Mid-Duration Energy Storage (MDES) Benefits and Challenges

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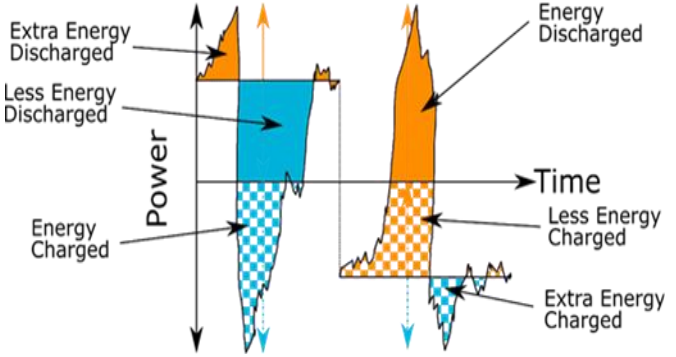
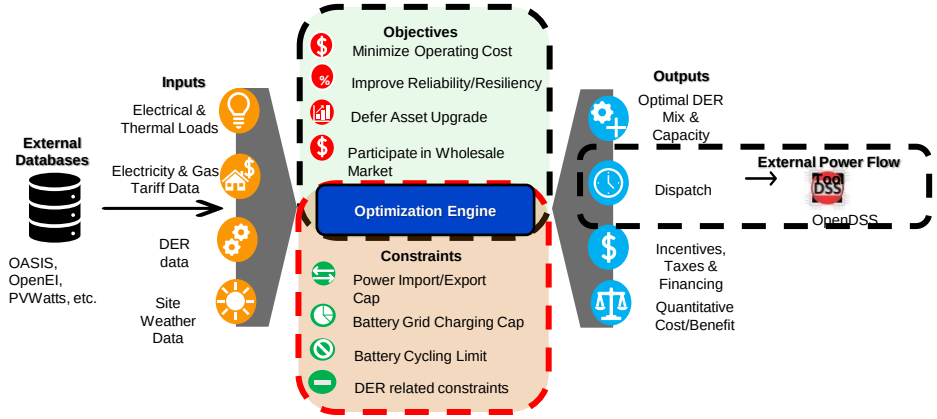
Background

- EPRI's DER-VET used to perform cost-benefit assessment
- Cost and performance data for MDES technologies obtained from developers
- 6-, 8-, and 10-hour durations selected for analysis
- Obtained pricing data from 2020–2045 for:
  - Multiple U.S. system operators
  - An example European grid



www.der-vet.com



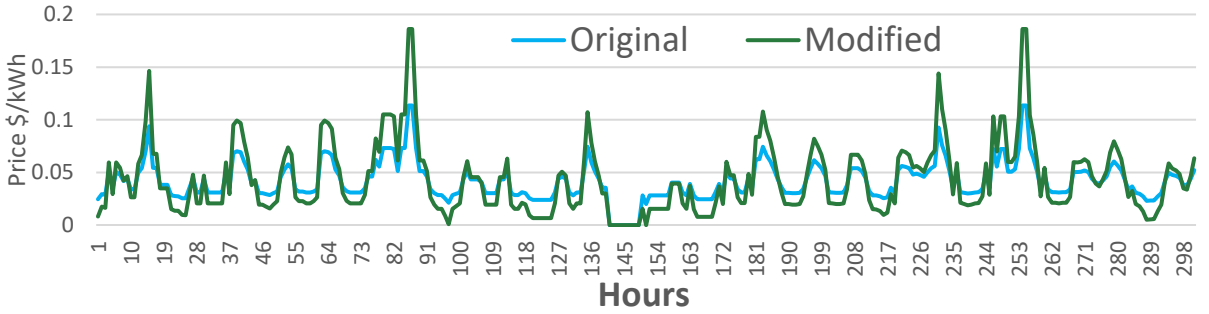
Understanding the future value potential of MDES

Energy Storage Technologies

Technology	Acronym
Thermal Energy Storage	TES
Gravitational Energy Storage	GES
Pumped Heat Energy Storage	PHES
Cryogenic Energy Storage	CES
Lithium-Ion Battery Storage	Li-Ion

