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Energy Storage Options & Selection Considerations

Sandia National Laboratories

AESTF Energy Symposium

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OUTLINE

Energy Storage

- Importance
- Promising Technologies
- Modeling
- Influence of Key System Parameters

Summary

Energy Storage

Importance

Promising Technologies

Modeling

Energy Storage

Importance

Energy Storage (LDES) needed to achieve full decarbonization

"…energy storage is not a luxury, but a necessity…" – Jeremy Twitchell of PPNL

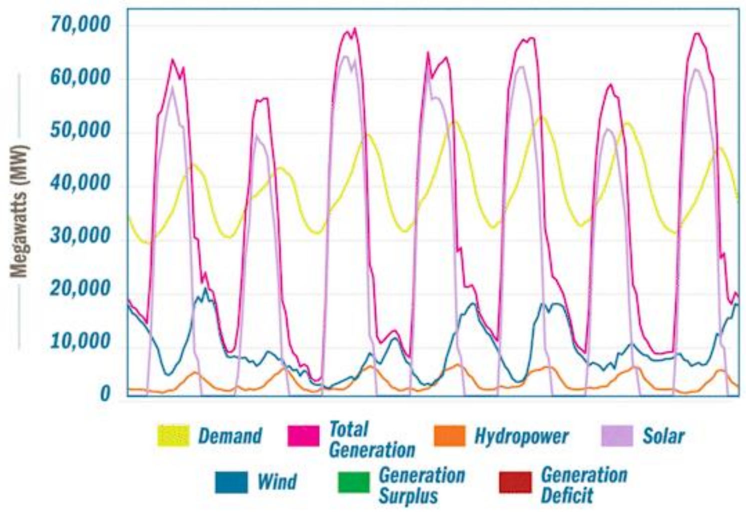
Long Duration Energy Storage (LDES)

- 8+ hrs (approximate duration)
- Dispatchable at maximum deficit

85-140 TWh LDES needed by 2040 to enable global net zero goals

- LDES Council Report: A path towards full grid decarbonization with 24/7 clean Power Purchase Agreements

Cost Reduction of LDES systems necessary



Courtesy of PNNL

Courtesy of DOE

Energy Storage

Promising Technologies

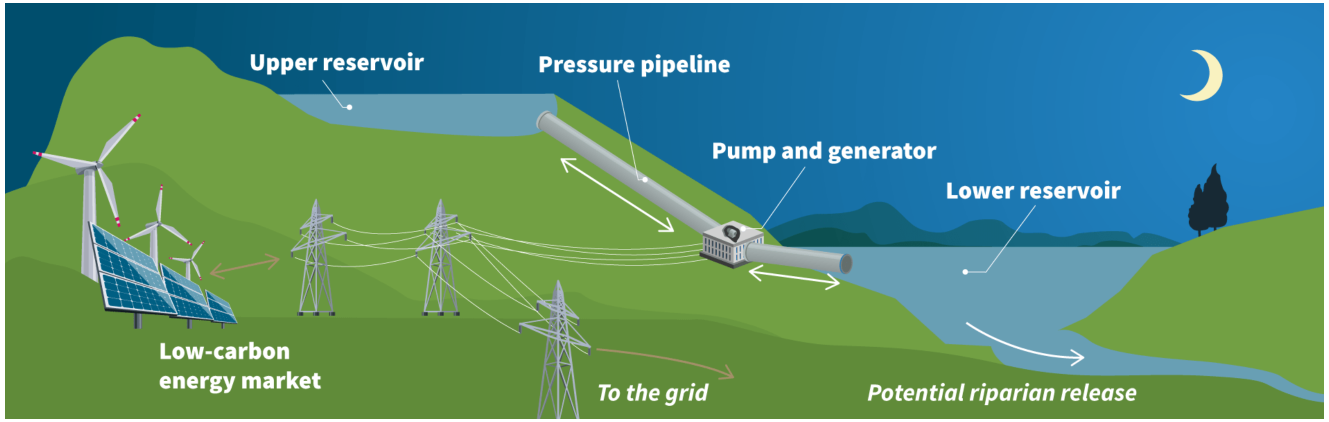
Commercially Available Technologies

- Lithium-ion (Li-ion) Iron Phosphate (LFP)
- Lithium-ion Nickel Manganese Cobalt (NMC)
- Lead Acid
- Vanadium Redox Flow (VRF)
- Zinc-based
- Compressed Air Energy Storage (CAES)
- Pumped Storage Hydropower (PSH)
- Thermal Energy Storage (TES)
- Gravity Energy Storage
- Hydrogen

