Firm Capacity Value of Long Duration Energy Storage on an Island System

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TELOS ENERGY

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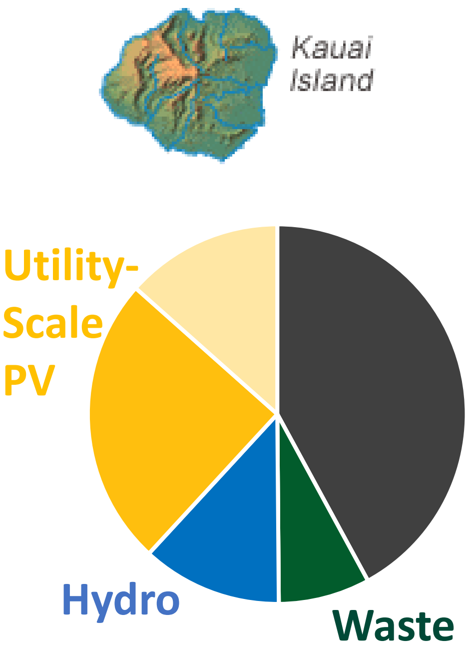
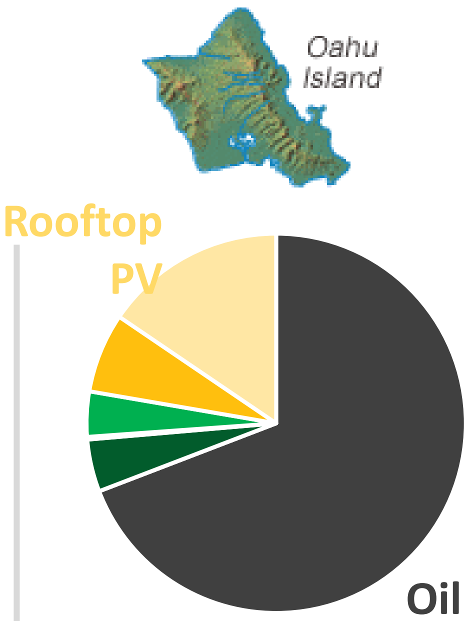
Six Isolated, Island Power Grids

Each with unique resource mix and renewable integration challenges



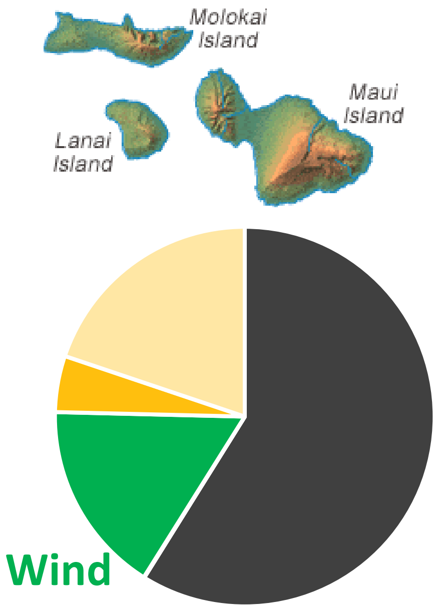
58% Renewable

- 75 MW peak load
- **Cooperative utility model (non-HECO)**
- Early adopter of solar+storage
- Highest solar share



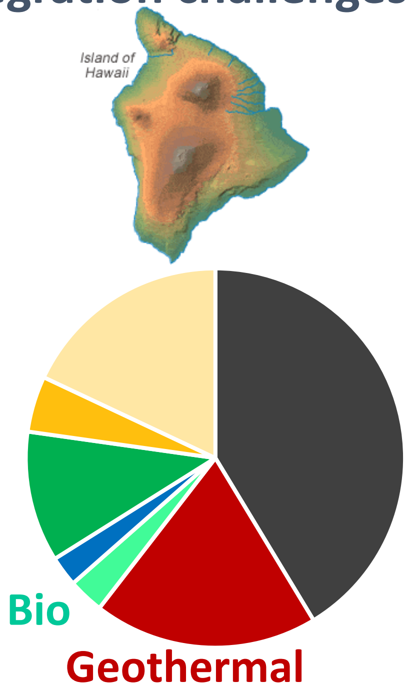
31% Renewable

- 1200 MW peak load
- **70% of state load**
- Coal (15% of energy) retired Sept 2022
- Rooftop PV largest source of renewables
- Land scarcity challenge



41% Renewable

- 200 MW peak load
- **Highest amount of wind energy (%)**
- Limited utility-scale PV
- Highest wind resource
- Near-term grid stability challenges

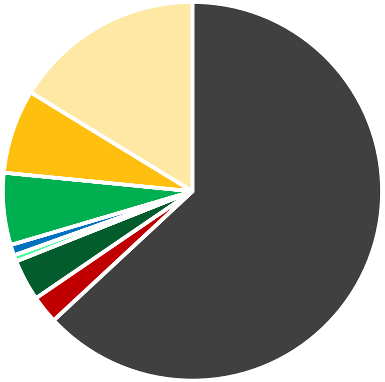


59% Renewable

- 200 MW peak load
- **Only island with operating geothermal**
- No utility-scale PV deployment to date
- Largest land area and renewable potential