- Modeling Inputs
  - Round-Trip Efficiency (Total AC power generated / total AC energy consumed)
  - Capital Costs (Anticipated costs for power [$/kW] & energy [$/kWh])
  - Operating Costs (Dwell energy losses, maintenance, and augmentation)
  - Startup Energy (Energy consumed during startup)

Use Cases



Base

- All technologies were run using the original pricing curves in each region for the 6-, 8-, and 10-hour duration cases (Li-ion batteries were also run at their prevalent 4-hour duration case)

Sensitivity Studies

- RTE was adjusted +/- 5% points
- Capital costs were adjusted +10% / -30%
- Energy prices were modified (mod) from their original (orig)

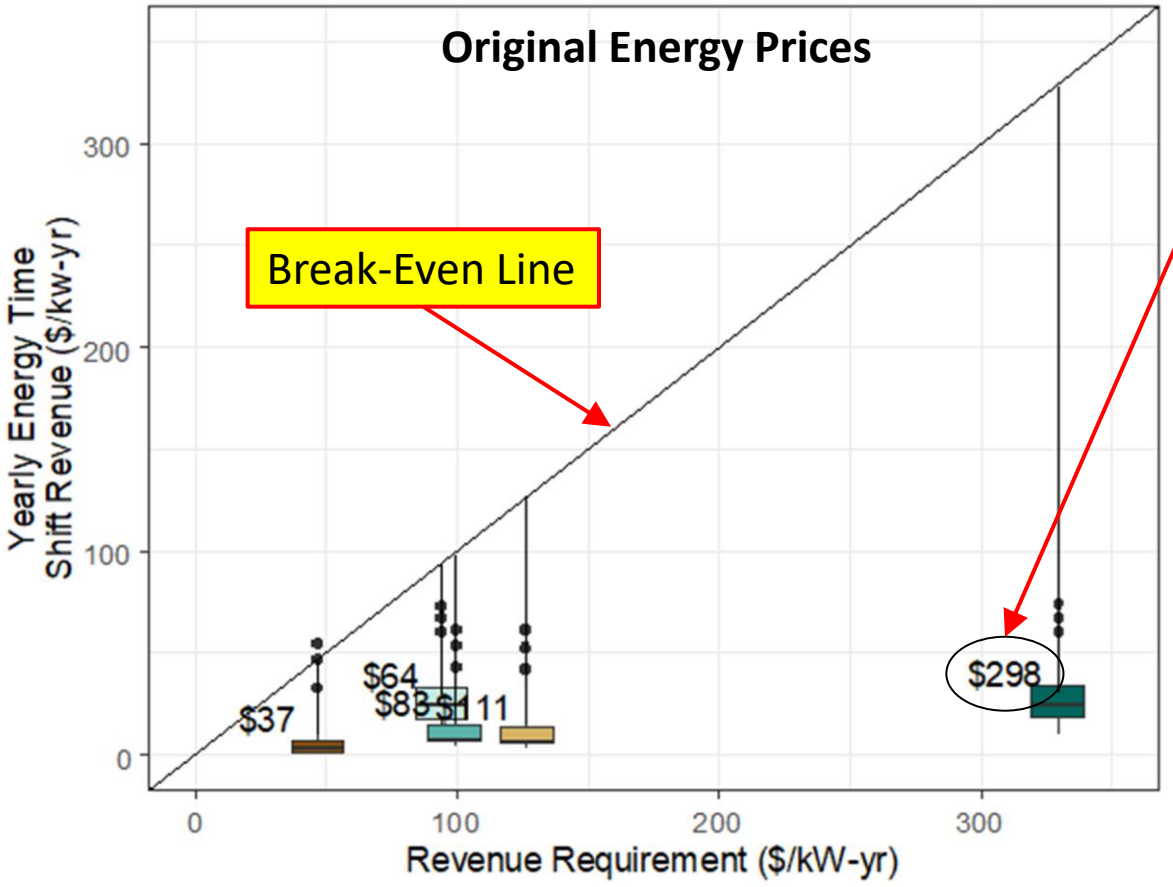
18 Cases per Technology per Hours of Duration

