Resource Adequacy Contribution of Solar + Storage in Florida

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Outline

- Resource Adequacy and Effective Load Carrying Capability
- Method for Approximating the Capacity Credit
- Comparison of Capacity Credit from Approximation to Detailed Benchmark
- Analysis of Capacity Credit of Solar+Storage in Florida
- Discussion

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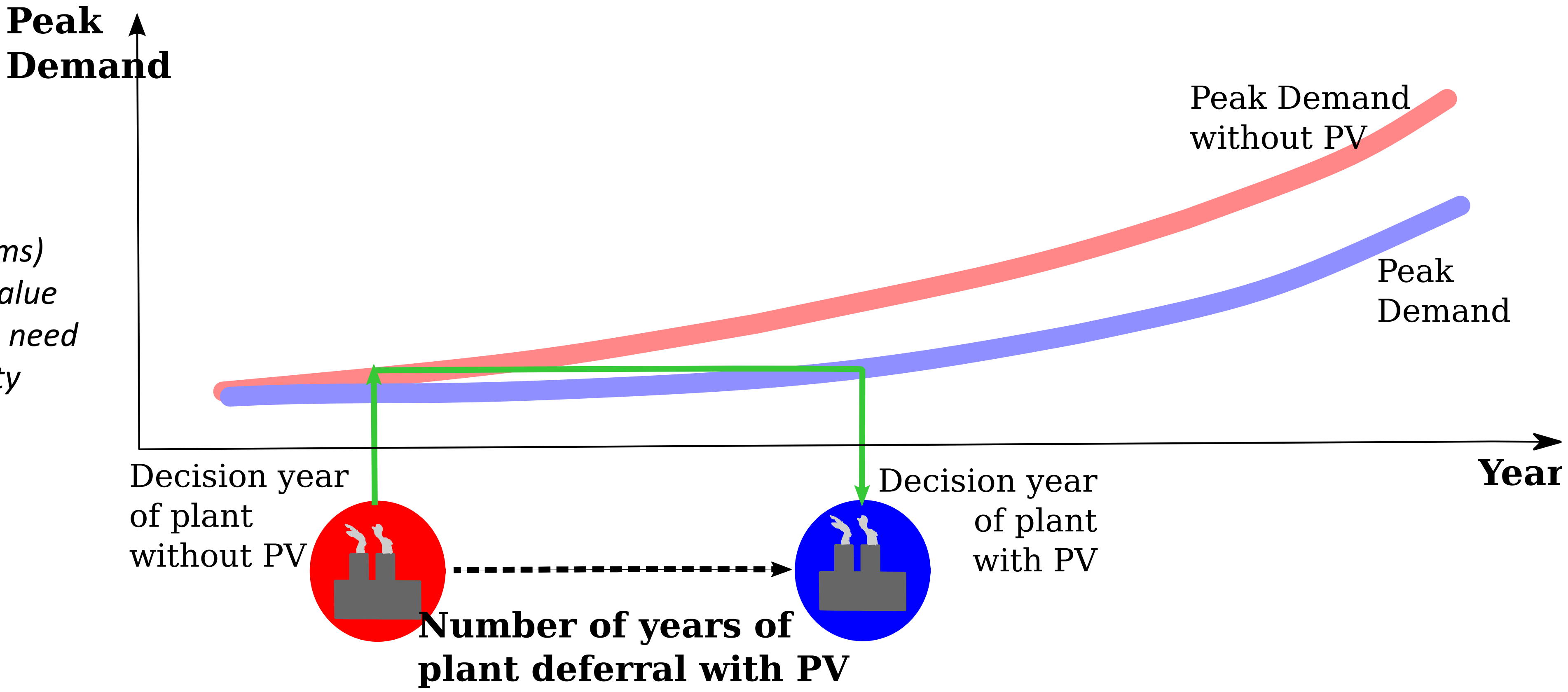
Contribution to Reliability is One of the Value Streams of Solar+Storage

Capacity value (in $ terms) depends on economic value of avoiding or deferring need to build peaking capacity