Technology solutions are scenario specific

https://electrek.co

https://www.renewablethermal.org



https://www.advisian.com

Energy Storage

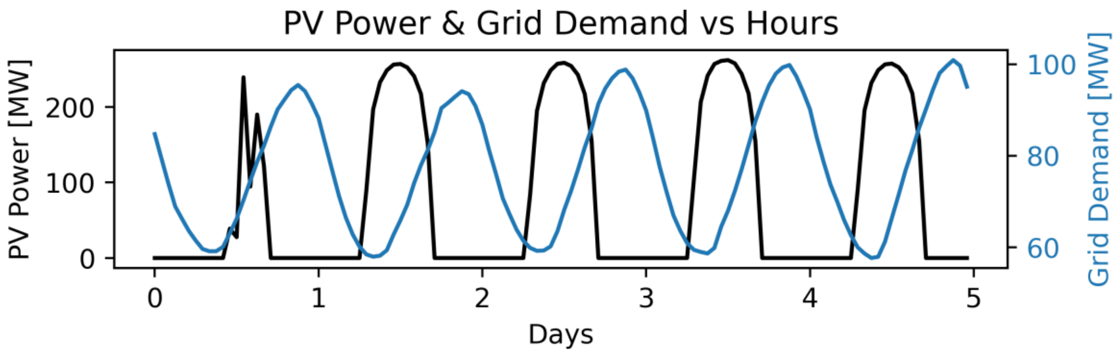
8760 Modeling

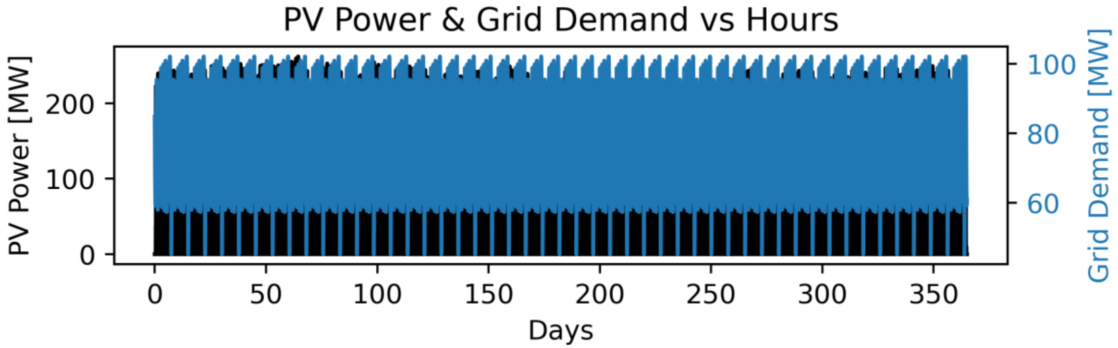
- Models energy storage system (ESS) using hourly data over a year
- Utilizes hourly grid demand and energy availability data
- Assesses system performance in dynamic environment

SNL 8760 Modeling

- Compare ESS within the same setting
- Assesses Impacts of:
  - Power purchase agreement
  - Energy available for charging
  - System efficiency

Modeling





Fixed Parameter	Value	Units
Peak grid demand/discharge	100	MW
Operational life	30	Years
Loan percentage	50	%
Interest rate	8	%
Base Electricity Price	0.05	$/kWh