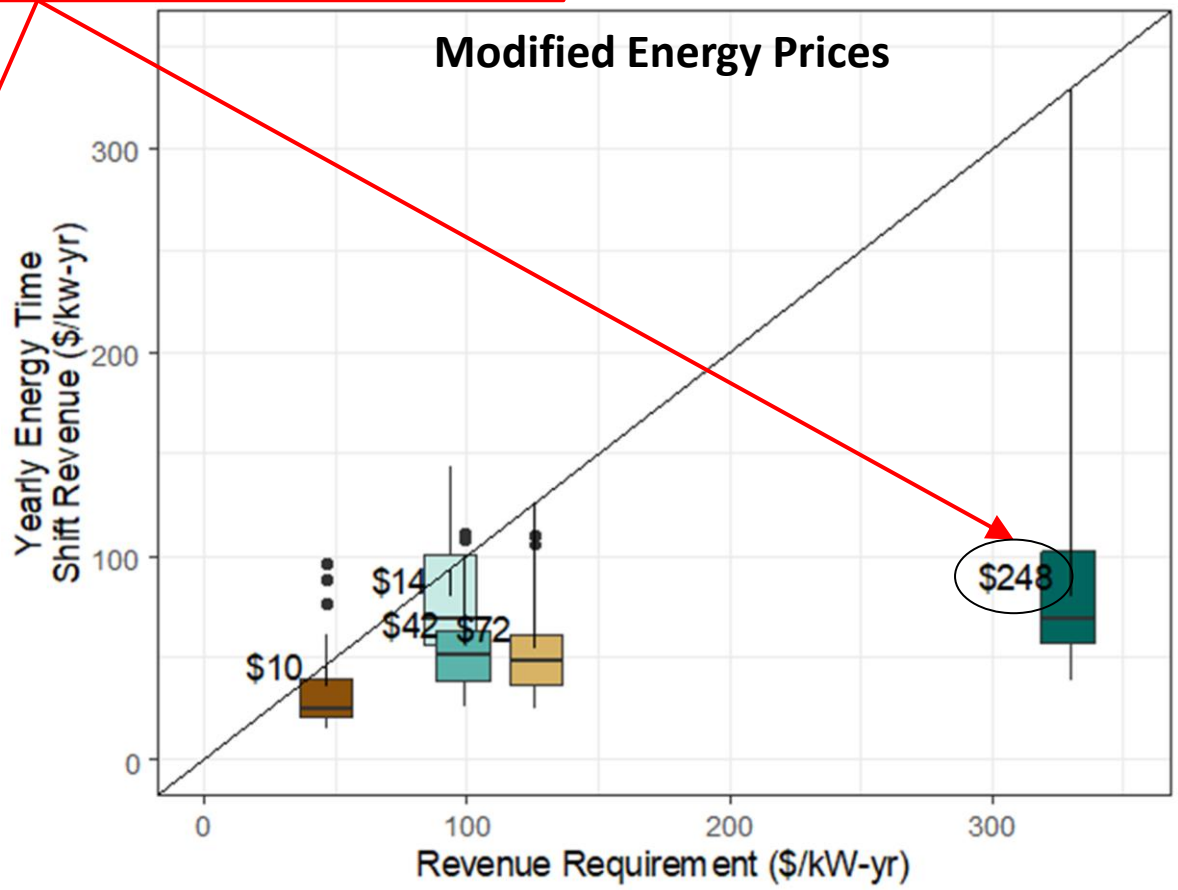
Pricing	Orig	Orig	Orig	Orig	Orig	Orig	Orig	Orig	Orig
RTE	Base	Base	Base	High	High	High	Low	Low	Low
Costs	Base	High	Low	Base	High	Low	Base	High	Low
Pricing	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod
RTE	Base	Base	Base	High	High	High	Low	Low	Base
Costs	Base	High	Low	Base	High	Low	Base	High	Base