State of Hawaii

2024 Actuals

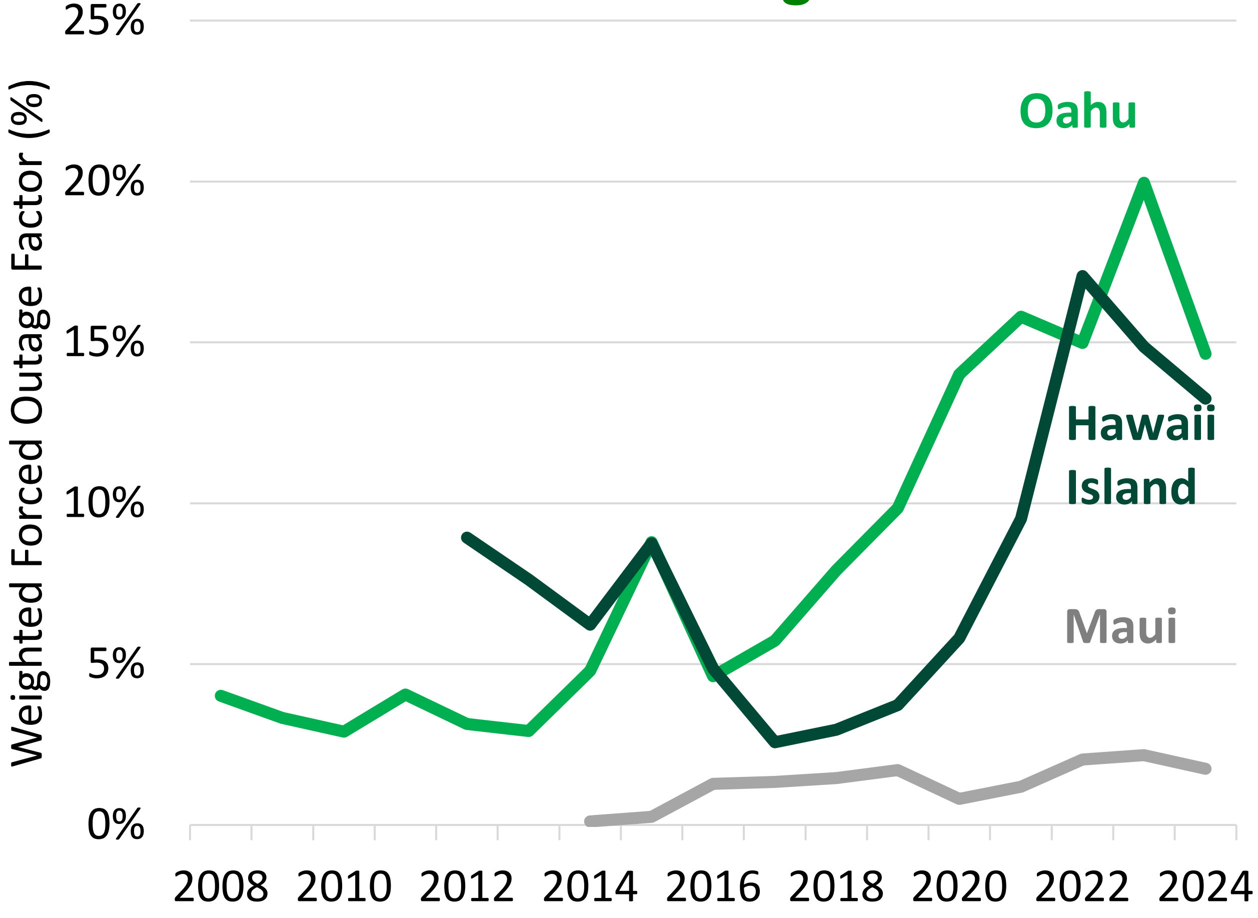


37% Renewable

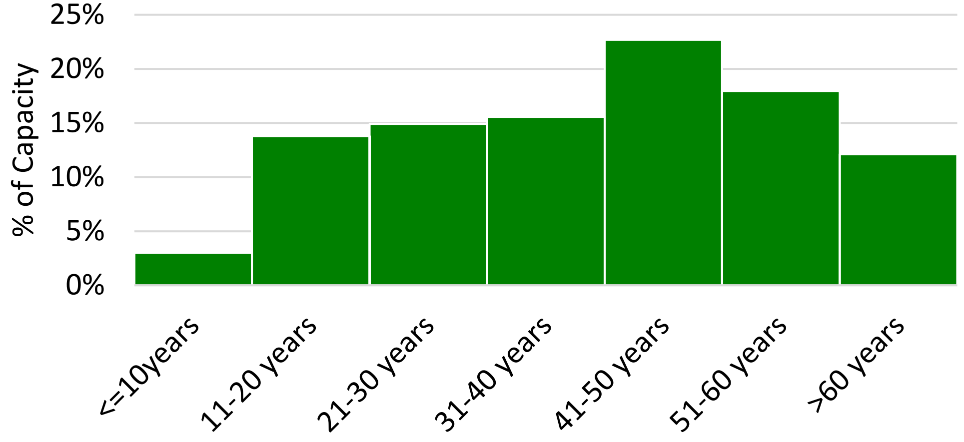
Legend
Oil
Waste
Bio
Geothermal
Hydro
Wind
Utility Scale PV
Rooftop PV

An aging oil fleet creating reliability challenges

Aging Steam Oil Fleet 15% Forced Outage Rate



~70% of Hawaii's thermal capacity over 30 years old



- Increased maintenance and forced outages causing reliability challenges
- Solar and storage can reliably replace some, but not all, firm capacity.

Long Duration Energy Storage Analysis

Enabling oil capacity retirements on an aging and islanded fleet

Study Objectives

Scope and Objectives
1. Evaluate firm capacity needs at increasing levels of solar and storage additions. 2. Quantify how LDES can reduce the amount of firm capacity needed. 3. Compare reliability contributions of firm capacity (CT/IC) against LDES 4. Evaluate modeling challenges of multi-day LDES in resource adequacy tools

Out of Scope (for now)
• Capital cost comparisons between LDES and CT/IC capacity • Optimal portfolio composition with and without long-duration storage • Review of specific HECO RFP proposals