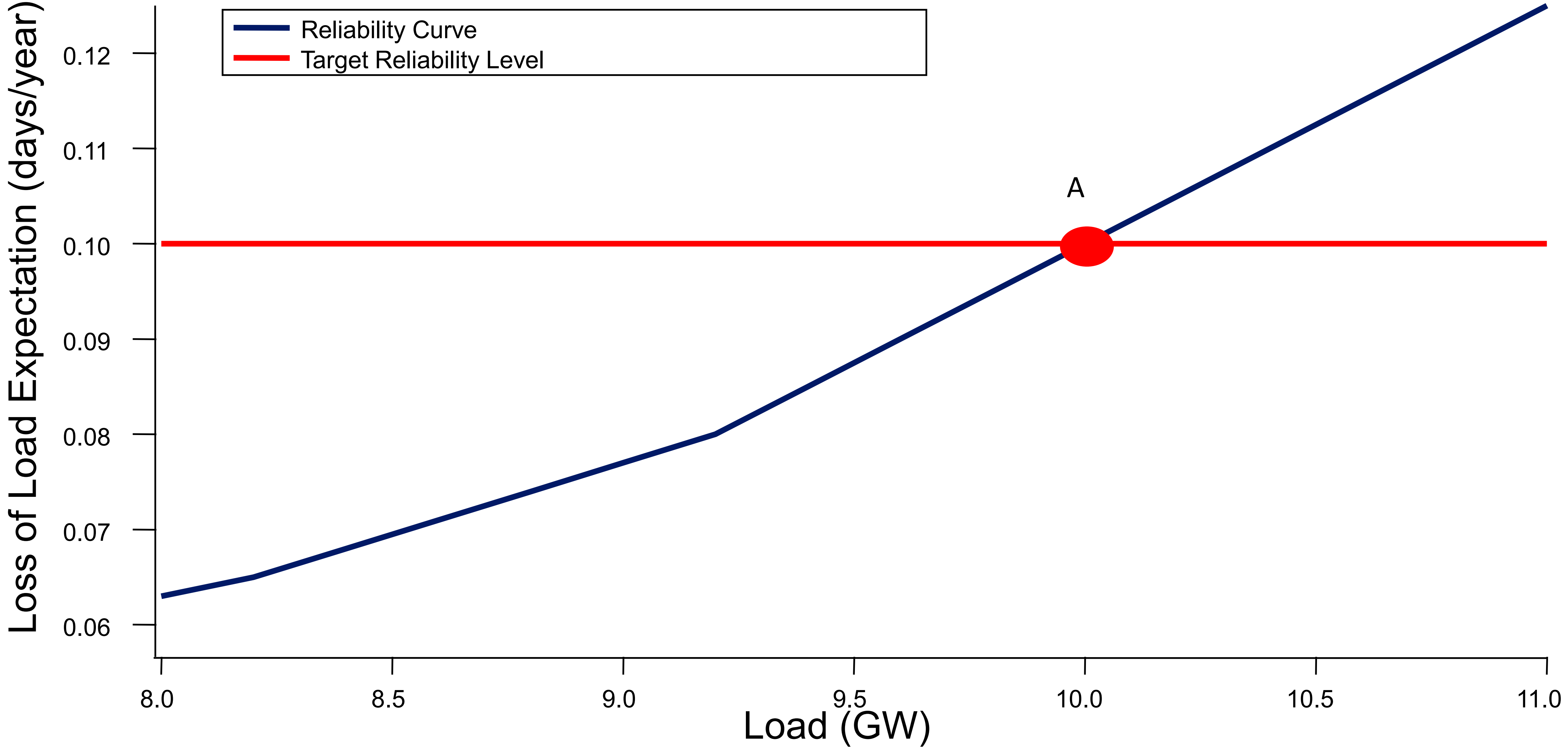


Capacity credit: Portion of the nameplate capacity that contributes to meeting utility peak needs

