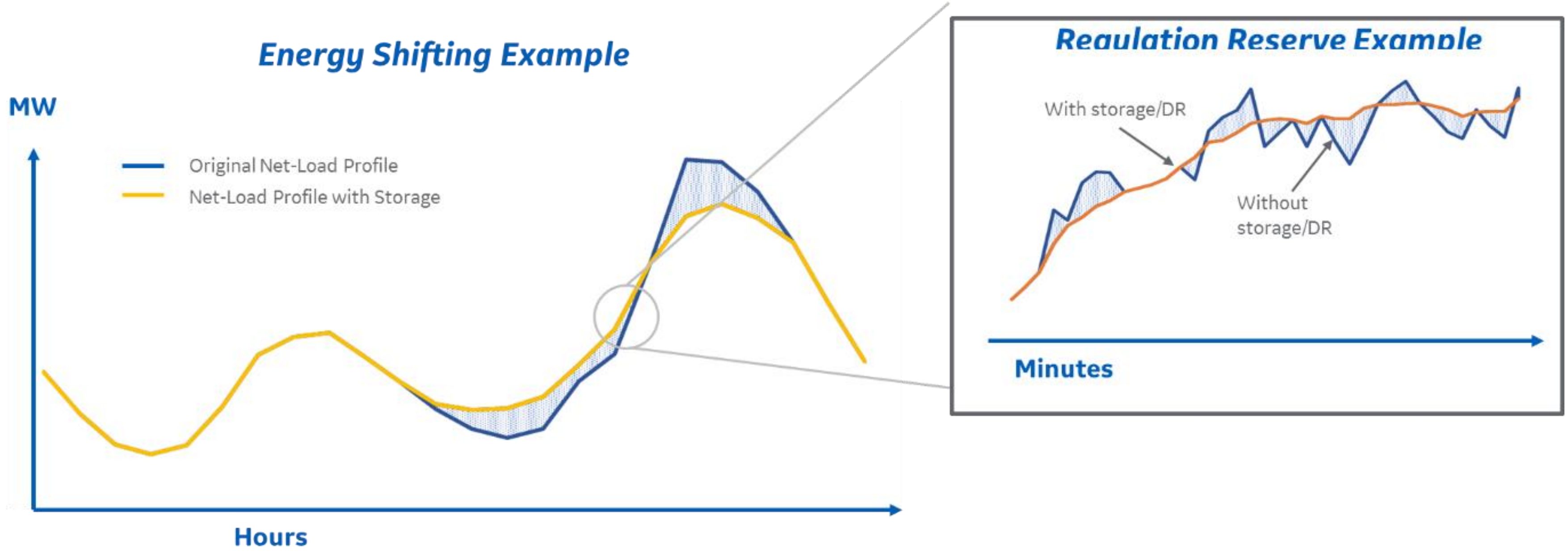
In-Scope

- ✓ Understand and illustrate BESS utilization patterns for reserves and energy shifting,
- ✓ Identify type of battery configuration (power:energy ratio) that is most beneficial on Oahu,
- ✓ Quantify a comparative review of annual costs and benefits associated with different configurations,
- ✓ Evaluate impact of utilization on BESS degradation and comparative economics

Out-of-Scope

- × Accounting for sub-10 minute cycling or SoC when used for regulation,
- × Exact project specific cost of capital assumption for BESS technology, using assumptions for relative comparison,
- × Precision on degradation impact of cell lifetime, looking for representative and relative costs only,

Storage Utilization – Shifting & Reserves



Battery storage primary use cases considered:

- Energy shifting: hours time-frame
- Reserves: minutes time-frame
  - Regulation
  - Contingency

Develop P:E Matrix → Estimate CapEx → Production Cost Simulations → Quantify Benefits → Compare Net Benefits

Grid-Scale Energy Storage

Evaluate different configurations of energy storage (power:energy ratios) on system economics *and* stability