Energy Storage

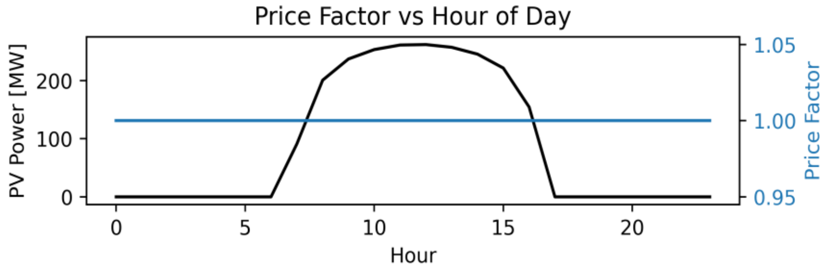
Modeling

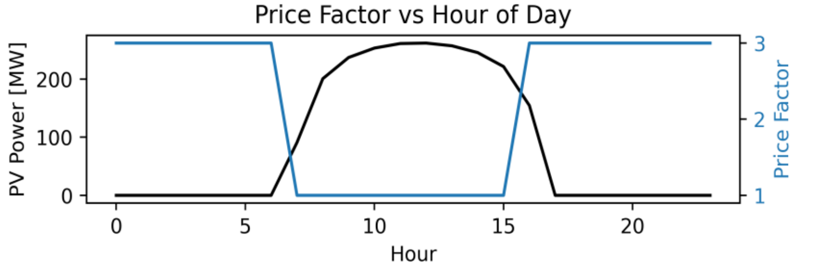
Model assesses standalone ESS

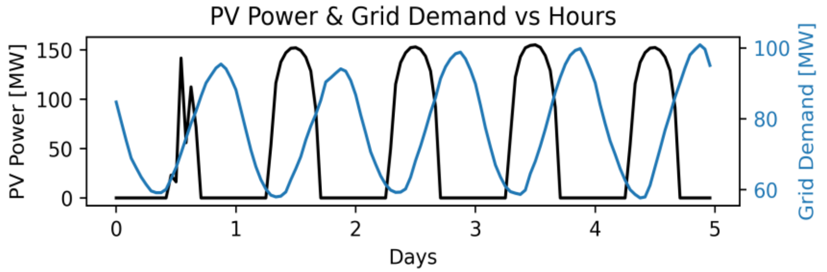
Excess PV energy for charging

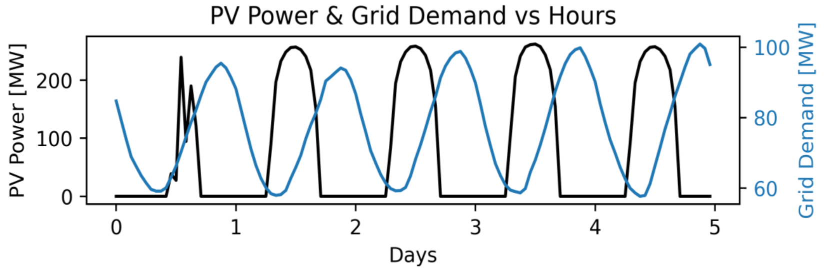
Varied Model Parameters

- **Electricity Pricing**
  - Flat
  - Hypothetical “100% RE” Scenario
- **Power available for charging**
  - 100 MW max charge
  - 200 MW max charge
- **System Efficiency**
  - TES system RTE
  - 35-60 %









Energy Storage

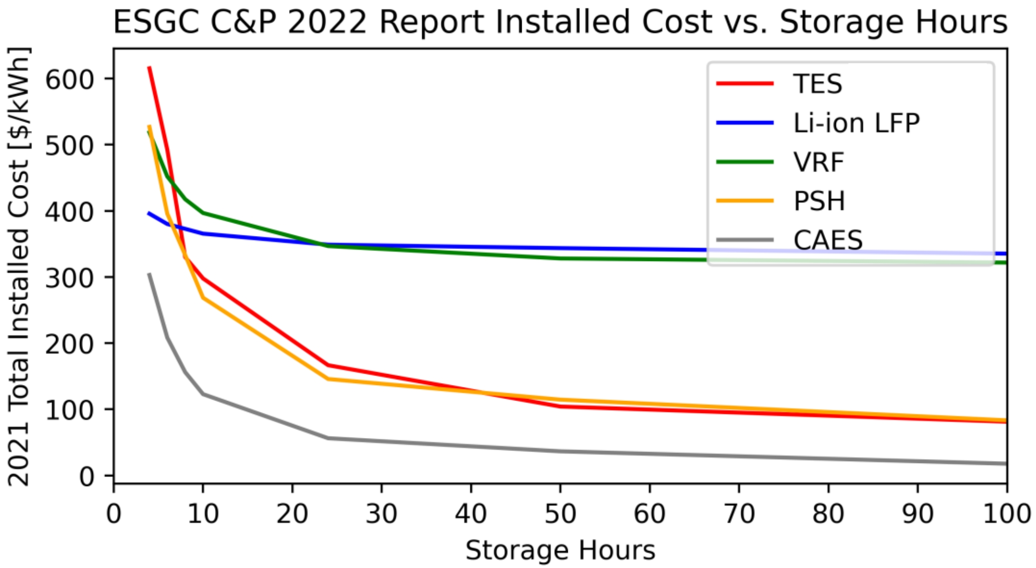
Systems Analyzed

- Li-ion LFP
- Vanadium Redox Flow (VRF)
- Pumped Storage Hydropower (PSH)
- Compressed Air Energy Storage – Caverns (CAES)
- Thermal Energy Storage (TES)

ESGC Cost & Performance 2022 Report used as basis for analysis

- Installed Cost
- RTE
- Lifespan
- O&M Cost

Modeling



ESS	Life Time [years]	RTE [%]	O&M [$/kW-yr]
PSH	59.9	79.9	28.19
Vanadium Redox Flow	11.9	65.5	12.08
Li-ion LFP	16.0	82.5	9.87
CAES	59.9	51.9	16.11
Thermal	33.9	51.7	32.31

Energy Storage

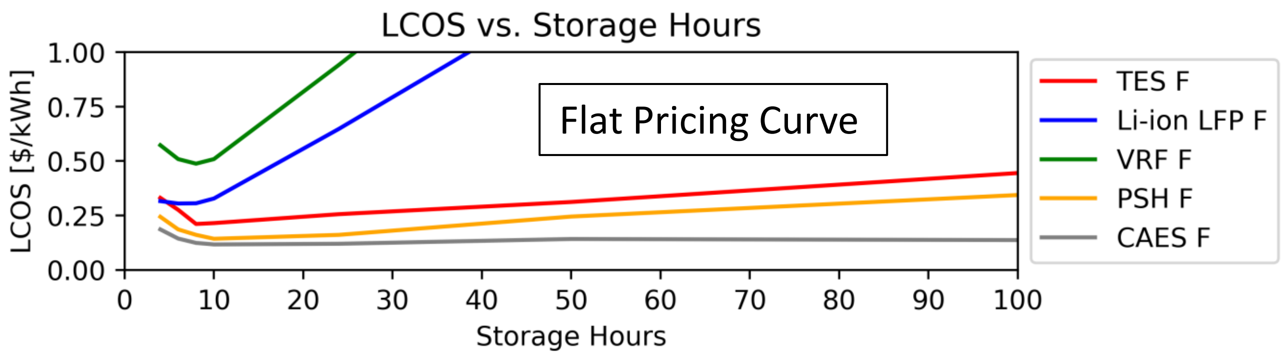
$$LCOS = \frac{\sum_1^n (CAPEX + O\&M + I - Net\ Profit)}{\sum_1^n E_{out}}$$