Scenarios and Solar + Storage Levels Evaluated

SCENARIOS

1) NO FIRM CAPACITY ADDITIONS
Existing Oahu oil fleet

2) 350 MW FIRM CAPACITY ADDITIONS
New CT/IC capacity

3) 350 MW LDES CAPACITY ADDITIONS
35,000 MWh of 100-hr storage

All cases include 800 MW of rooftop solar

SOLAR LEVELS

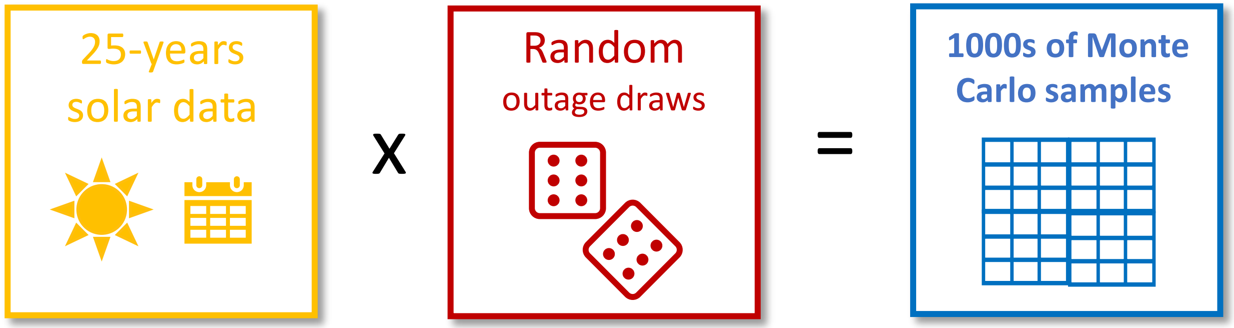
A) ~40% RPS
500 GWh of PV+BESS

B) ~45% RPS
1000 GWh of PV+BESS

C) ~55% RPS
2000 GWh of PV+BESS

D) ~70% RPS
3000 GWh of PV+BESS

Resource Adequacy to Evaluate LDES-Enabled Oil Capacity Retirements



- Historical solar and wind variability applied to future grid
- Uncertainty and timing of generator outages considered
- Detailed characterization of loss of load events
- PLEXOS stochastic simulations

Modeled 520 simulations per case
~4.5 million hours of simulation per case

Loss of Load Hours by Sample

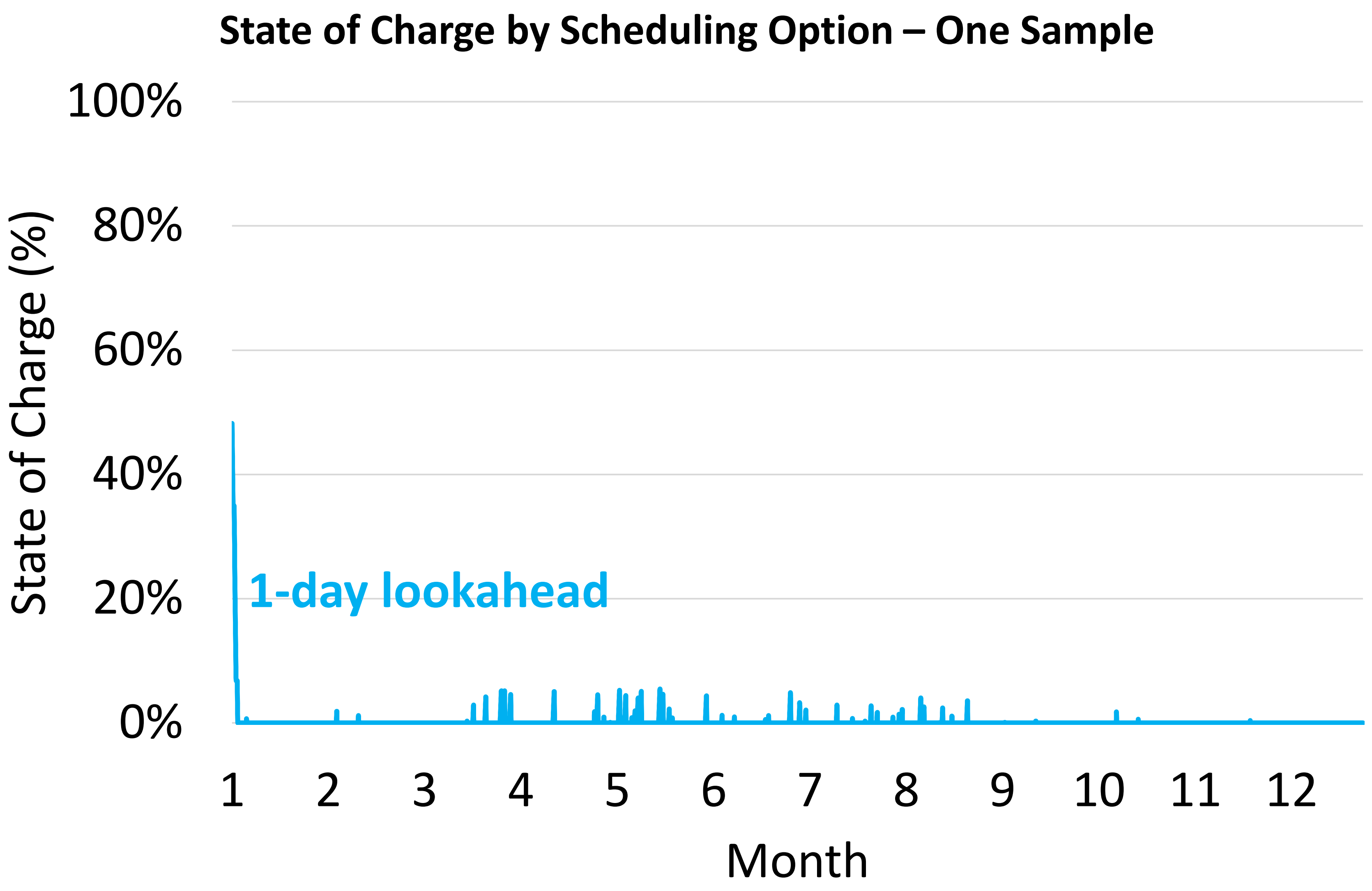
Outage Draws (columns) / Solar Years (rows)

Solar Year	1	2	3	4	5	6	7	8	9	10	11	12
1998	0	0	10	3	0	0	2	0	3	6	0	0
1999	2	0	9	0	3	0	0	0	0	0	3	0
2000	0	0	0	0	0	0	0	2	0	0	6	0
2001	0	0	0	2	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	6	0	0	0	0
2003	0	0	1	0	0	0	0	0	0	0	0	1
2004	0	2	0	0	0	1	0	0	0	0	0	0
2005	0	0	0	4	0	0	0	1	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	3	0
2007	0	3	0	0	0	2	0	0	0	0	0	0
2008	3	0	0	0	0	0	0	5	0	0	0	0
2009	0	0	2	0	1	0	0	1	0	0	3	0
2010	0	0	0	0	0	0	0	0	0	0	0	0
2011	11	0	2	0	0	0	0	0	1	0	3	0
2012	0	3	0	0	0	0	0	0	0	0	0	0
2013	2	0	3	3	0	2	0	0	0	0	0	7
2014	0	0	10	0	0	0	0	0	0	0	0	0
2015	1	0	0	0	3	0	8	0	0	0	0	0
2016	0	1	0	2	0	0	0	0	1	0	0	0
2017	0	0	0	0	0	0	1	1	0	0	0	0
2018	0	10	0	0	0	0	0	0	0	0	0	1