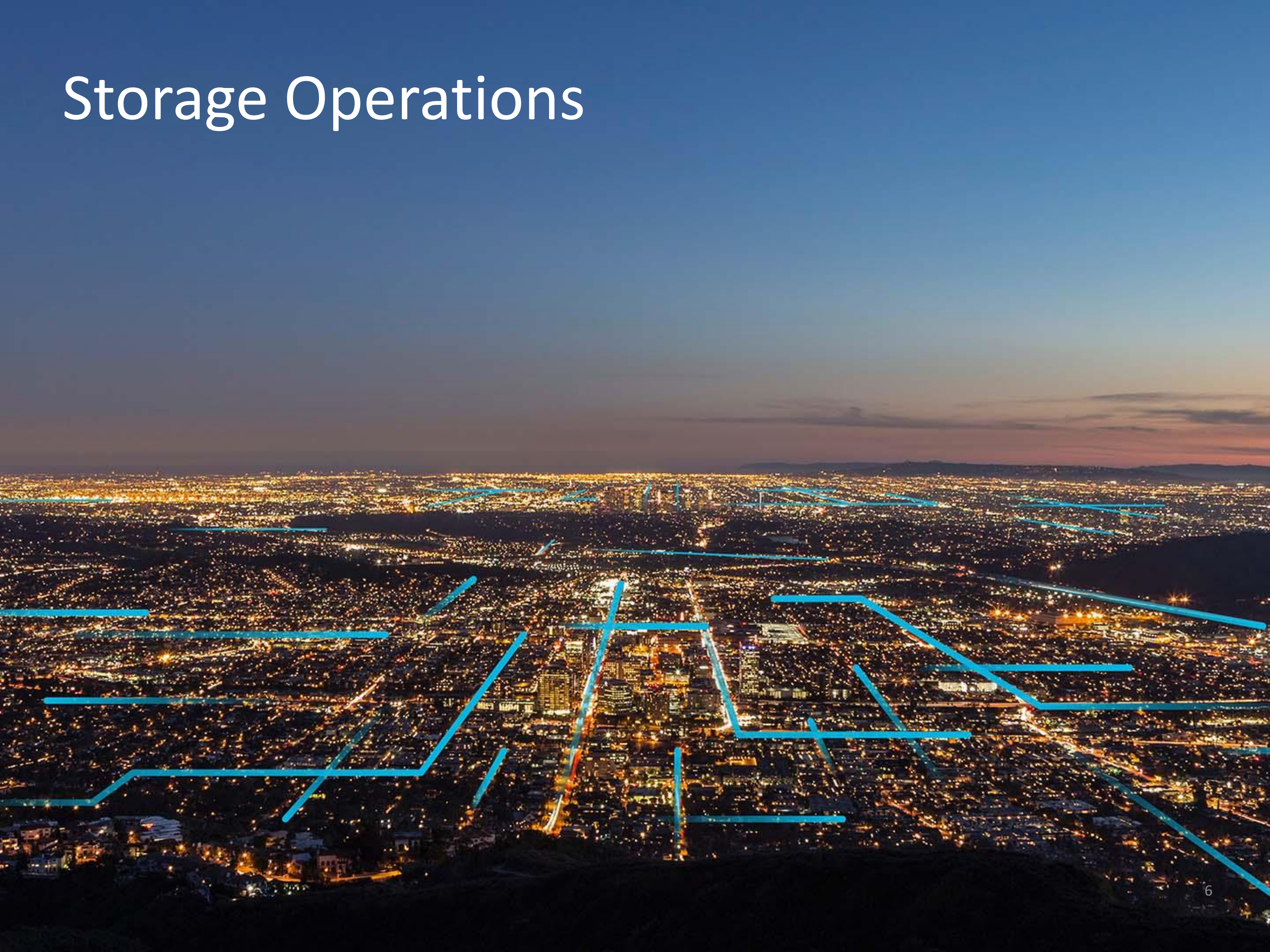
- Considering energy shifting, ramp rate support, regulation and contingency reserves, etc.
- Calculate *both* economic benefits (production cost savings) and capital costs to determine the net benefits and/or break-even costs of storage.
- Determine appropriate sizing, from a MWh and inverter rating perspective

Assumptions:

- Grid operator has control over the storage asset
- Assumes take-or-pay (fixed cost) for wind and solar, absorbing curtailment is direct savings