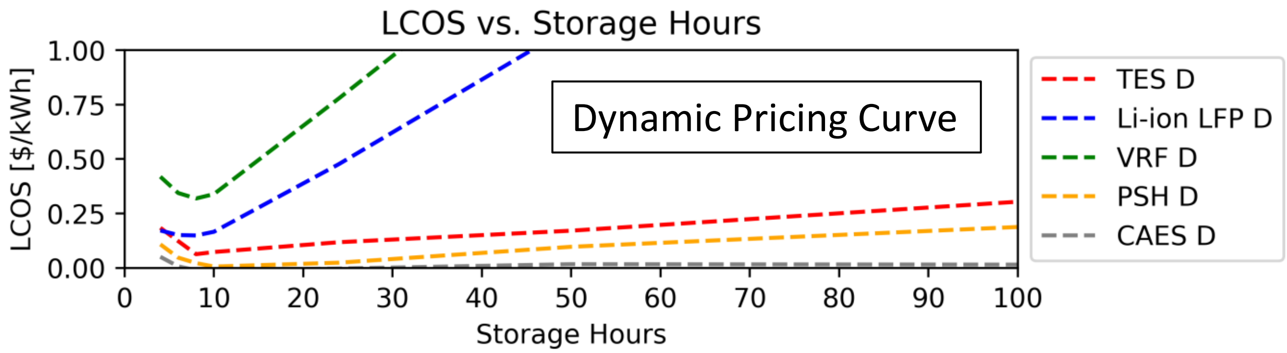
200 MW Charge General Trends

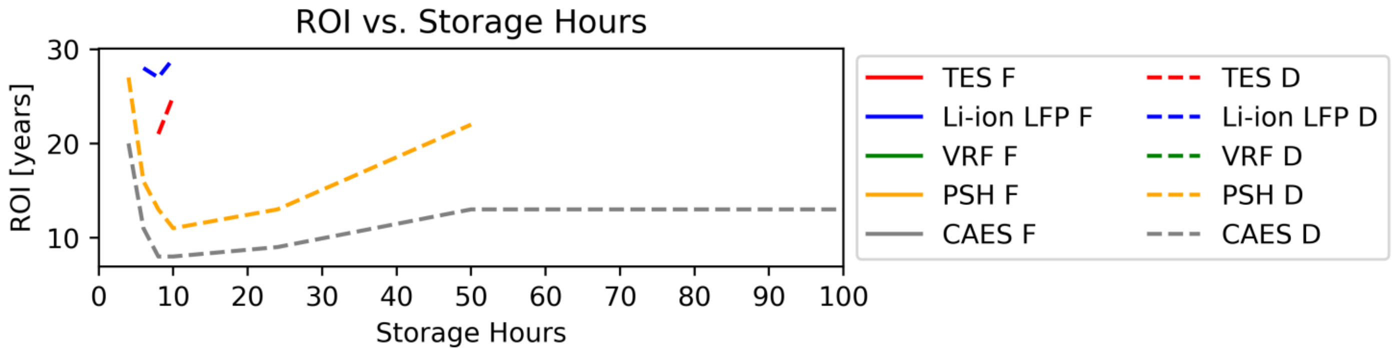
- CAES & PSH lowest LCOS
- TES lowest LCOS 8+ hours without geographical constraint
- Li-ion LFP lowest LCOS 4 hours without geographical constraint

Influence of Electricity Pricing

- Buying "low" and selling "high" reduces system cost via increased Net Profit of electricity sold
- Enables return on investment (ROI)