Scheduling Long Duration Energy Storage

Challenges with modeling multi-day long duration energy storage

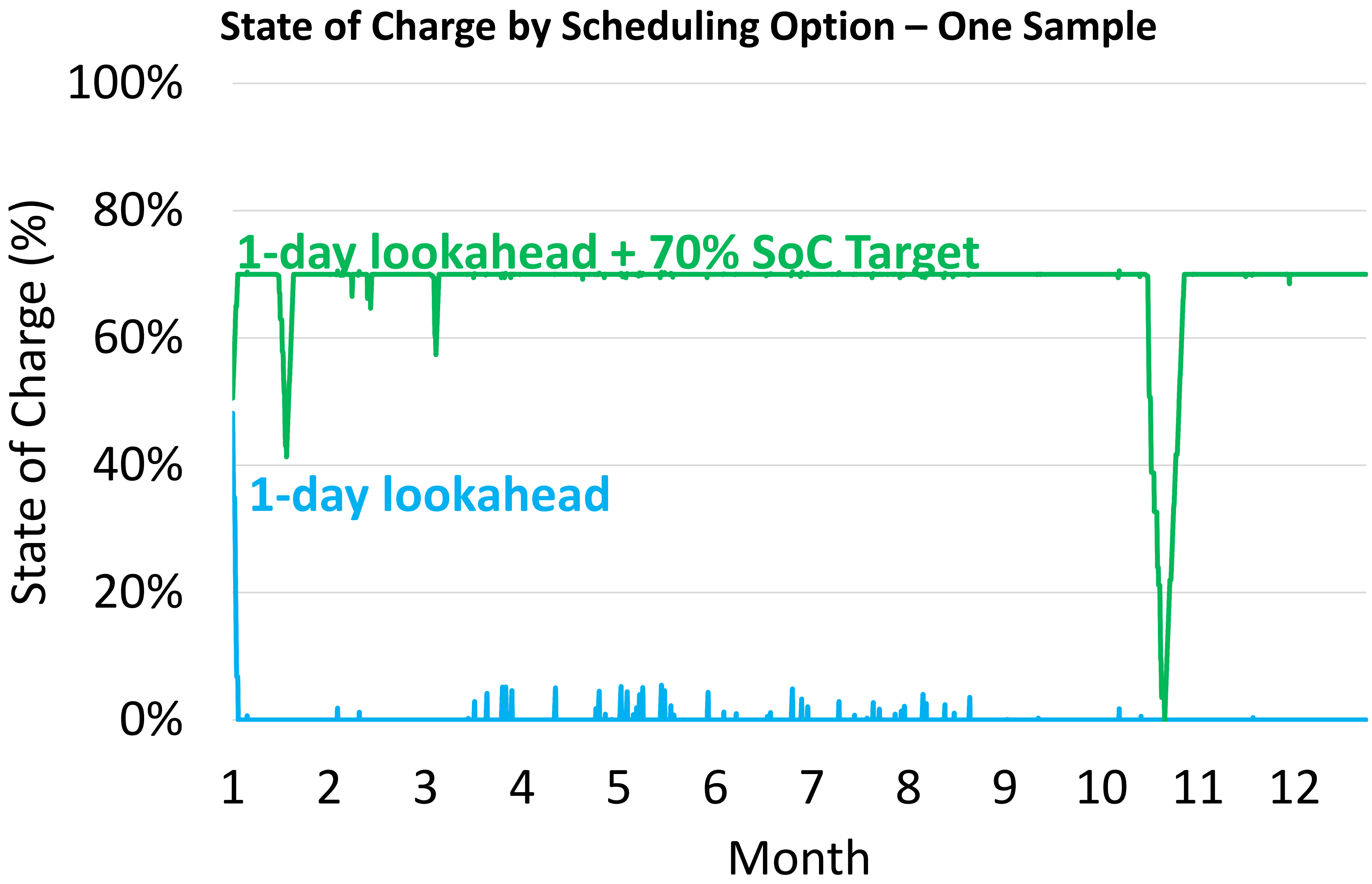
Multi-Day Storage Scheduling



Problem: without foresight or operating rules, the multi-day battery does not contribute to reliability.

Analysis: Assess different modeling methods to balance realism, cost, and reliability.