- Storage can be utilized for both arbitrage and reserves (when charging, idle with SoC, or discharging below max)
- 90% round-trip efficiency
- Not evaluating voltage support, transmission/distribution services, or capacity value

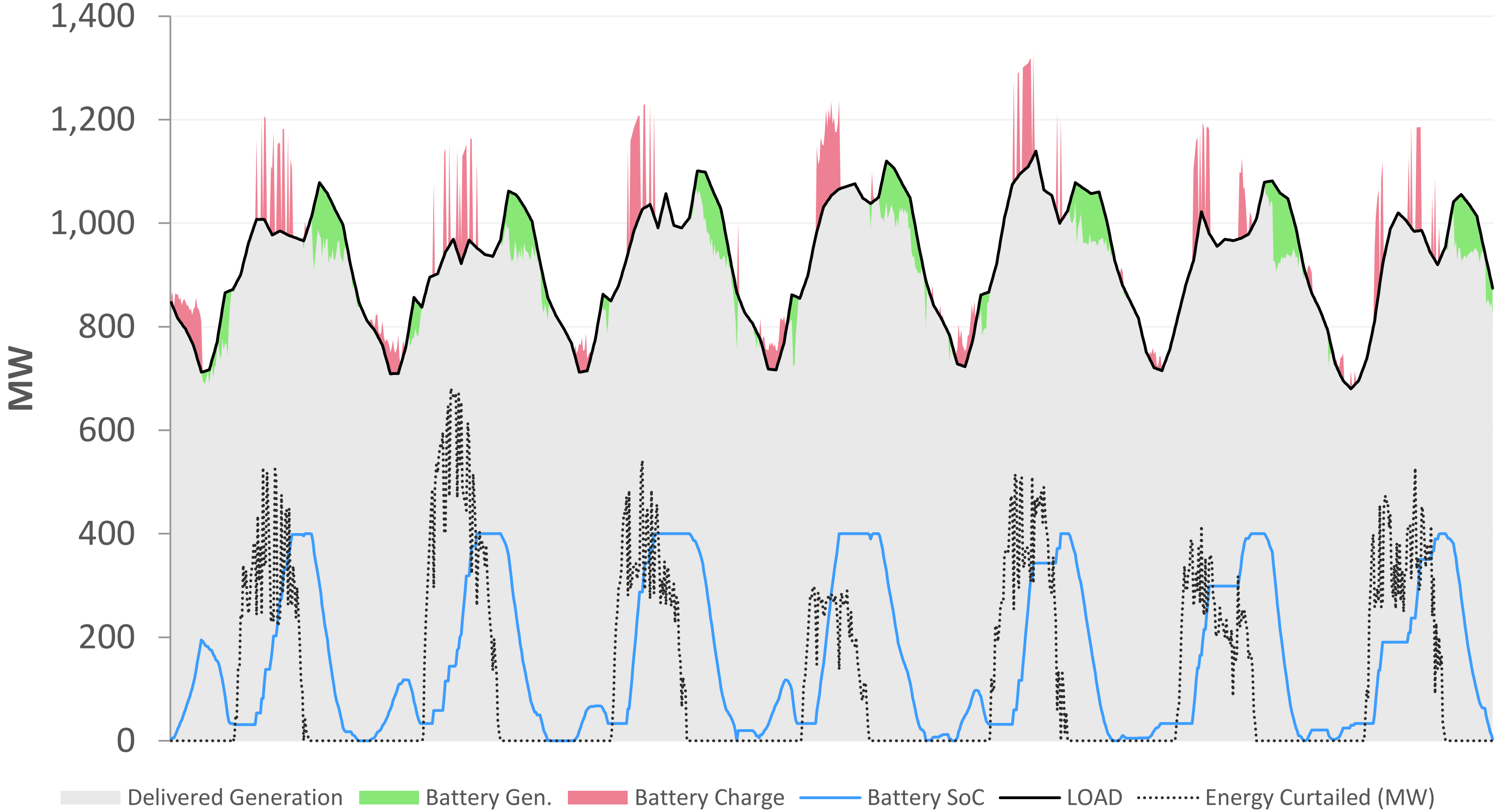
Energy (MWh)		Power (MW)			
		25	**50**	**100**	**200**
Storage (Hrs)	**0.50**	12.5	25	50	100
	1.00	25	50	100	200
	2.00	50	100	200	400
	4.00	100	200	400	800