Energy Storage

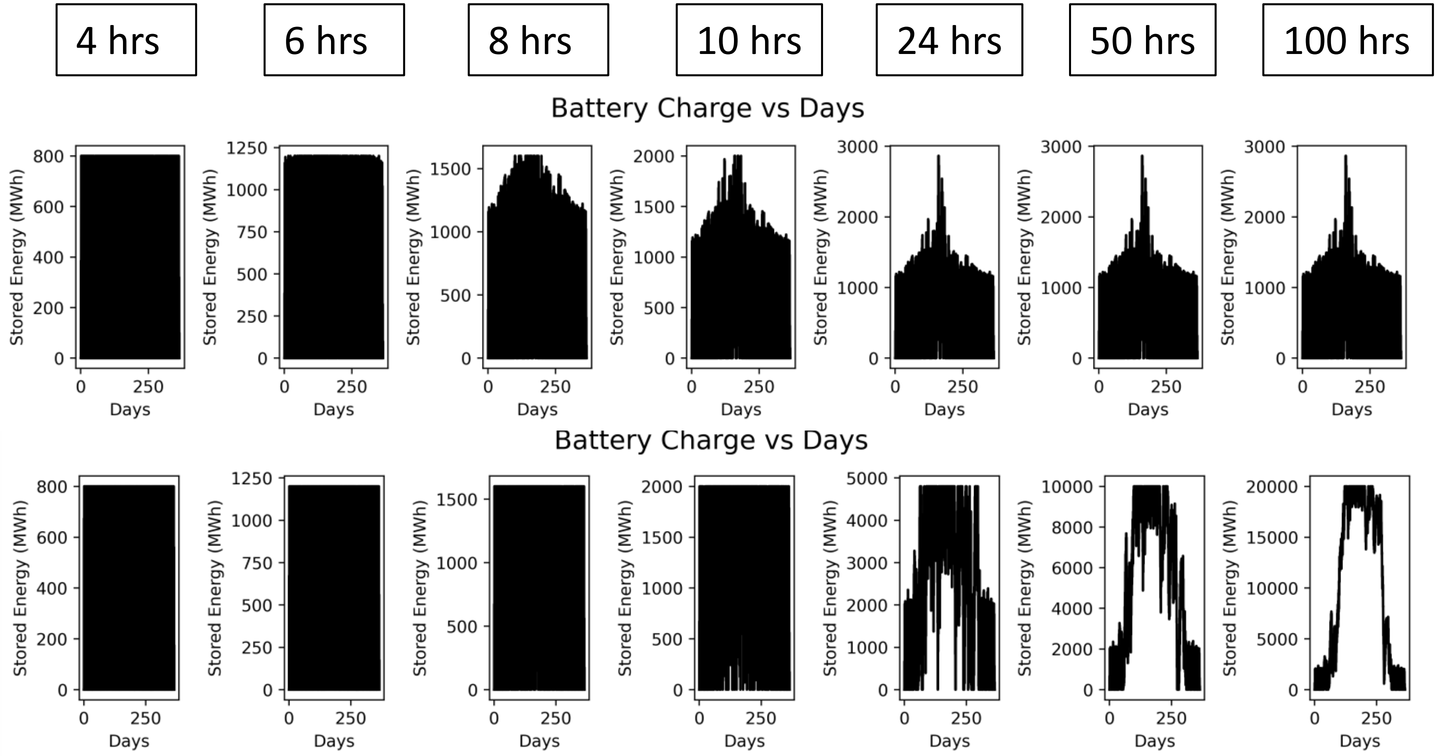
Influence of Available Charging Energy

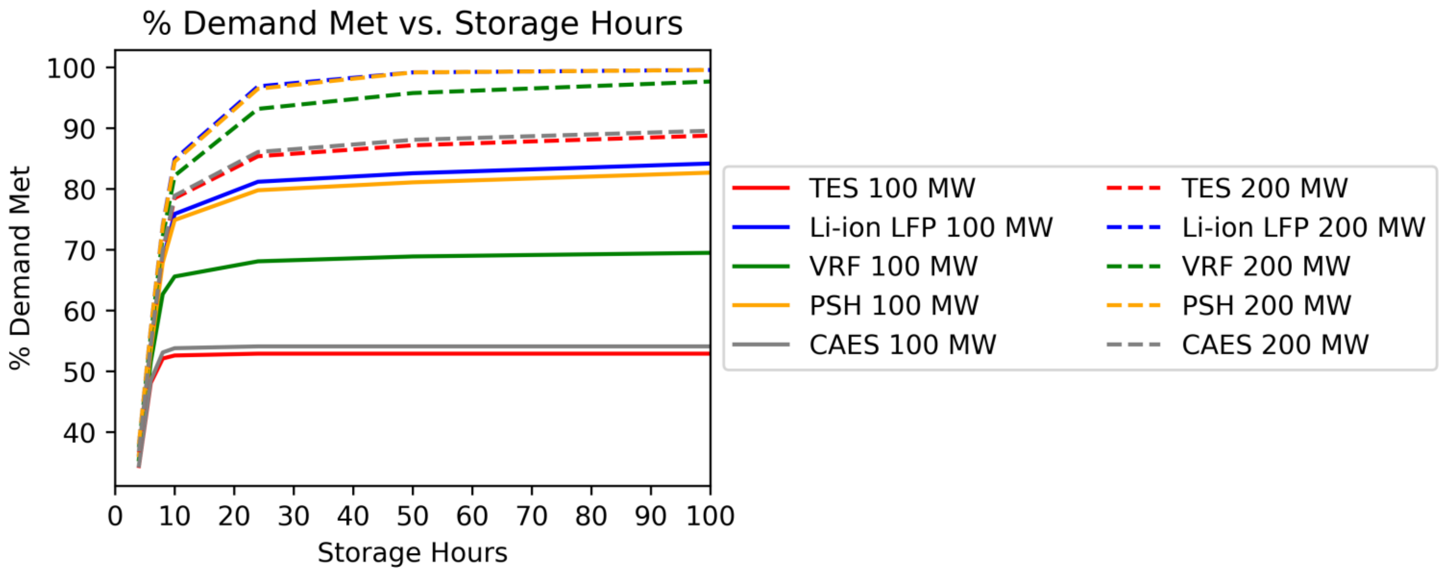
- Increased storage duration requires sufficient power to charge
- Increased charging power increases % demand met by system