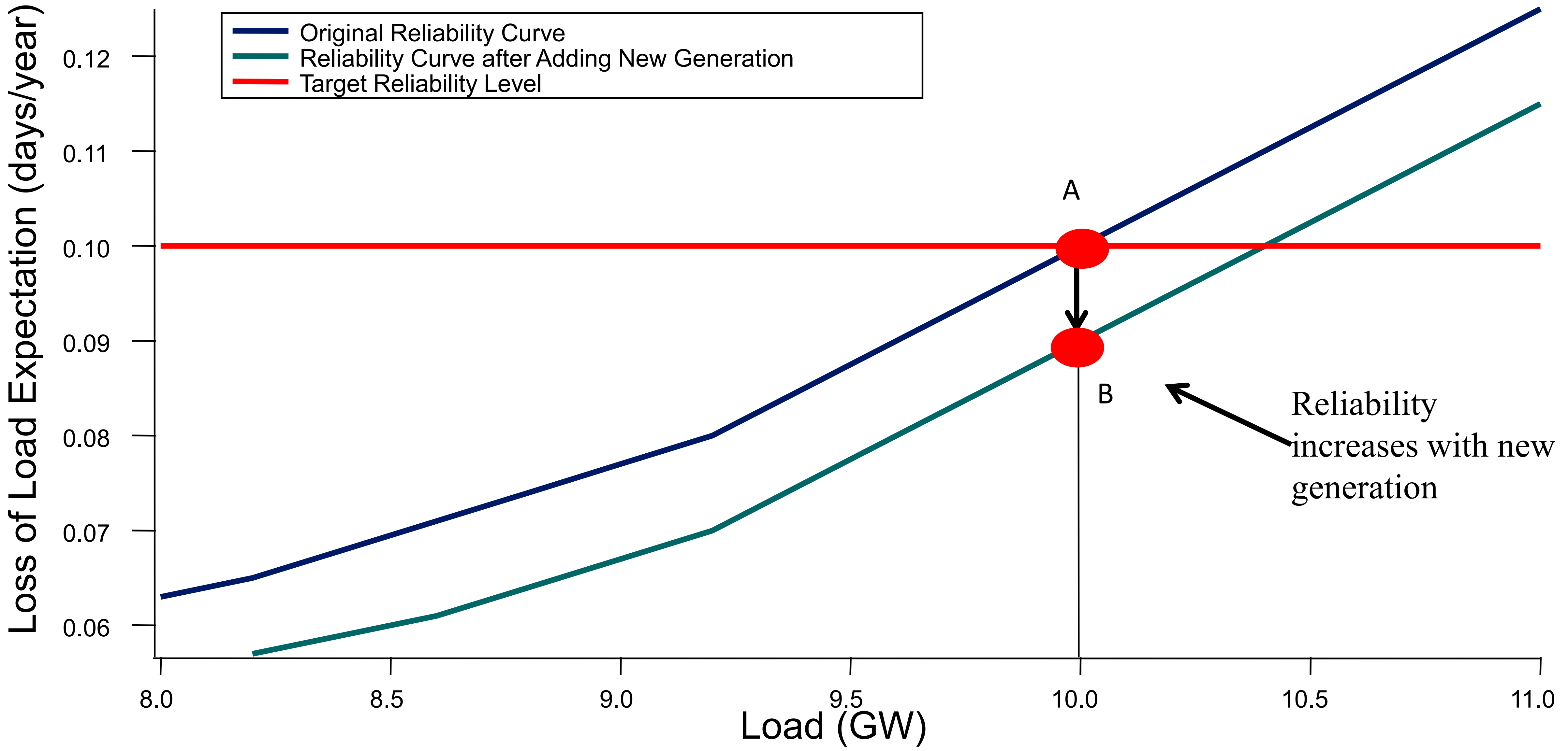
Benchmark: Effective Load Carrying Capability (ELCC) Based on Loss of Load Probability (LOLP)

- Each conventional generator has a chance of not being available: depends on the forced outage rate
- Treat generator outages as independent events
- Chance of multiple simultaneous outages is lower, but not zero
- Loss of load probability (LOLP) is the chance that available generation capacity is less than the load
- Loss of load expectation (LOLE) is expected amount of time over the year where demand exceeds available generation
- Expected load carrying capability (ELCC) is the amount that load can be increased after adding a generator while maintaining the same level of LOLE