Multi-Day Storage Scheduling

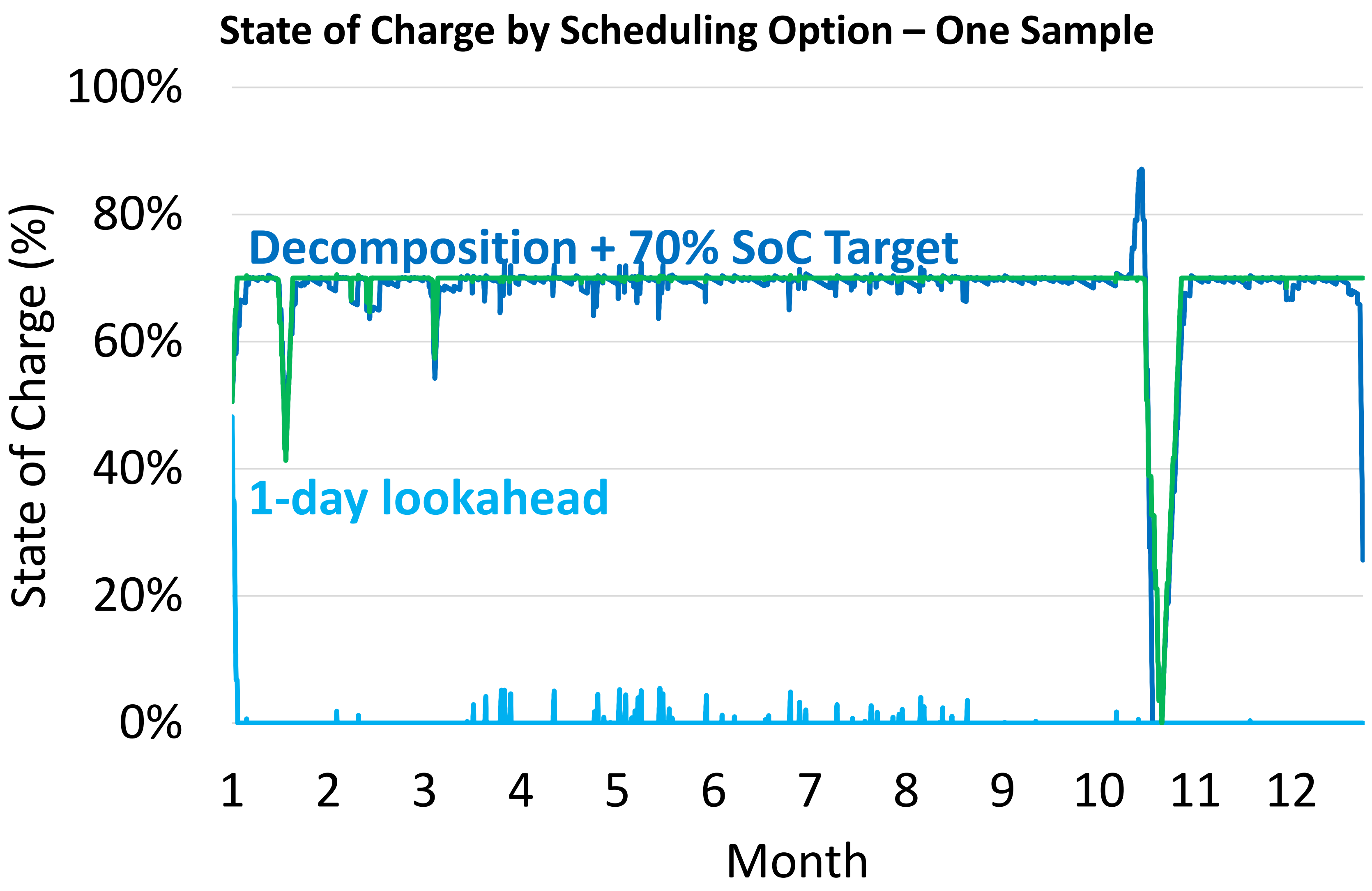


Option 1: give the model a state of charge (SoC) target that can be violated to avoid load shed.

Results: State of charge target is met and LDES cycles to avoid load shed.

LDES never charges above the target.

Multi-Day Storage Scheduling



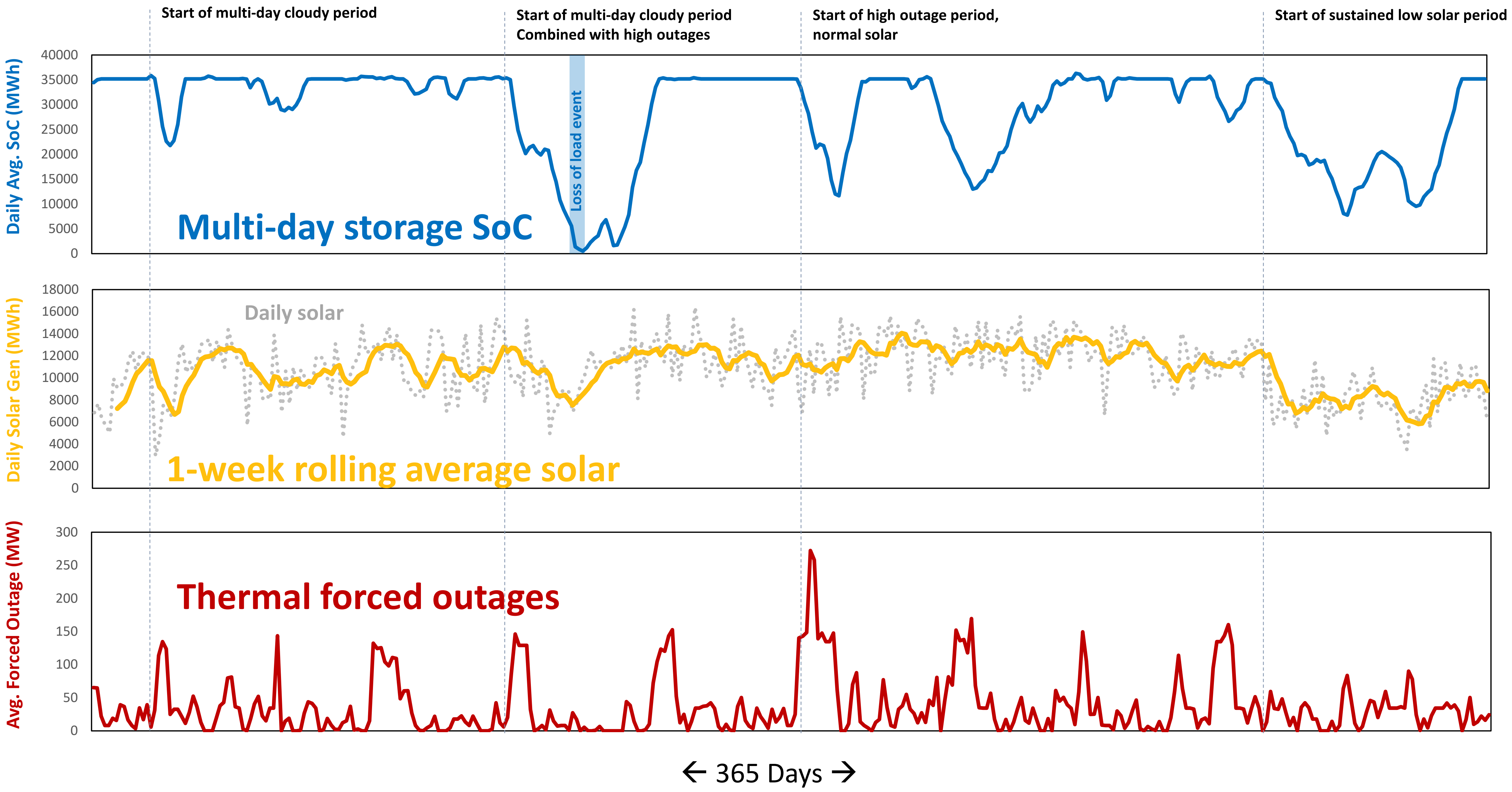
Option 2: Formulate storage decomposition targets + SoC target.