$$\%_{demand} = \frac{E_{out,ESS}}{E_{grid\ demand}}$$

100 MW Charge

200 MW Charge

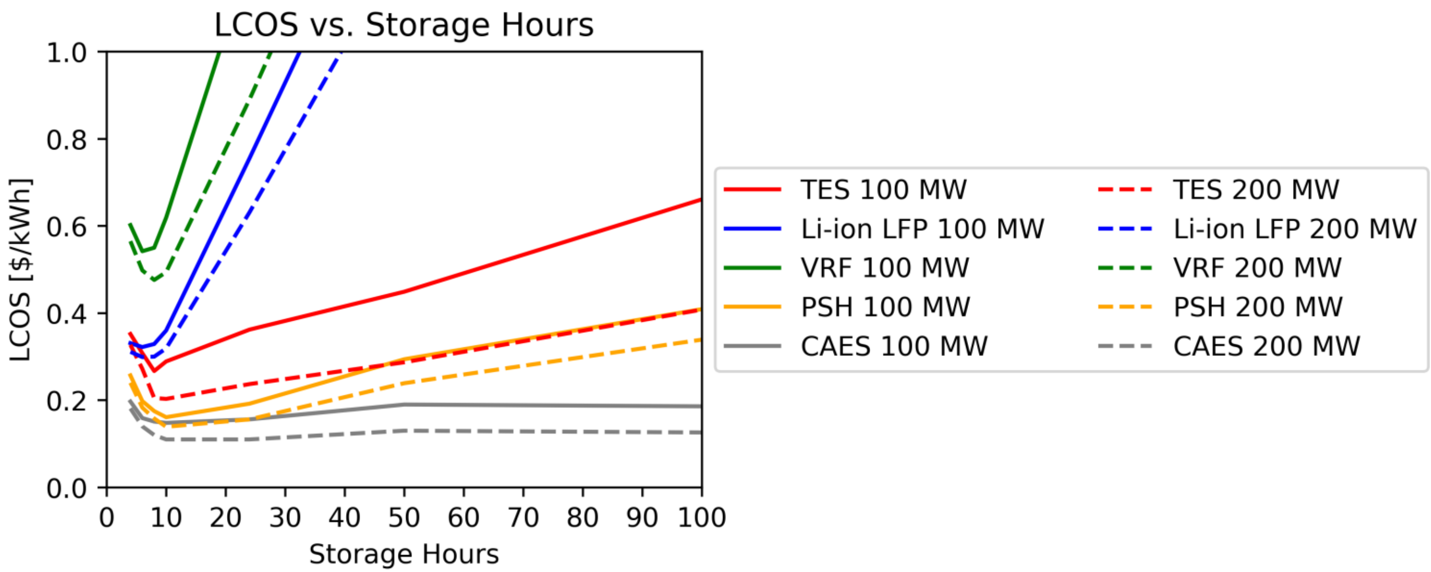


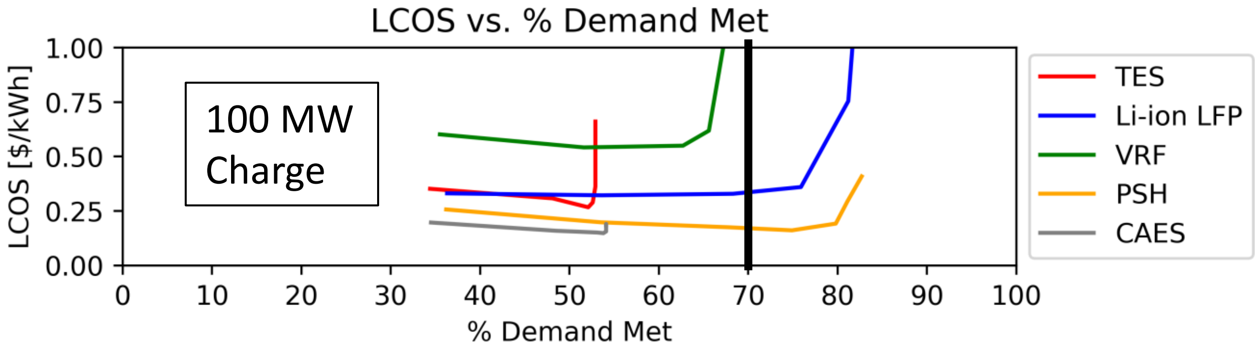


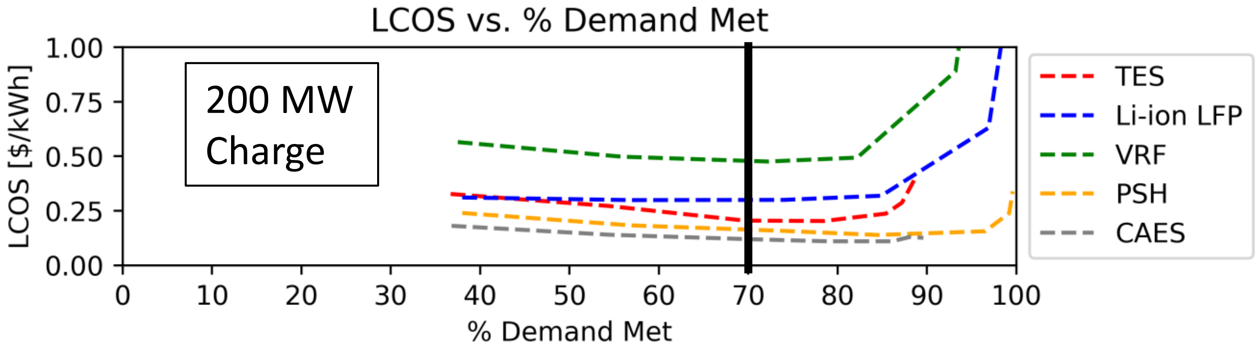
Energy Storage

Influence of Available Charging Energy

- Increased battery utilization decreases system cost
- Lowest cost solution may not meet % met demand requirement