Storage Operations



Storage Utilization (example week)

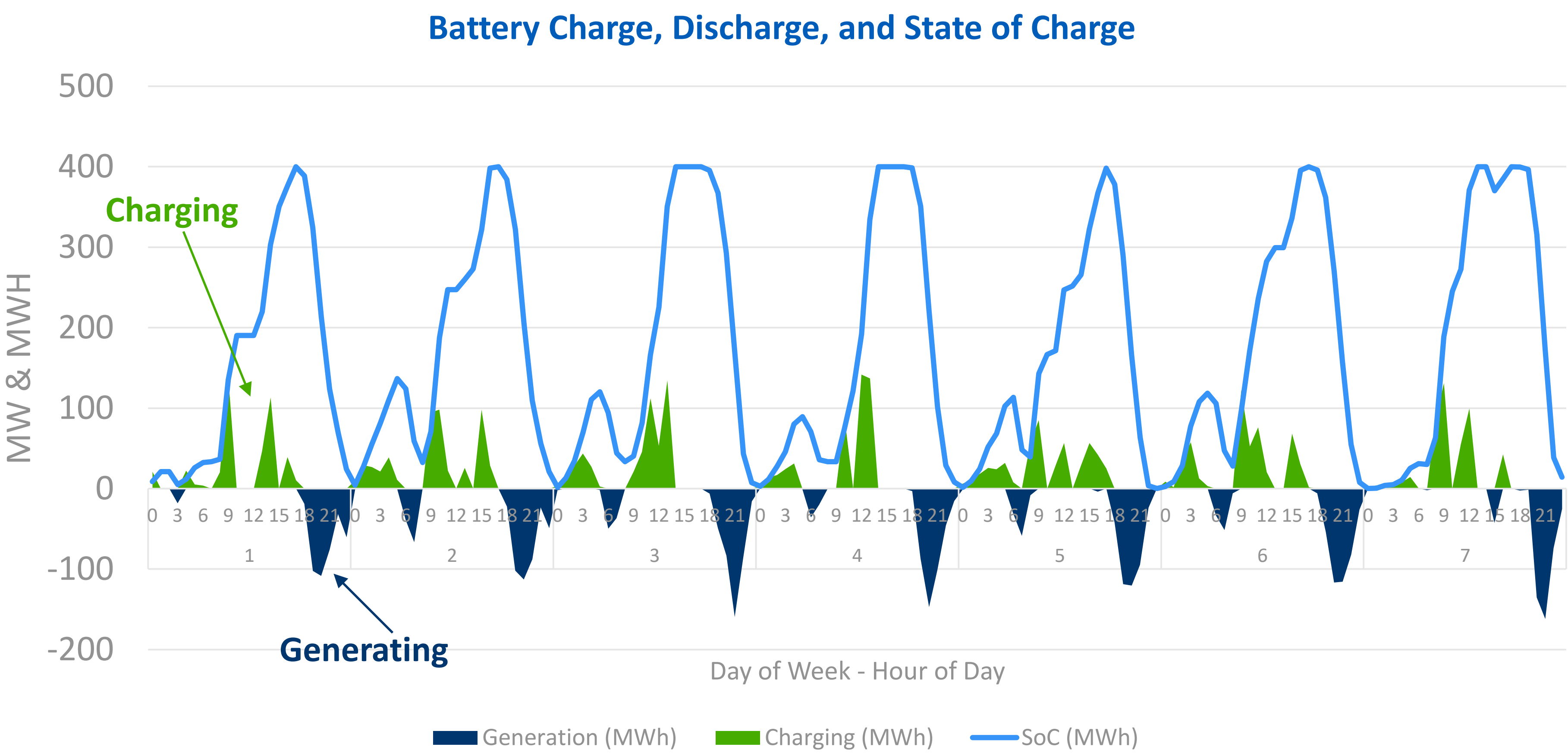
200MW-2HR
Battery
Week 5



- Storage absorbs excess curtailed energy mid-day, for use in early evening peaks
- This pattern is seen consistently throughout the year