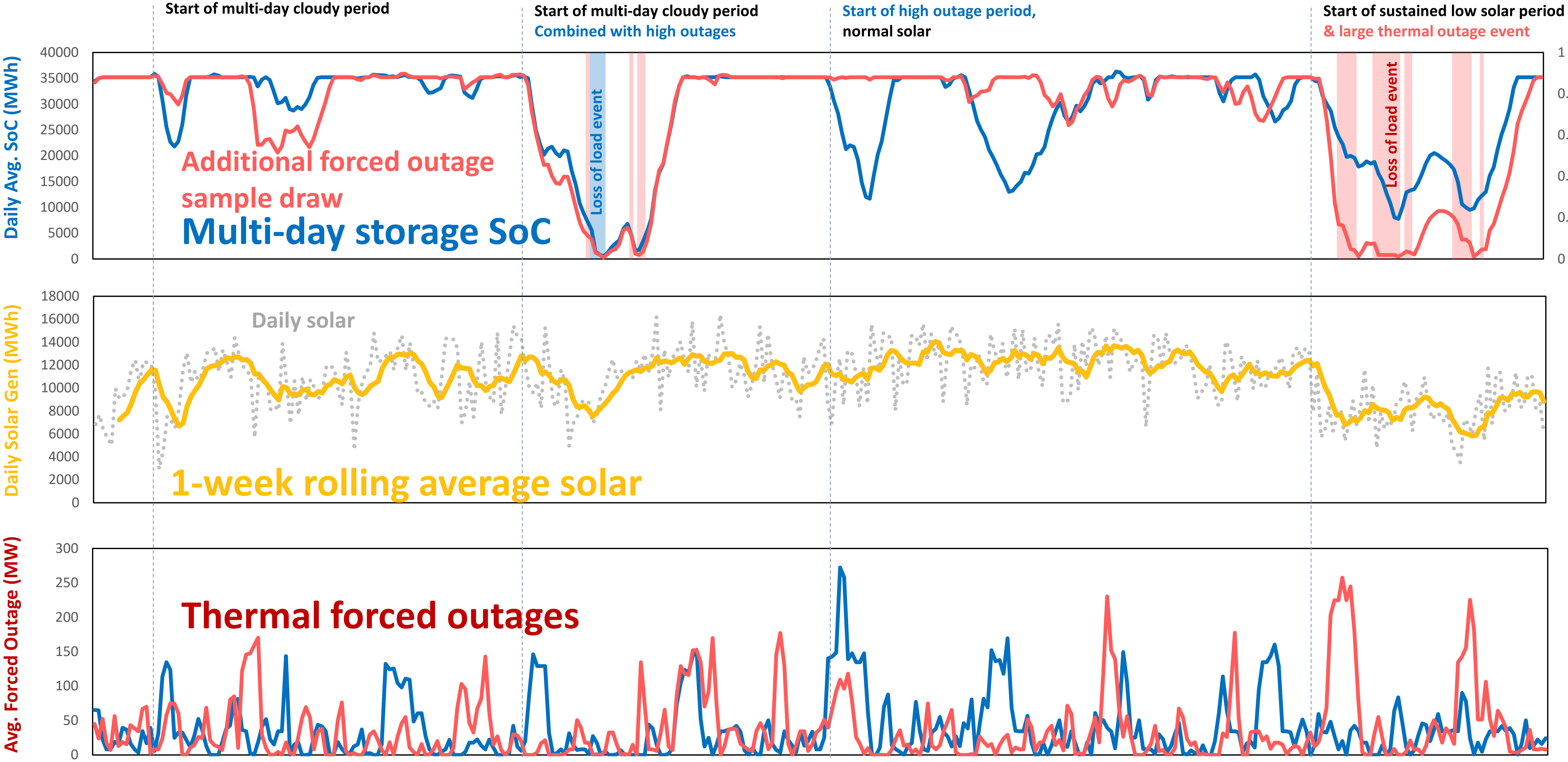
Results: Storage decomposition plus targets allows for "pre-charging" in advance of an event.

Downside is the decomposition "knows" about random outage events.

Modeling Long Duration Energy Storage

Storage State of Charge, Solar Availability, Thermal Forced Outages


Start of multi-day cloudy period
Start of multi-day cloudy period
Combined with high outages
Start of high outage period,
normal solar
Start of sustained low solar period
Daily Avg. SoC (MWh)
40000
35000
30000
25000
20000
15000
10000
5000
0
Loss of load event
Multi-day storage SoC
Daily Solar Gen (MWh)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Daily solar
1-week rolling average solar
Avg. Forced Outage (MW)
300
250
200
150
100
50
0
Thermal forced outages
← 365 Days →



Analysis will repeat across 520 combinations of weather years and outage draws, <u>across different scheduling options</u>

Modeling Long Duration Energy Storage

Reliability Metrics for 100-hr Batteries on O'ahu at to Enable Oil Capacity Retirements

Oahu Loss of Load Expectation Matrix

Oil Capacity Retirements Enabled by increasing solar + storage levels

Loss of Load Expectation (days/year) for Oahu

	Plant Name	Cumulative Retirement	45% RPS	55% RPS	70% RPS
Incremental Retirement		0			
	AES	180			
	W3-4	274	**0.04**		
	W5-6	382	**0.24**		
	W7	466		**0.10**	
	W8	551		**0.47**	**0.12**
	K1	635			**0.37**
	K2	720			
	K3	805			
	K4	889			
	K5	1024			
	K6	1159			

Solar + Storage Enabled Oil Capacity Retirements:

45% RPS: 274 MW

55% RPS: 466 MW

70% RPS: 551 MW

Oahu Loss of Load Expectation Matrix

Oil Capacity Retirements Enabled by 350 MW of 100-hr batteries at increasing solar + storage levels