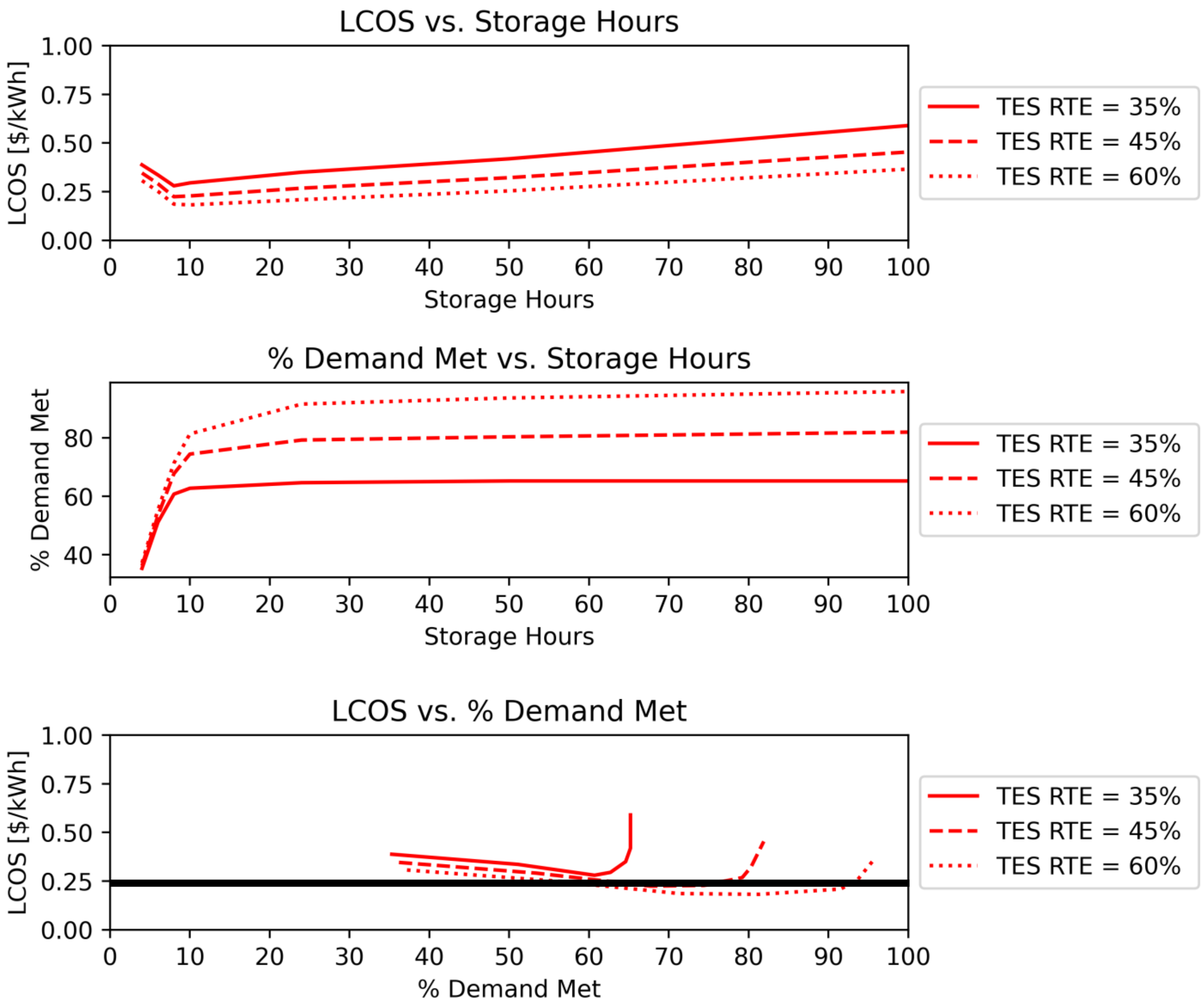




Energy Storage

Influence of Round Trip Efficiency

- Increased ESS RTE reduces LCOS
- Increased ESS RTE increases % demand met for specific scenario
- Higher % demand met for same LCOS