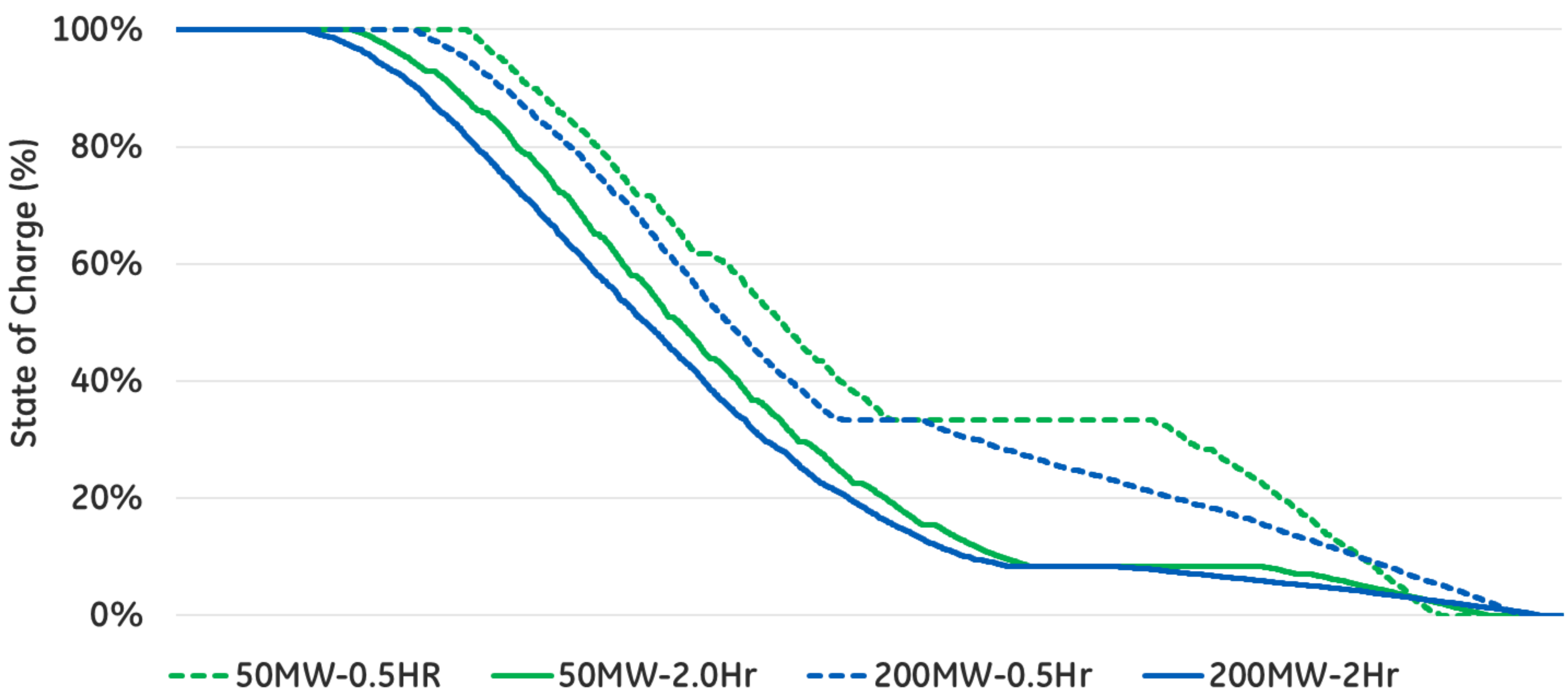
State of Charge Profile

200MW-2HR
Battery
Week 5



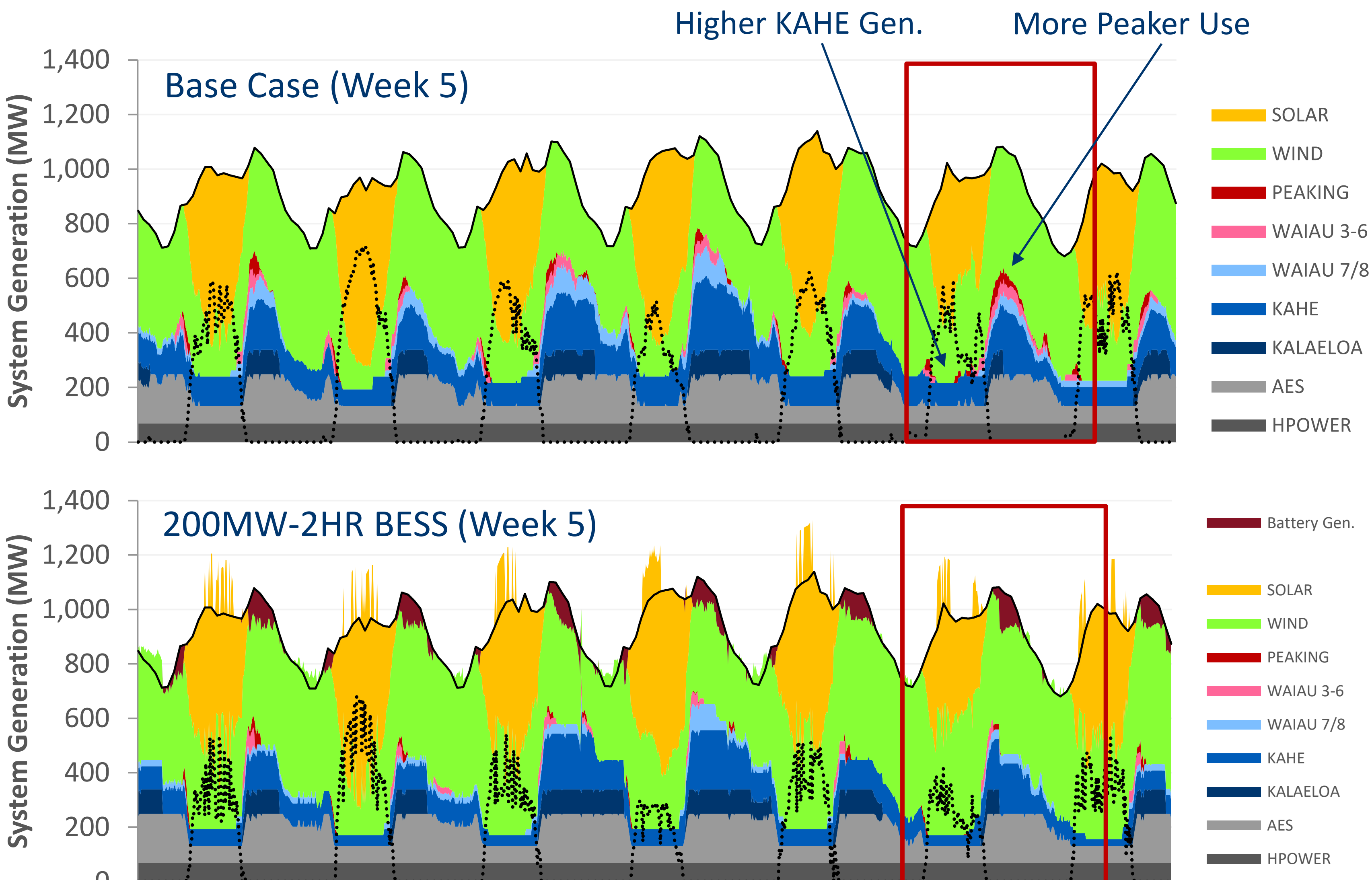
- State of Charge represents how much is "in the tank". Raises when charging, falls when generating
- Typically peaks towards end of afternoon after absorbing excess curtailed renewable energy