Loss of Load Expectation (days/year) for Oahu

	Plant Name	Cumulative Retirement	45% RPS	55% RPS	70% RPS
Incremental Retirement		0			
	AES	180			
	W3-4	274			
	W5-6	382			
	W7	466			
	W8	551			
	K1	635	0.05		
	K2	720	0.58	0.03	
	K3	805		0.24	0.03
	K4	889			0.26
	K5	1024			
	K6	1159			

100-hr LDES Enabled Oil Capacity Retirements:

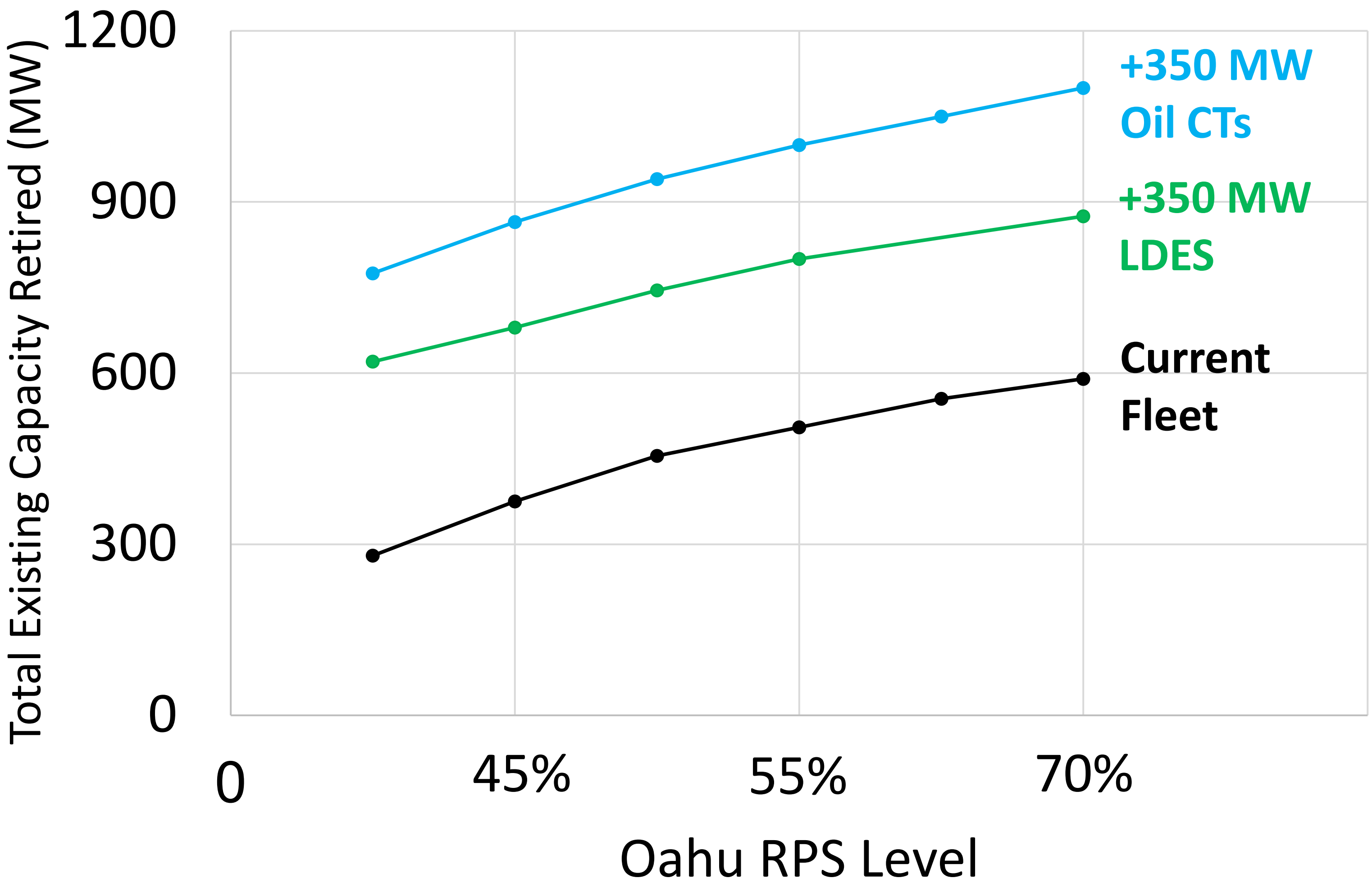
45% RPS: 635 MW (+361)

55% RPS: 720 MW (+254)

70% RPS: 805 MW (+254)

Oahu Oil Capacity Retirements Analysis

All data points represent a 0.1 days/year LOLE system at that RPS level



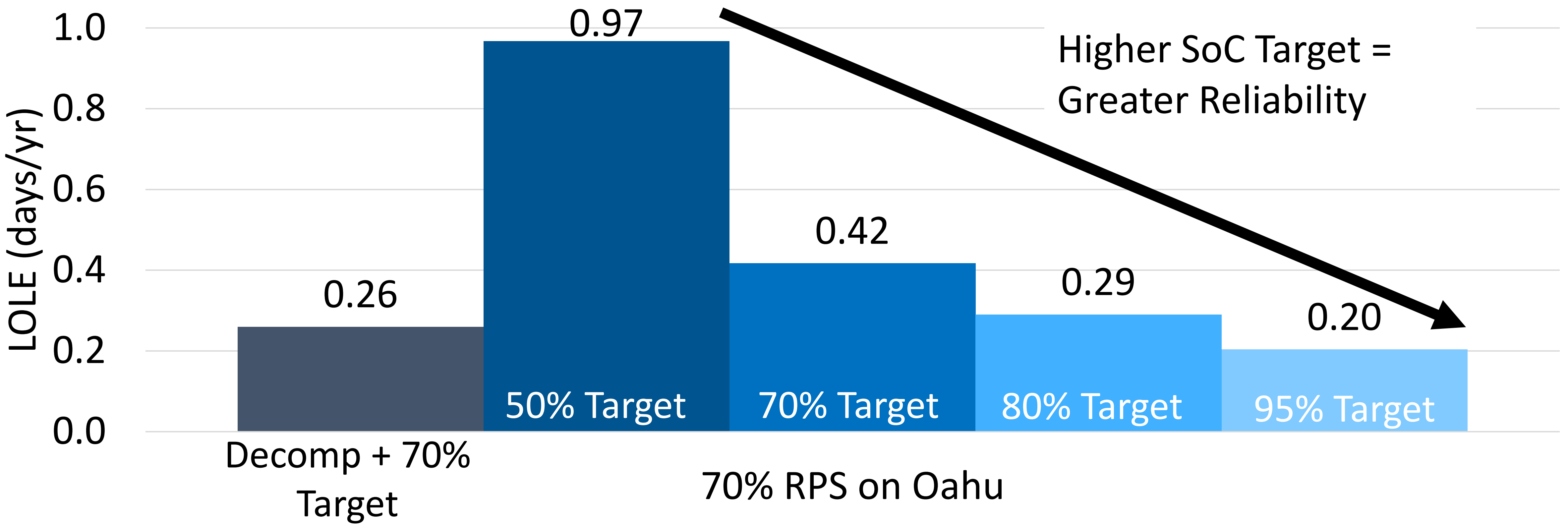
100-hr LDES can enable oil capacity retirements.