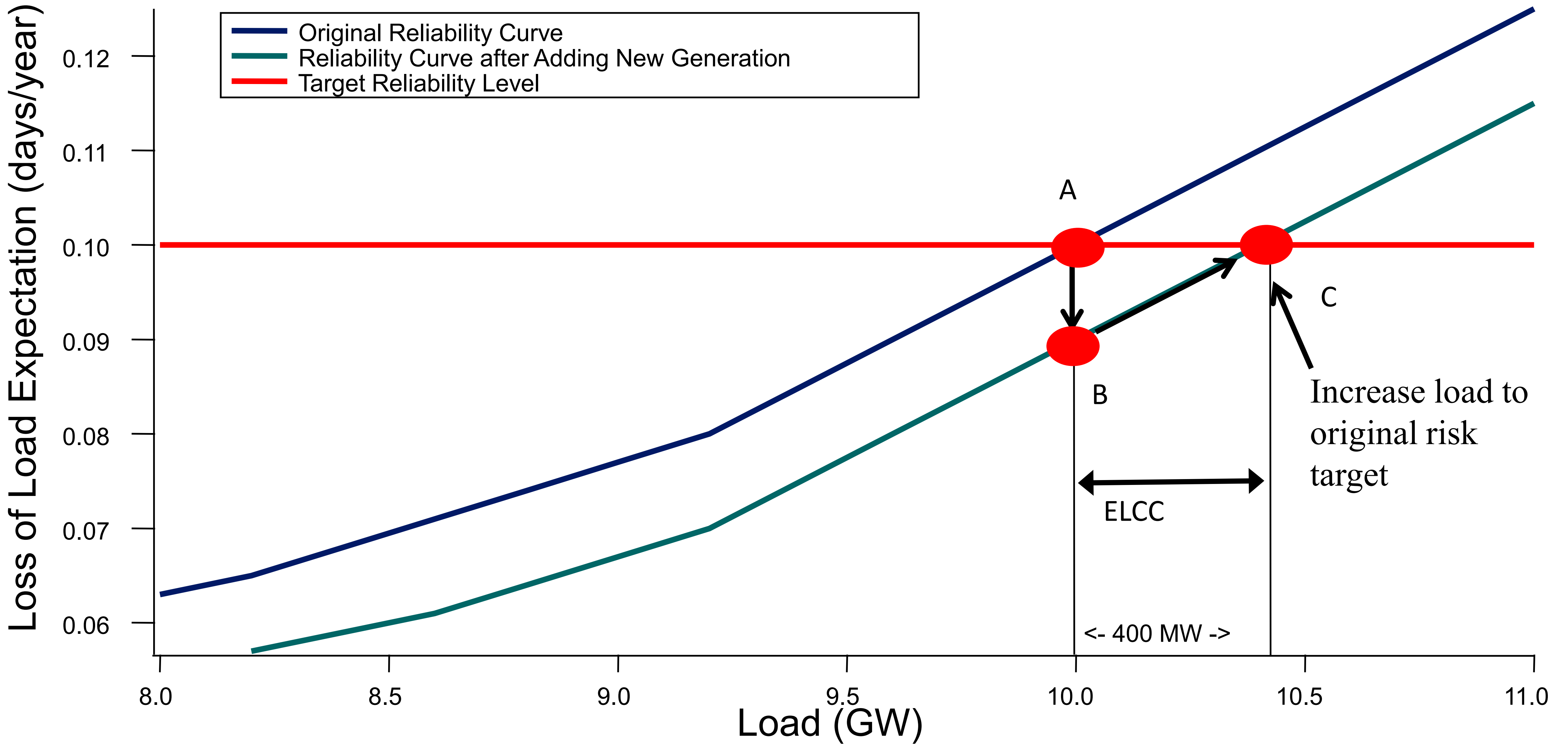
Reliability Assessment: How Reliable is the System for Different Levels of Peak Load?



Addition of New Generation Lowers Risk (LOLE) and Increases Reliability



Effective Load Carrying Capability (ELCC): Increase in Load to Return to Target Level of Reliability with New Generation



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Scope and Objectives

Develop simple methods to explore the capacity credit of solar+storage

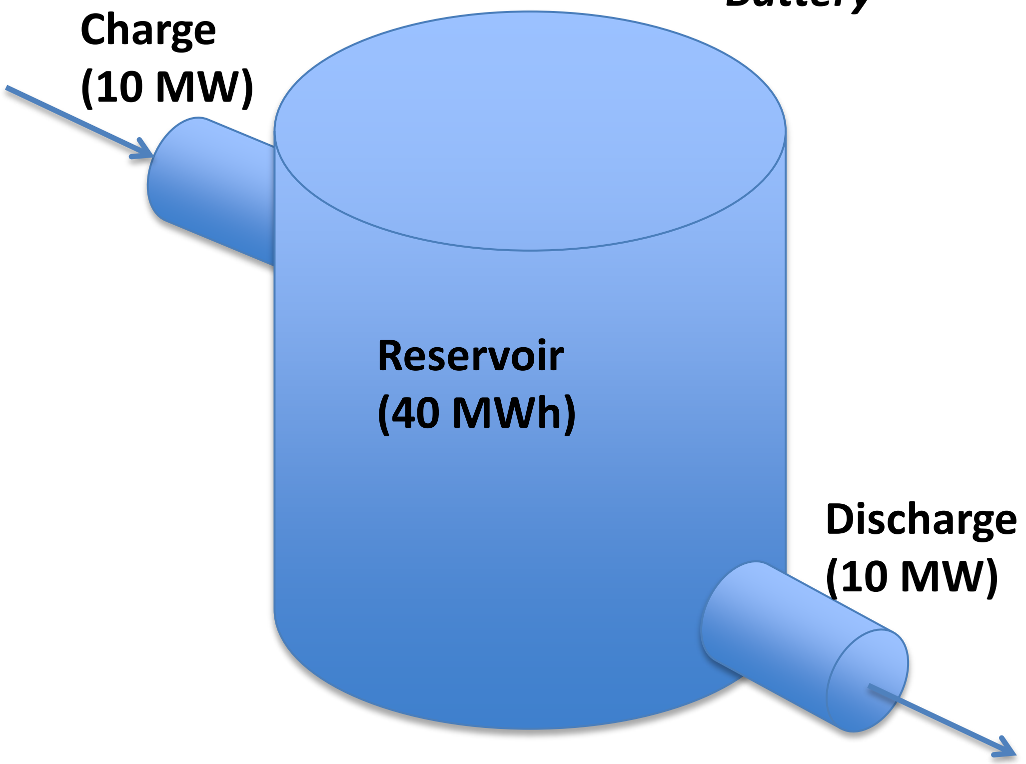
Develop intuition for results from NREL's Resource Planning Model (RPM) model