Storage State of Charge (SoC) Duration Curves

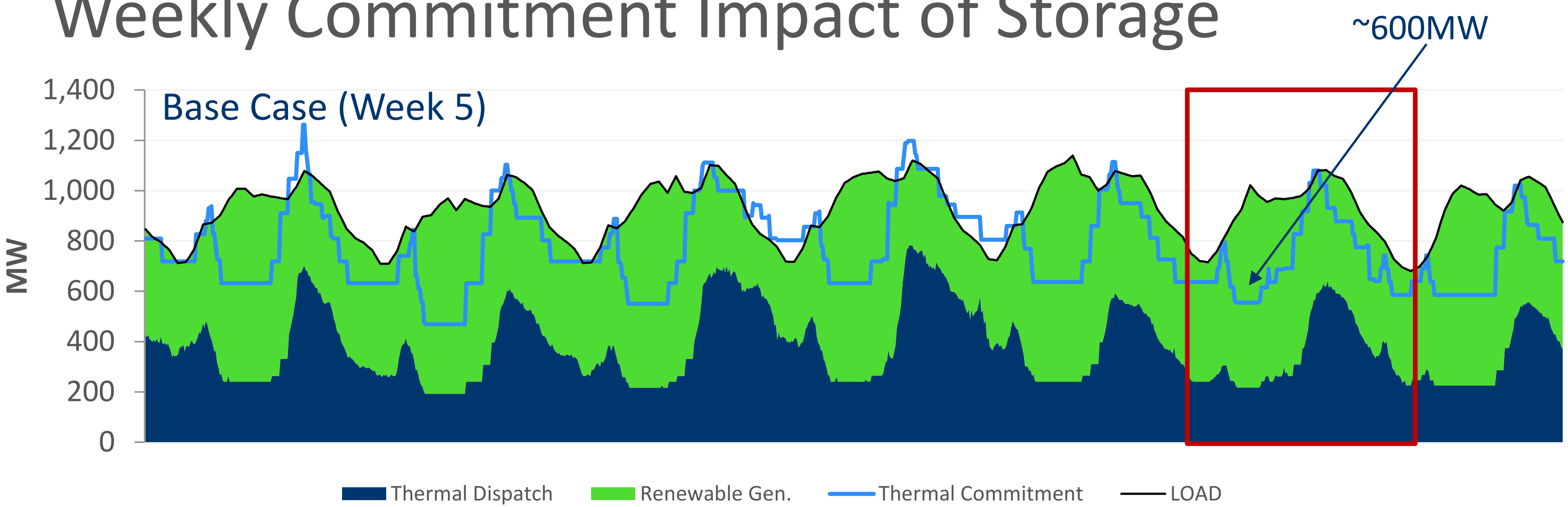


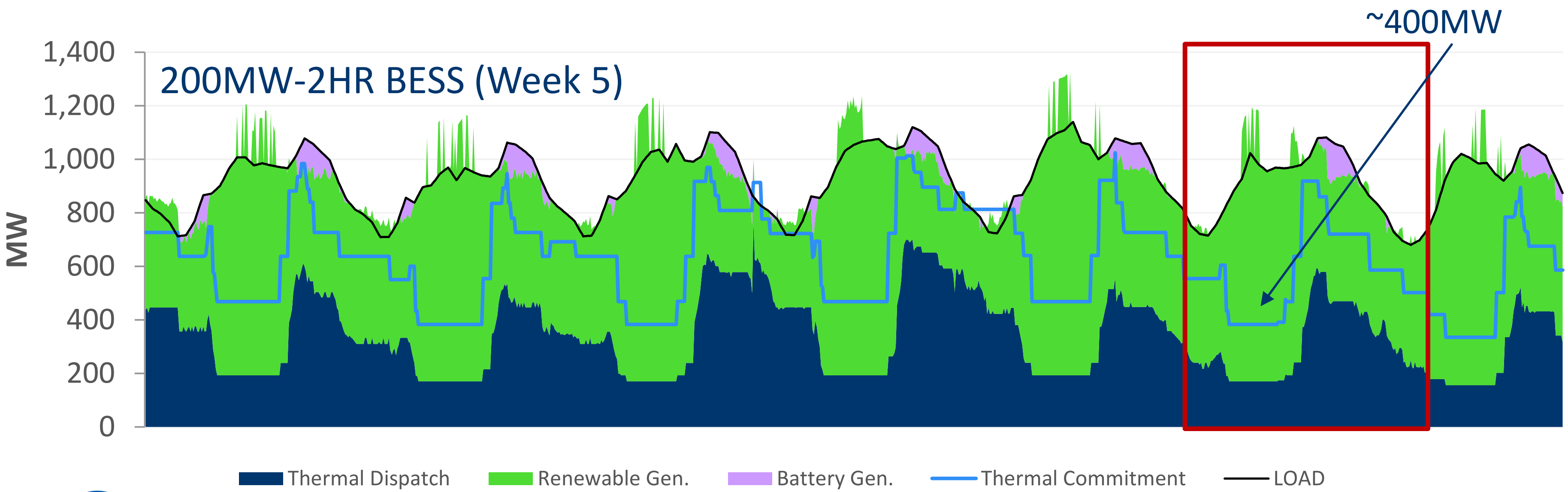
- Within each power class, the units with higher energy ratings spend more time at a lower SoC
- With additional energy, units can be held back less, while still providing reserves (solid lines)
- Units with less energy spend more time fully charged for reserve provision (dashed lines)