Significant number of use cases: 1728 total

How to Interpret the Results

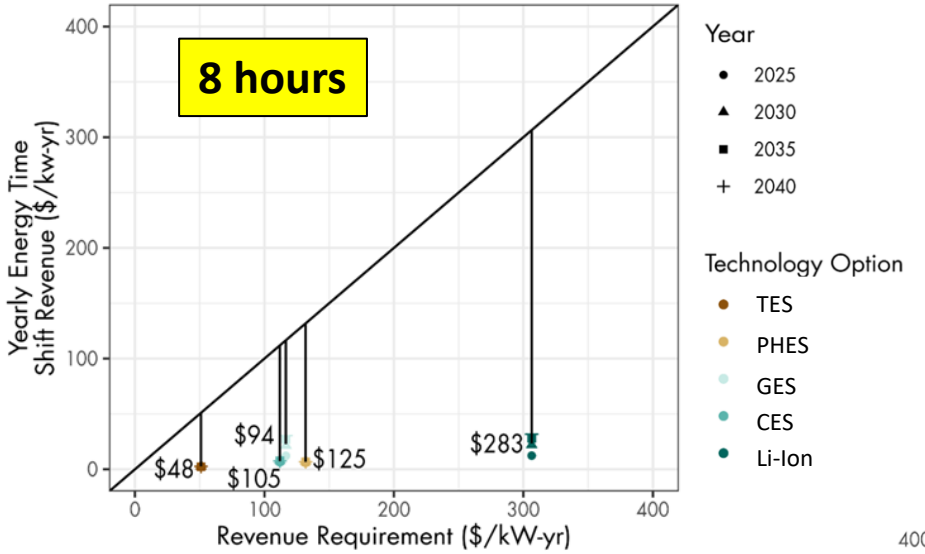
These numbers represent the capacity payment required to break even if there are no other services





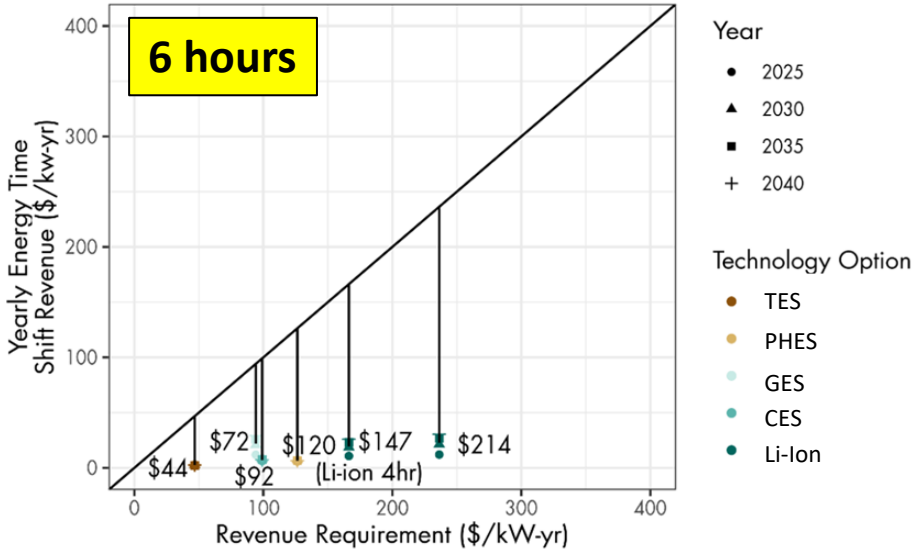
If yearly revenue > revenue requirement, value is made

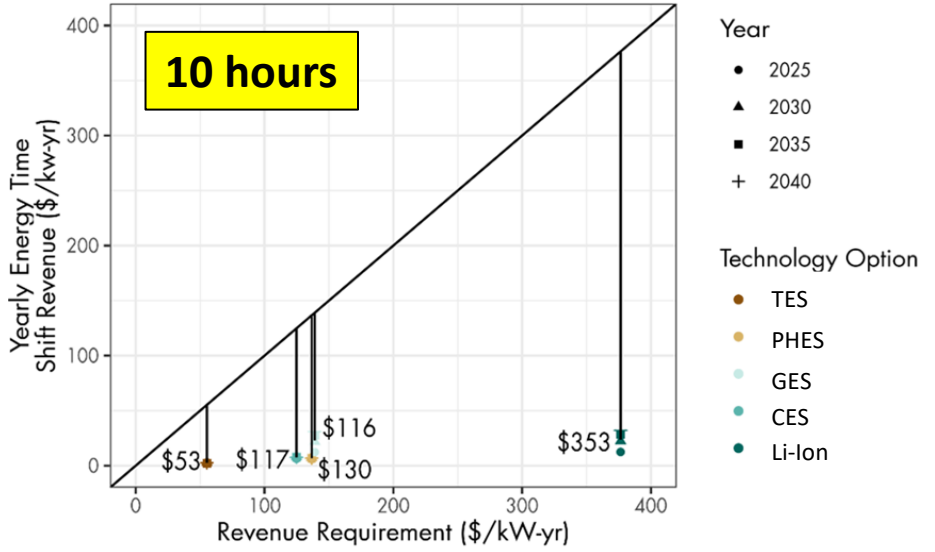
Example: Energy Time Shift Only Value



Missing Money ($/kW-yr)