ID factors that lead to ***relative changes*** in the capacity credit, rather than precise estimates of the capacity credit of any one configuration

Help prioritize additional research directions

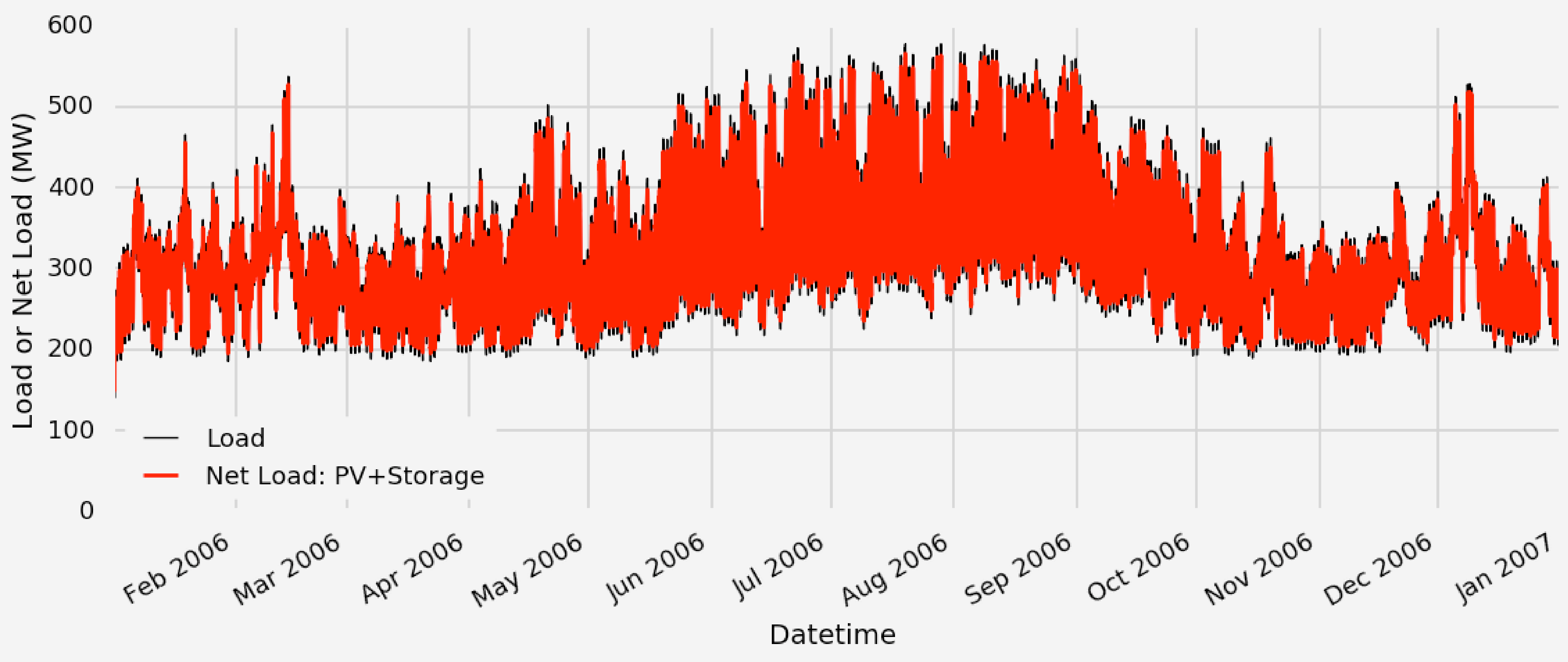
A Note on Storage Sizes

- Batteries have a maximum rate of charge or discharge (the MW nameplate rating).
- And they have a limited amount of energy that can be stored in a reservoir (MWh rating).