New, more efficient fossil units could enable greater retirements, but leave residual emissions.

Development of LDES or new fossil units in Hawaii will be challenging but is required as aging units are rapidly degrading.

LDES State of Charge Target Sensitivity

- Scheduling approach significantly changes reliability metrics when assessing multi-day LDES
- Work in progress to evaluate tradeoffs in costs when holding high reserves



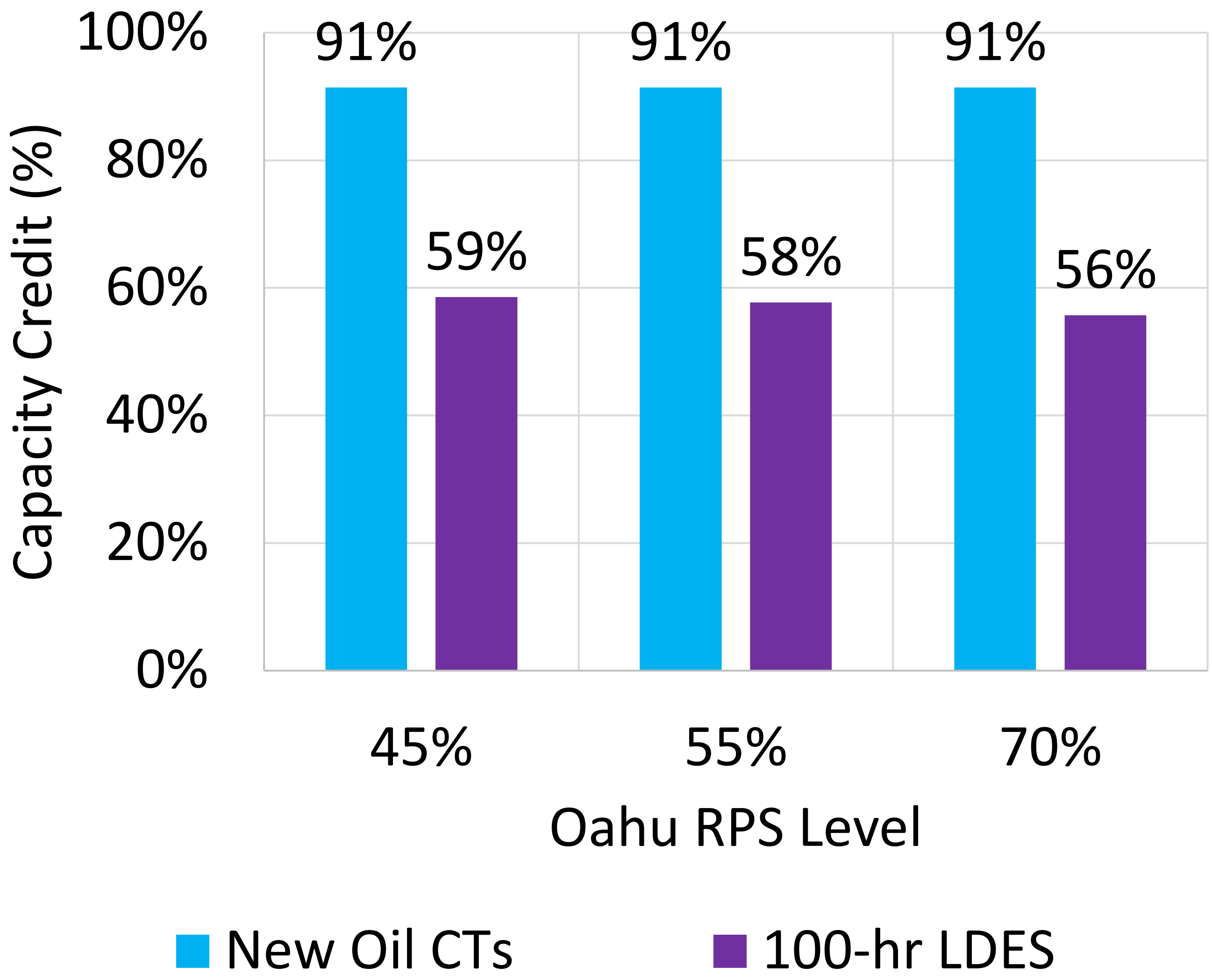
100-hr LDES and New Oil CT Capacity Value

As RPS levels increase with solar + storage (4-hr), LDES maintains ~55-60% ELCC.

This indicates strong performance of LDES in Oahu as solar grows.

<u>Results may differ with alternative renewable portfolios.</u>

New Oil CTs perform better, but conflict with Hawaii's goal to reduce oil dependency.



Takeaways for Multi-day LDES on an Island System

Island systems are unique, and results may not translate to continental systems.

Forced outages have a high impact on reliability (compared to weather) and there are no neighbors for support.

Multi-day batteries (100-hrs) in Oahu maintain an ELCC of ~55 to 60% even at very high RPS and 4-hour storage levels (40% to 70%).

For LDES, especially multi-day, model setup is crucial. Balancing realism vs over-optimization is essential to not overstate performance.

Thank You!

Questions?

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