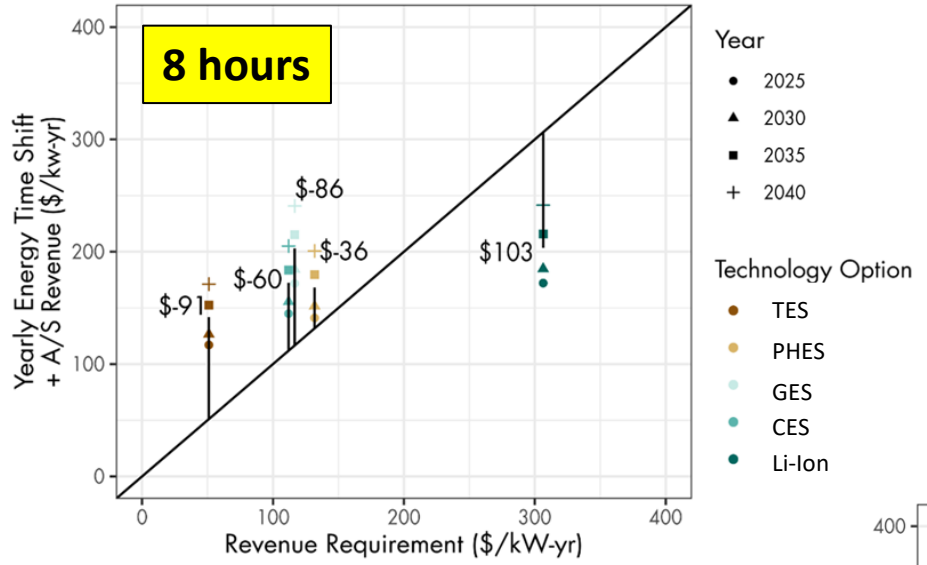
Duration, hours	TES	PHES	GES	CES	Li-ion
4	---	---	---	---	147
6	44	120	72	92	214
8	48	125	94	105	283
10	53	130	116	117	353





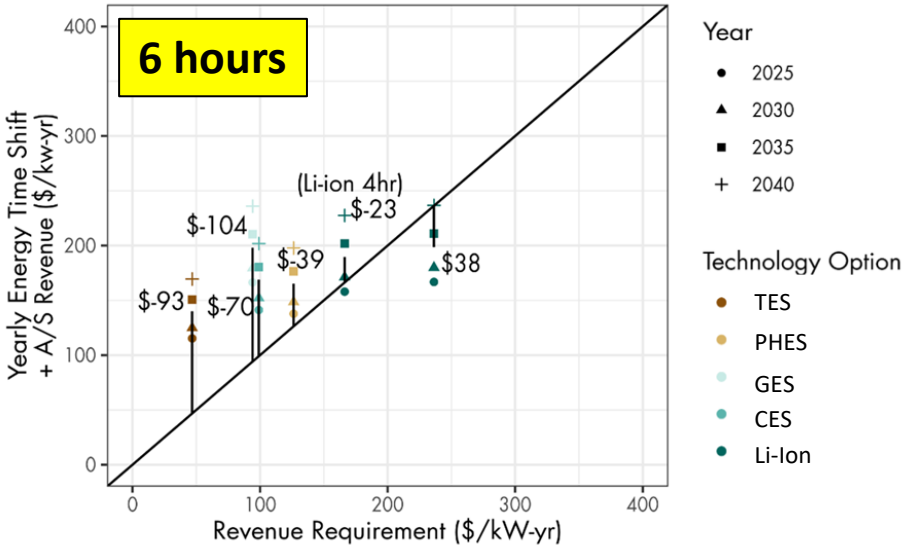
With the given projected energy prices only, there is no value