- We refer to the duration of the battery as the number of hours that it can be discharged at its full rate of discharge.
- Here a 10 MW battery can provide 10 MW of power or consume 10 MW of load.
- If the 10 MW battery can store 40 MWh of electricity then we call it a 4-hour duration battery.

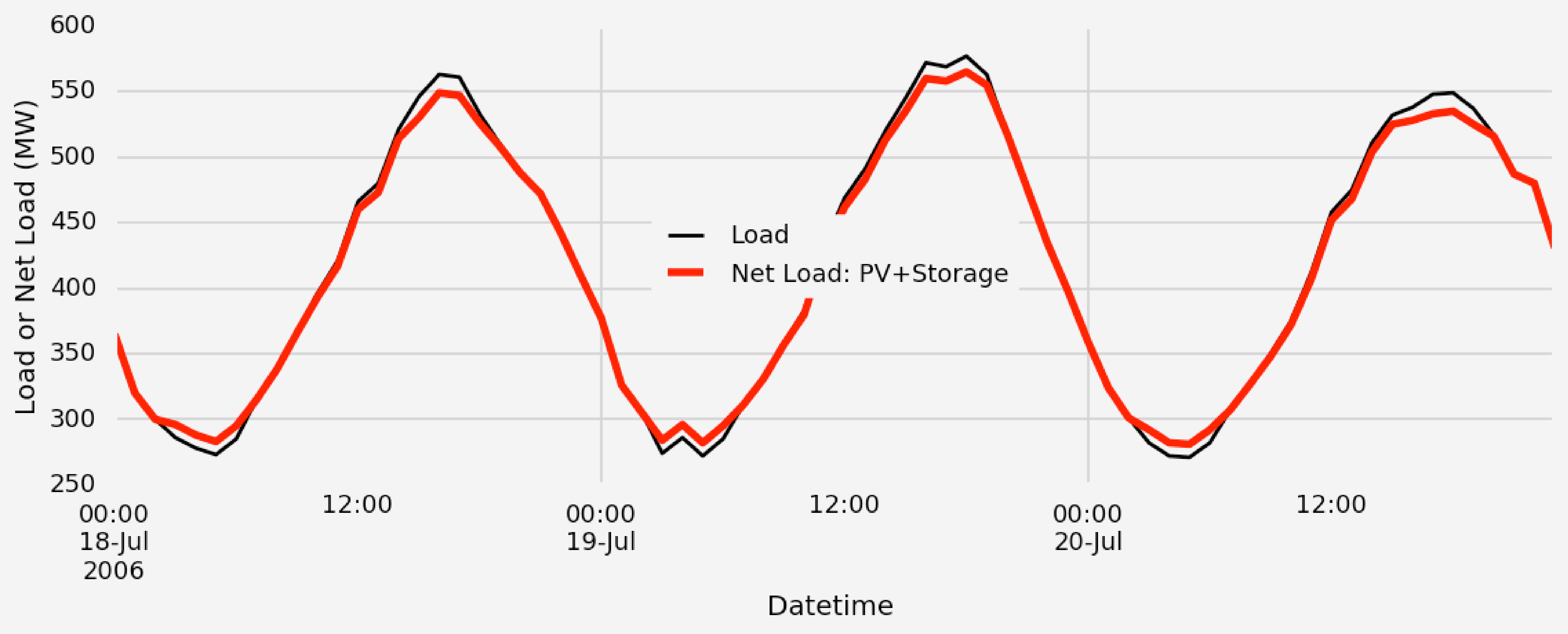


Real batteries may not be able to fully charge and discharge (i.e. may not achieve 100% depth of discharge). We use the* **accessible energy, *which may be less than the rated energy.*