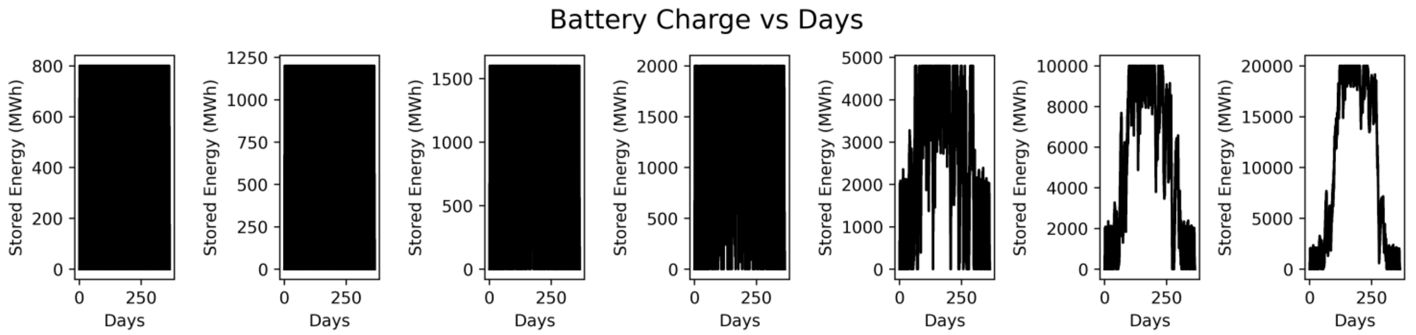
Summary

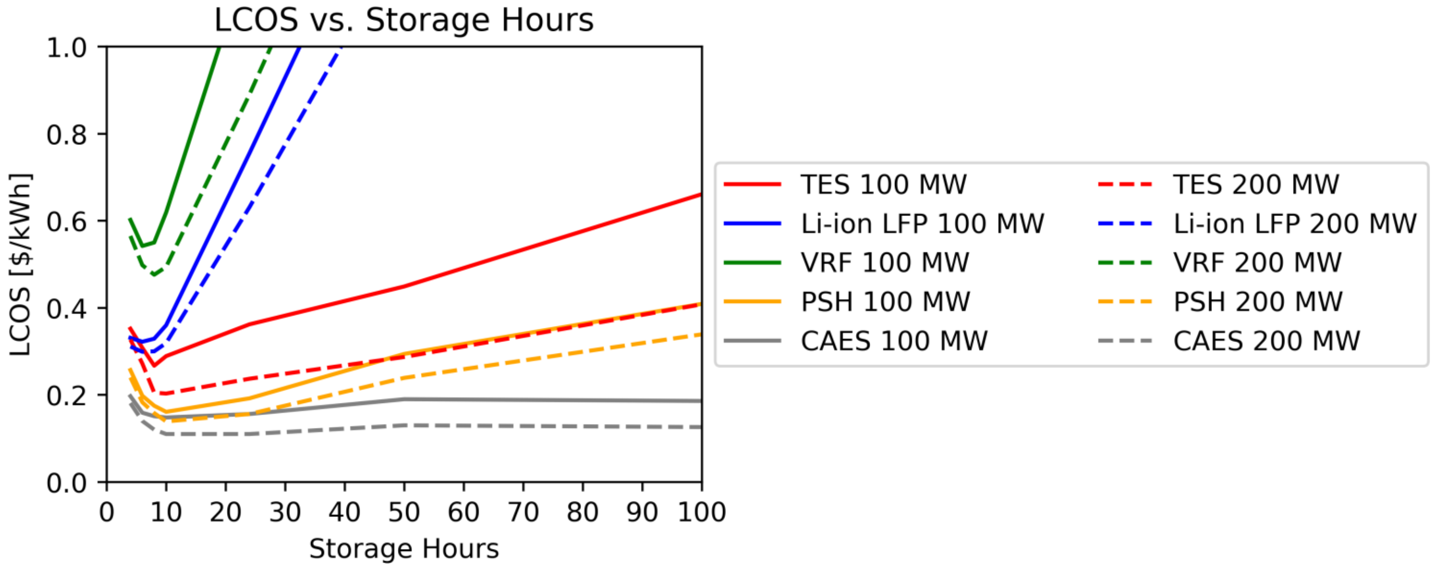
Summary

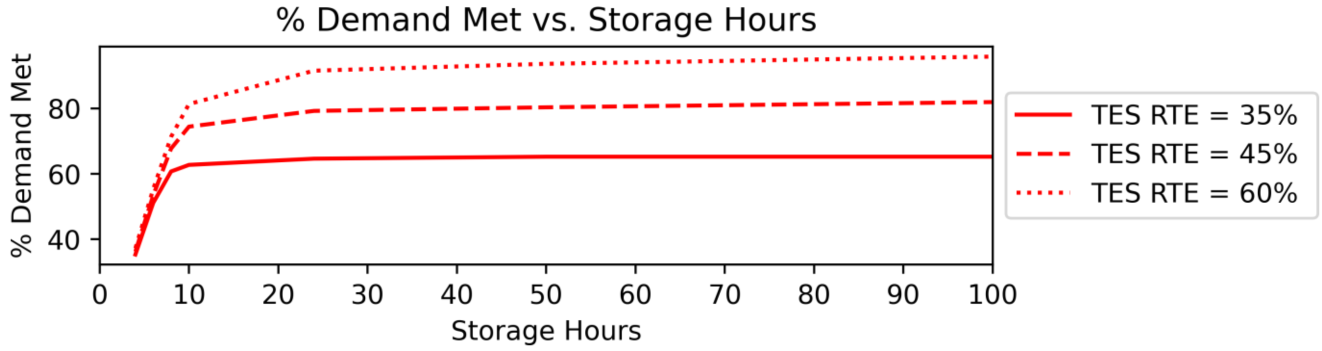
ESS selection is scenario specific

Key ESS selection considerations:

- Power purchase agreement
- Grid demand
- Available energy for charging
- System RTE
- % demand met requirement
- LCOS requirement/ROI requirement







Questions?