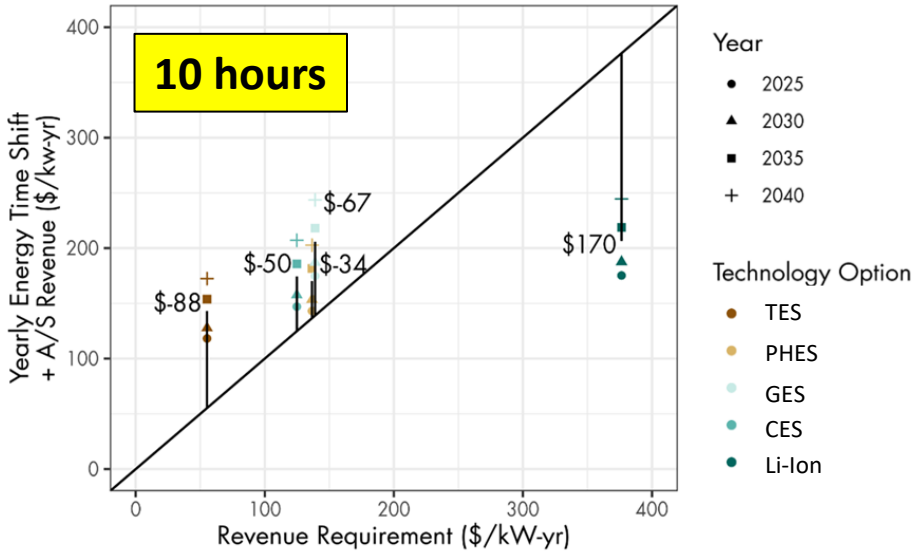
Time Shift + Ancillary Services Value



Missing Money ($/kW-yr)

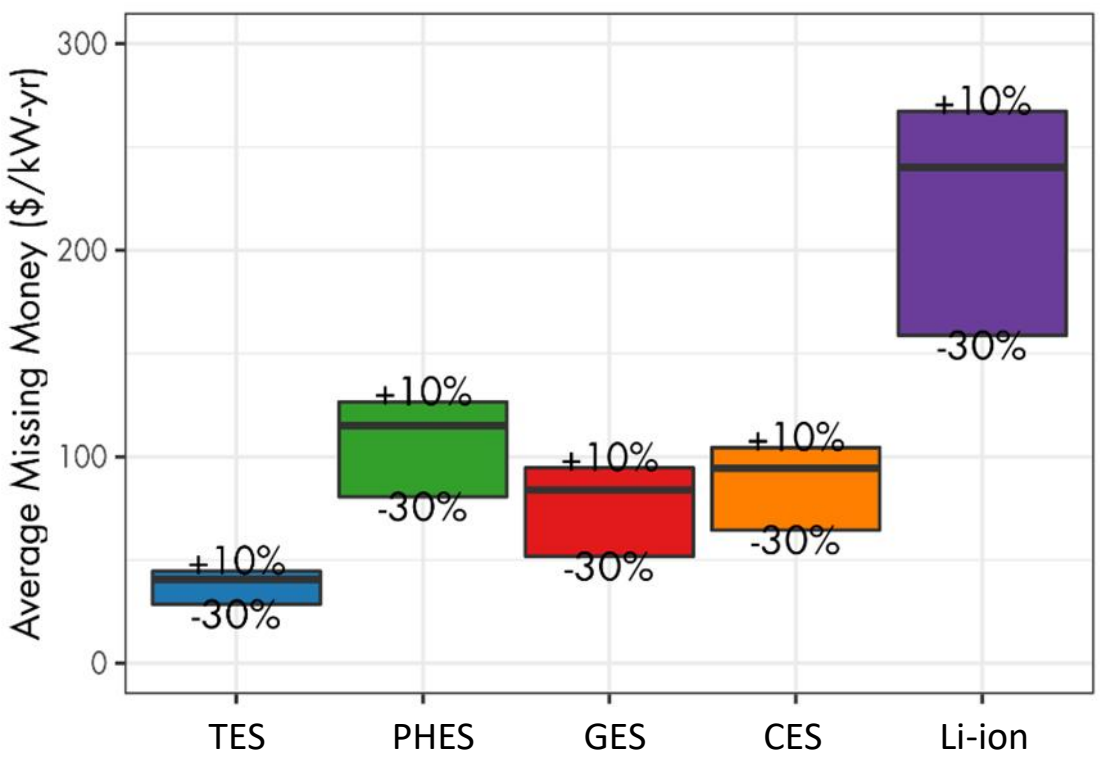
Duration, hours	TES	PHES	GES	CES	Li-ion
4	---	---	---	---	---
6	-93	-39	-104	-70	38
8	-91	-36	-86	-60	103
10	-88	-34	-67	-50	170