Weekly Dispatch Impact of Storage



Weekly Commitment Impact of Storage

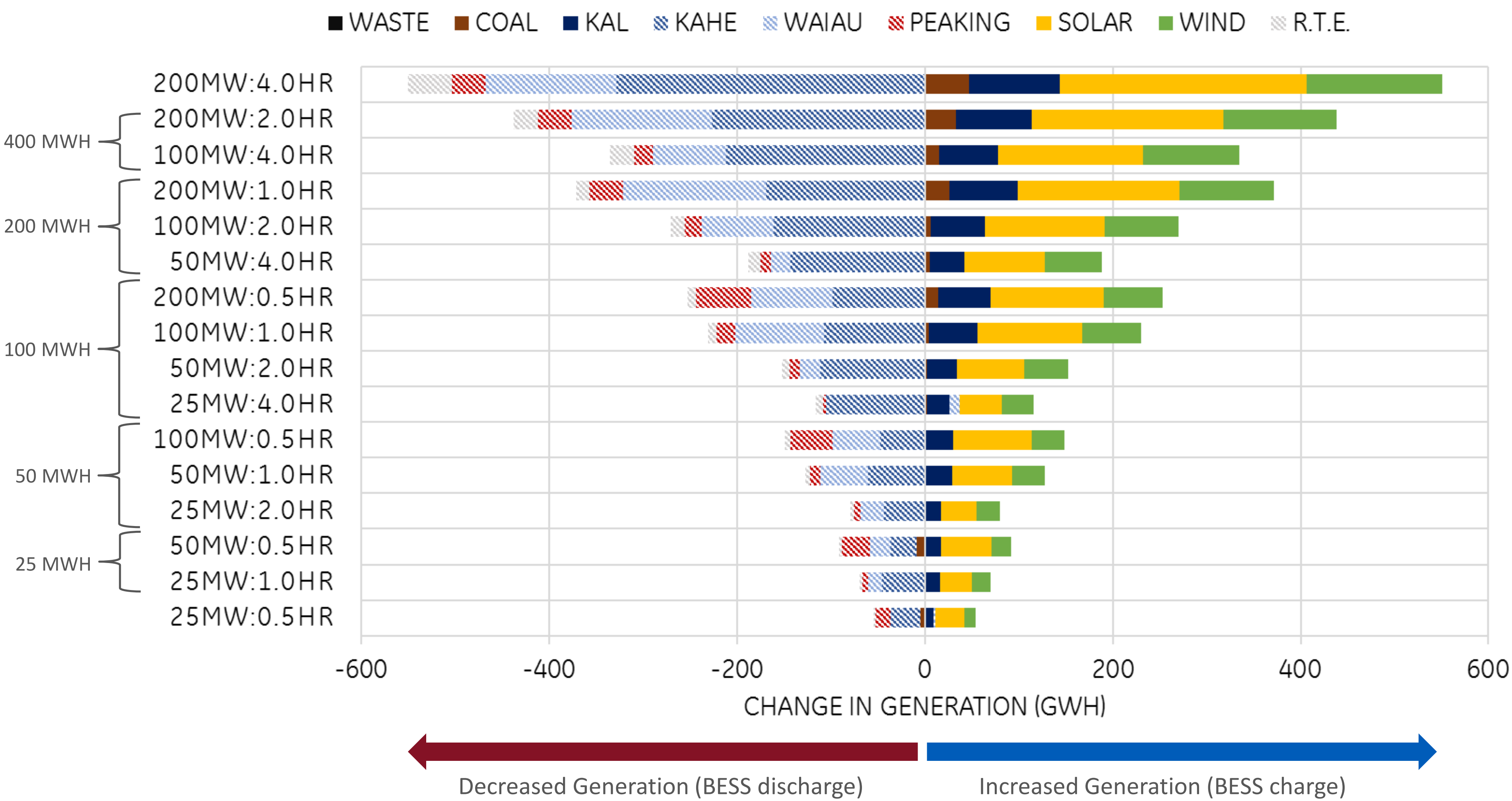




Scenarios Evaluated

TABLE I. Overview of Future Grid Scenario Assumptions		
	Current Power System	50% Wind and Solar System
Peak Load (MW)	1,225	1,225
Annual Energy (GWh)	7,734	8,450
Electric Vehicles (GWh)	44	791
Wind & Solar Capacity (MW)	809	1965
Utility-Scale Wind	123	565
Utility-Scale Solar	148	565
Distributed PV	538	840
Available W&S (GWh)	1547	4225
Available W&S (% of Load)	20%	50%

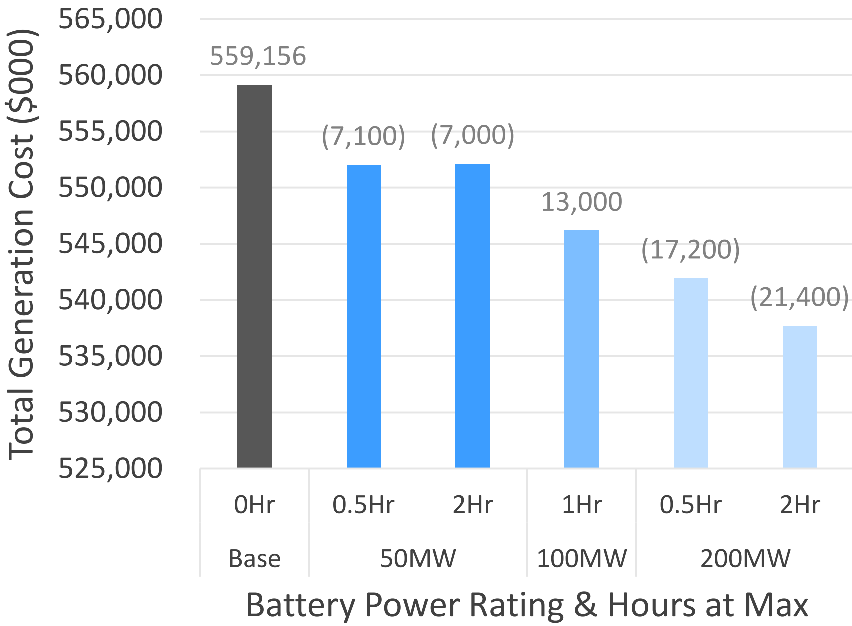
Change in Generation by Type with Storage