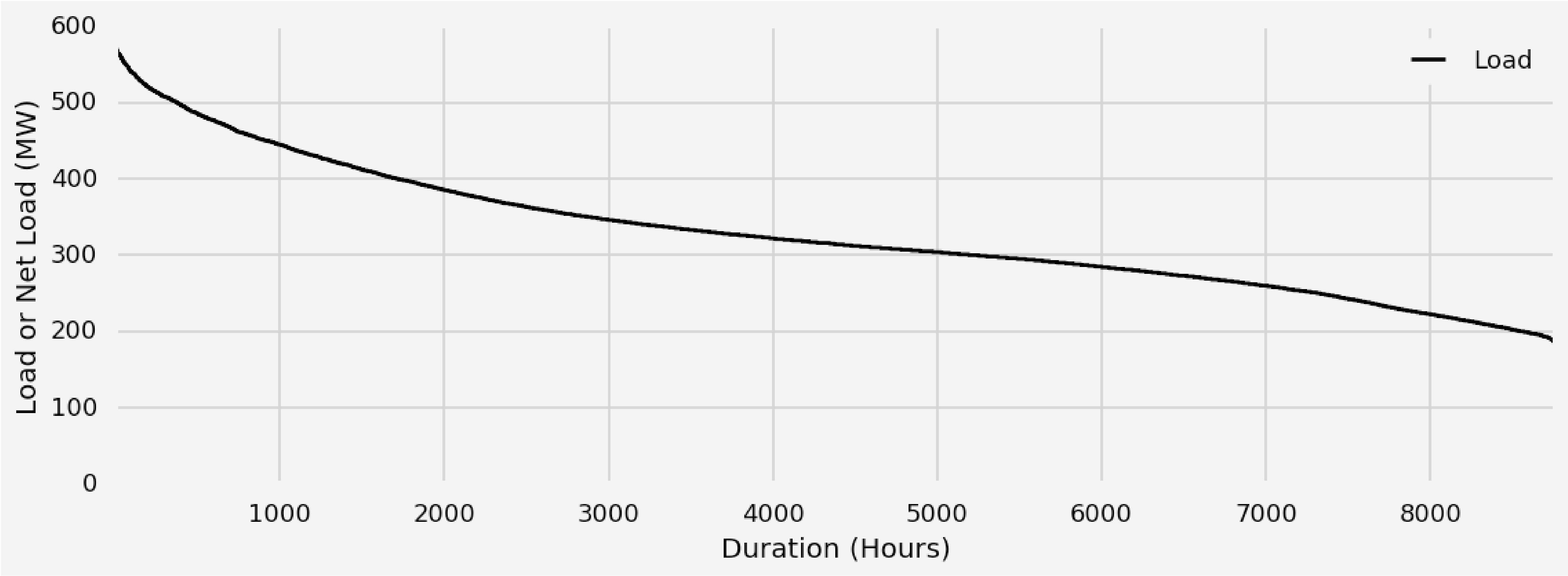
Hourly Load and Net Load with 10 MW of PV and 40 MWh Storage (4 Hour Duration)



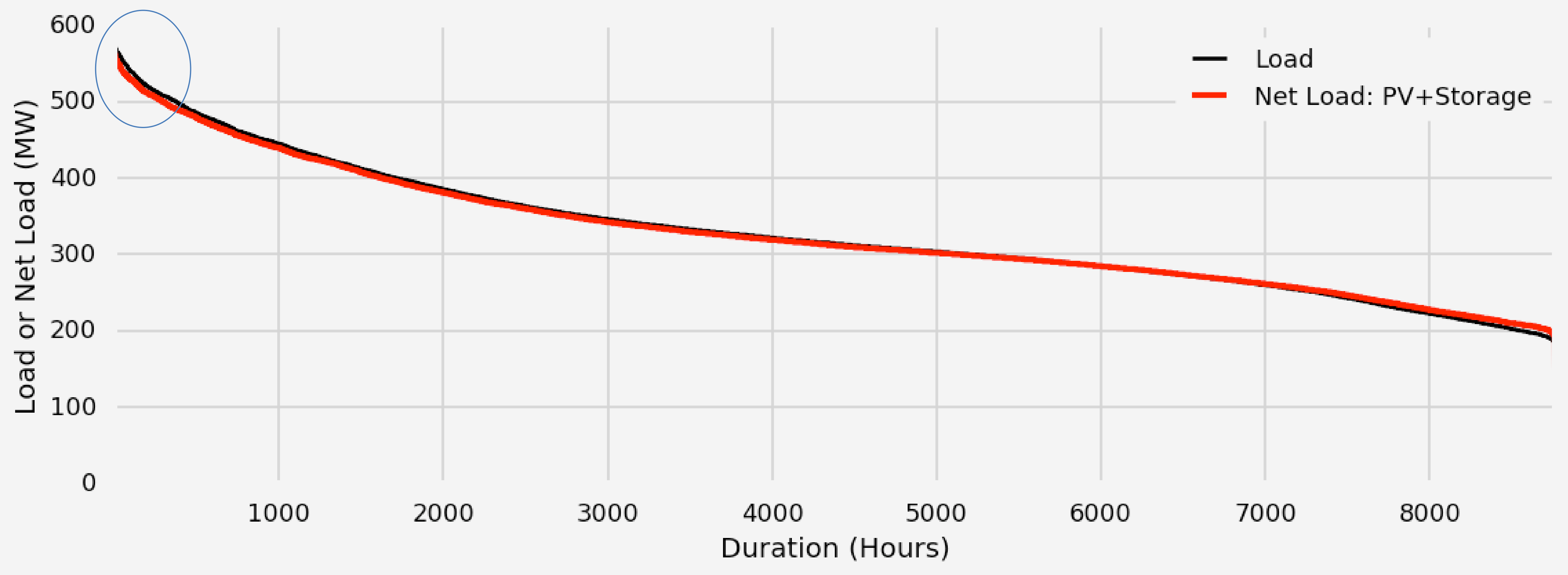
Peak Days: Load and Net Load with 10 MW of PV and 40 MWh Storage (4 Hour Duration)