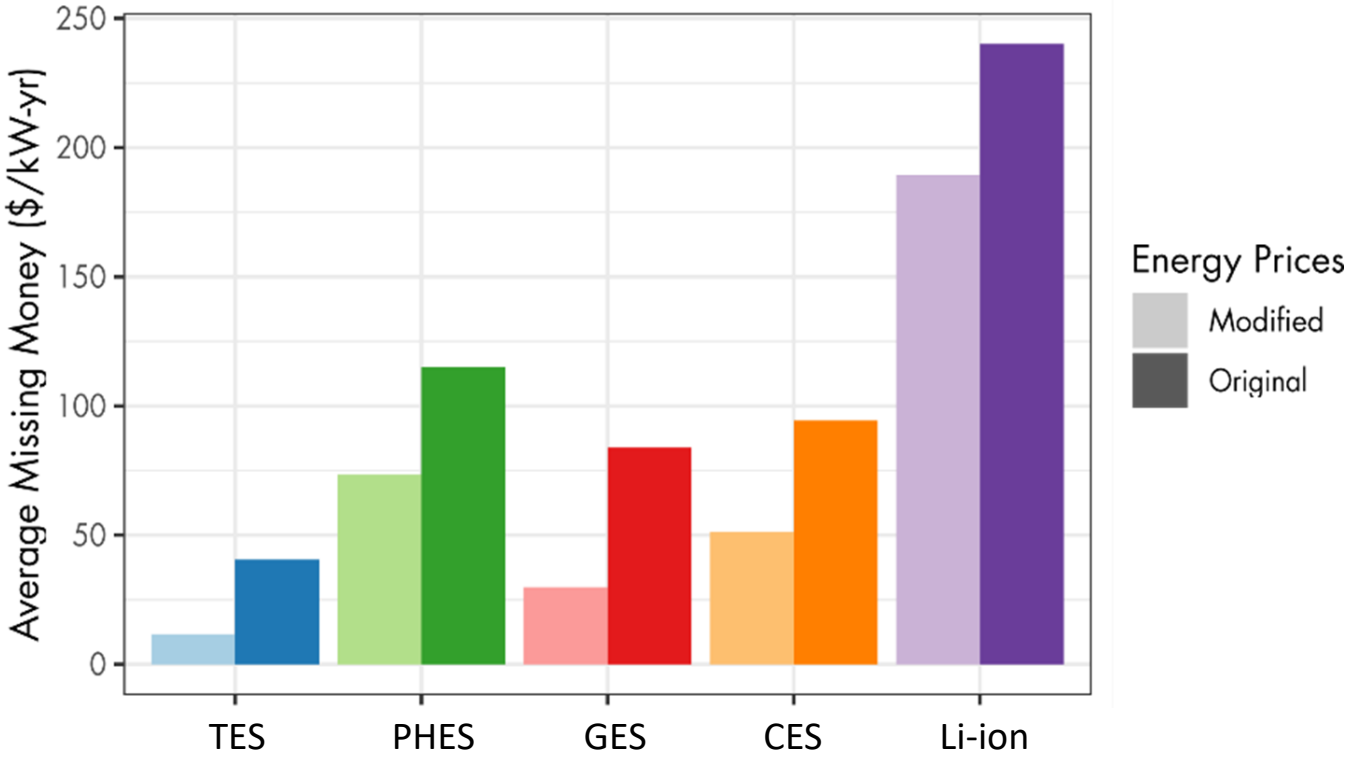




Adding ancillary services produces significant value

Capital Cost and Energy Price Sensitivity

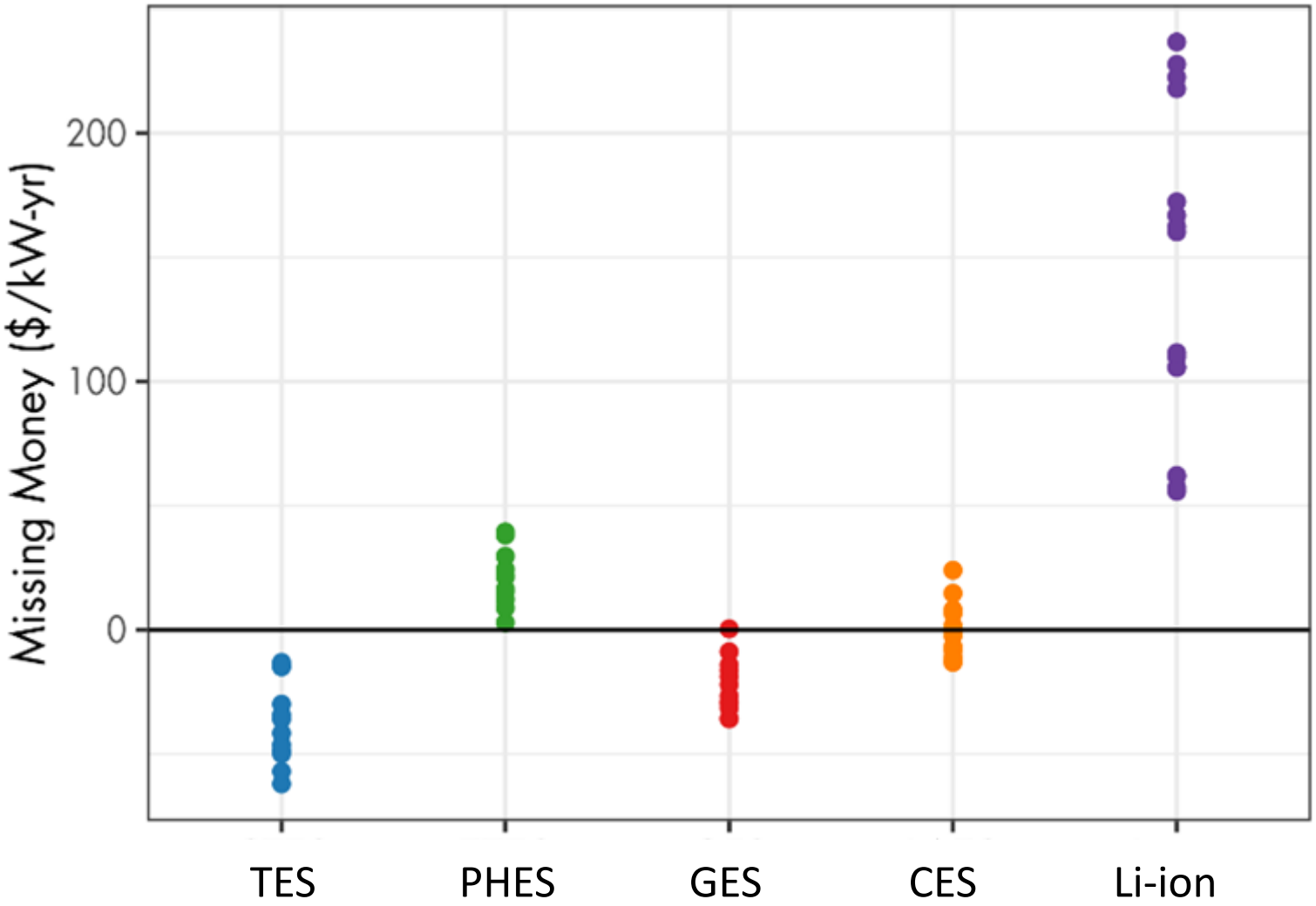




Cost reductions alone do not yield a profit for energy only cases

Changes to the energy price have the biggest impact on value

Missing Money with High Renewable Energy Prices



Region with significant amount of renewables, shows value

Summary

- Energy time shifting revenue alone yields a net loss
- Regions with more renewables had more revenue for energy storage
- At longer durations, value for non-battery energy storage, whose cost to add more duration is low, improved in comparison to Li-ion batteries
- When ancillary service prices were coupled with energy prices, the “stacked” revenue resulted in a profit, save for Li-ion batteries above 4 hours
- Best-case scenarios showed significant net revenue for non-battery energy storage even without ancillary services
- Adding ancillary services markets or tariff-based incentives will improve the economics for energy storage as would capacity payments
- Markets for system inertia and low-carbon generation could also add value