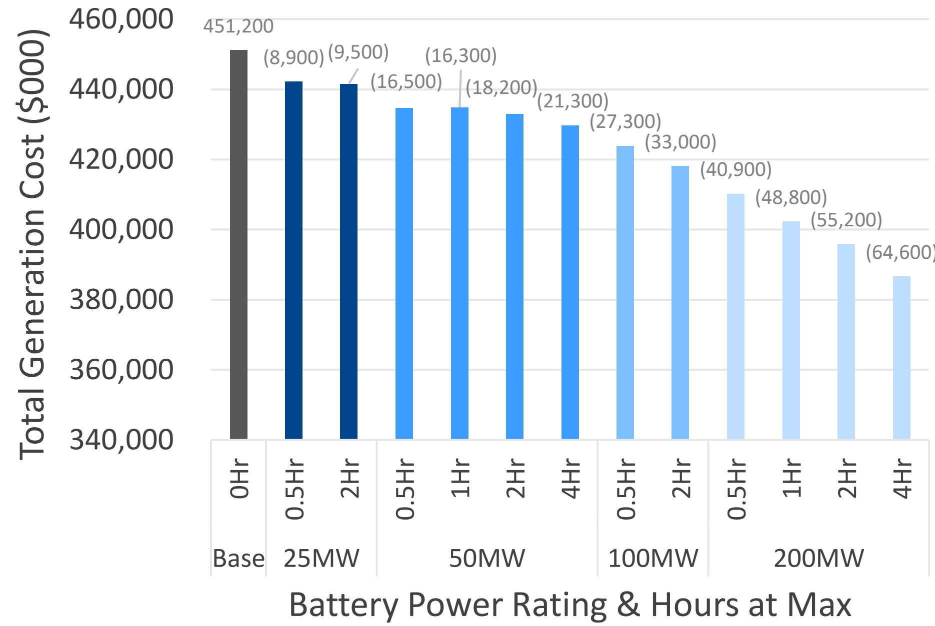
Economic Benefits of Storage

Production Cost Savings by BESS Configuration

20% Wind & Solar System Operating Cost by Battery Configuration



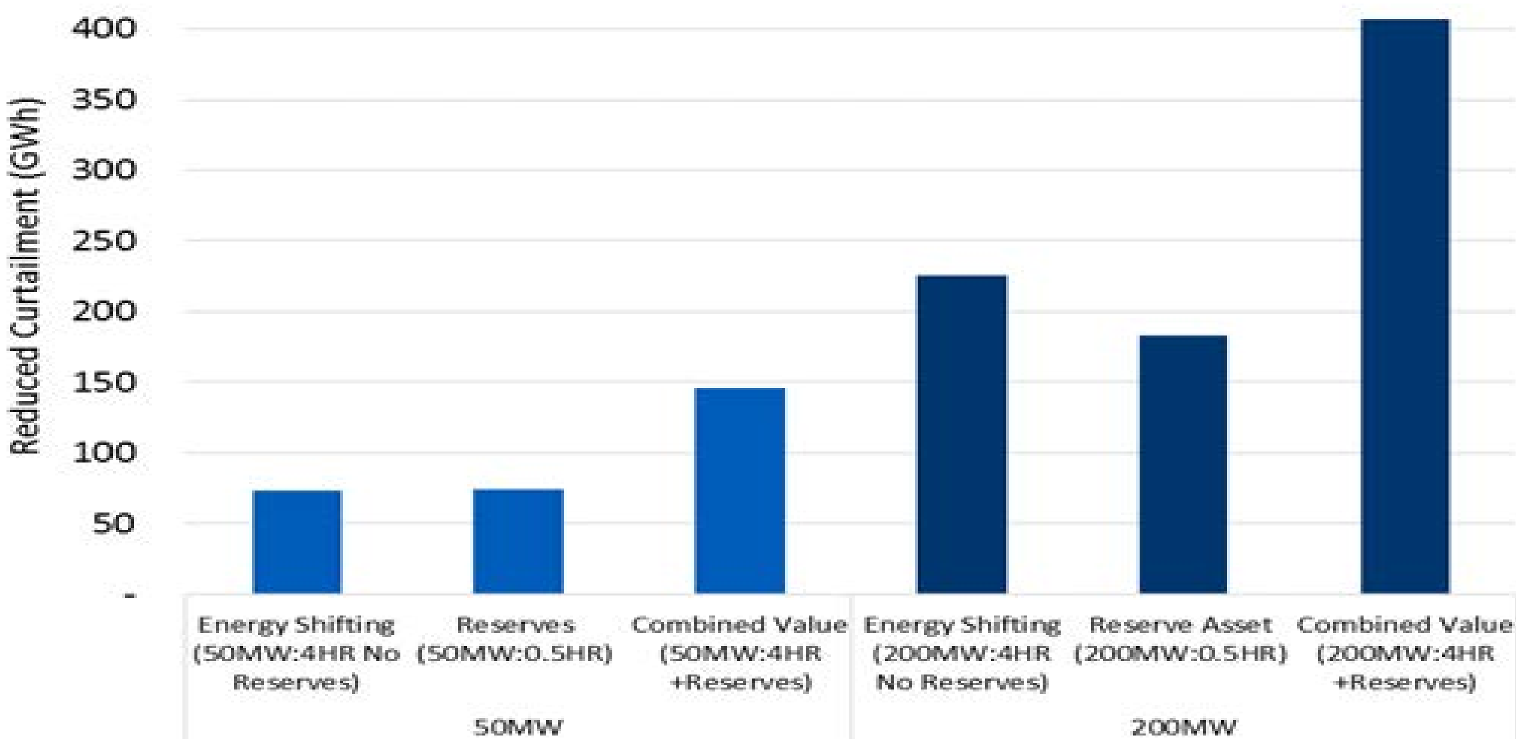
50% Wind & Solar System Operating Cost by Battery Configuration



- Production cost savings due to decreased curtailment, less thermal unit commitment, and increased generation from lower cost thermal resources (assumes take-or-pay W&S)
- Savings increase with larger power rating, and to a lesser extent larger energy rating

Energy Shifting Compared with Reserves

Production Cost Savings by BESS Use Case				
Power Rating	Energy (MWh)	BESS Use Case	Annual Production Cost (k$)	Annual Savings (k$)
Base Case	N/A	N/A	451,222	
50 MW	25 MWh	Reserves	434,706	16,516
50 MW	200 MWh	Energy Shifting	436,151	15,071
50 MW	200 MWh	Combined	429,949	21,273
200 MW	100 MWh	Reserves	409,224	41,998
200 MW	400 MWh	Energy Shifting	411,614	39,608
200 MW	400 MWh	Combined	383,646	67,576



Key Findings

Preliminary analysis and current assumptions, suggest that:

- ✓ Storage can be co-optimized to provide both reserves and arbitrage
- ✓ Charging mostly takes place during mid-day hours, discharge during evening peak
- ✓ Energy storage will increase generation from wind and solar (decreased curtailment) along with more efficient and lower cost thermal resources (Kalaeloa CC, AES)
- ✓ Increasing power rating (inverters) is less expensive than increasing energy rating (lithium-ion cells)
- ✓ Economic cost-benefit analysis favors high-power, low-energy ratio storage configurations

These Oahu-specific findings may be applicable to other island power systems

Thank You

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