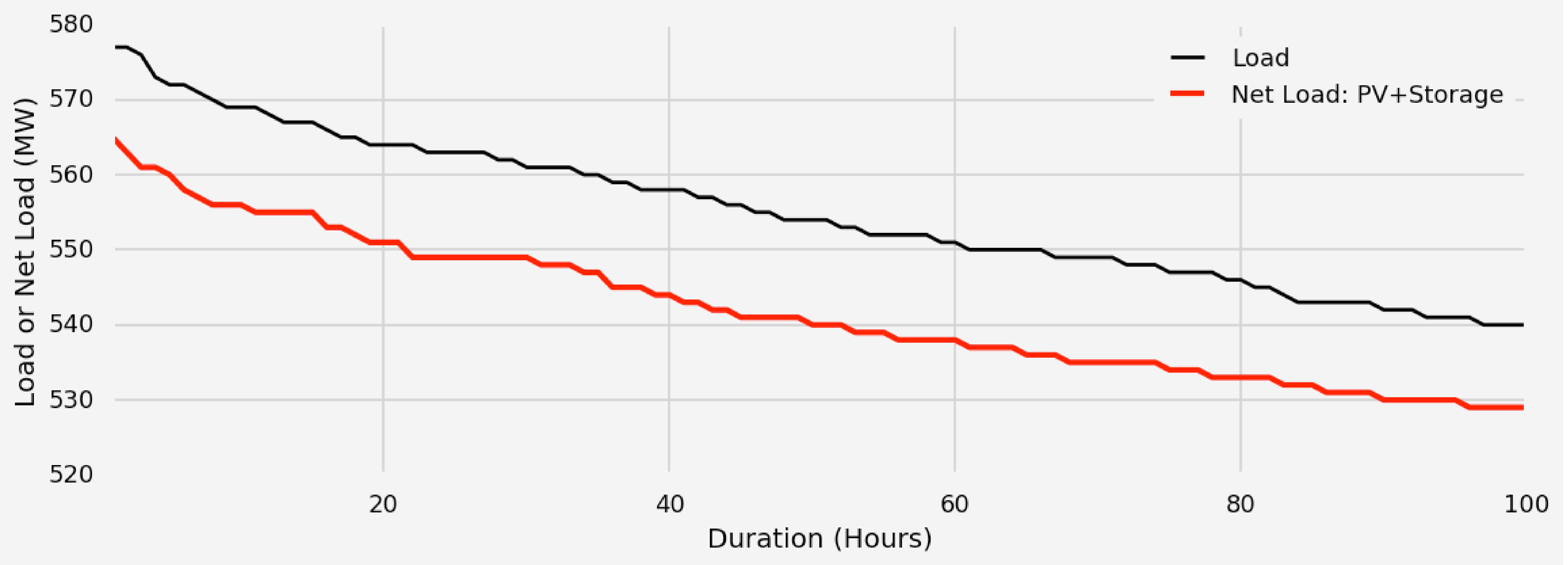
Load Duration Curve: Sort Load from Highest to Lowest Load



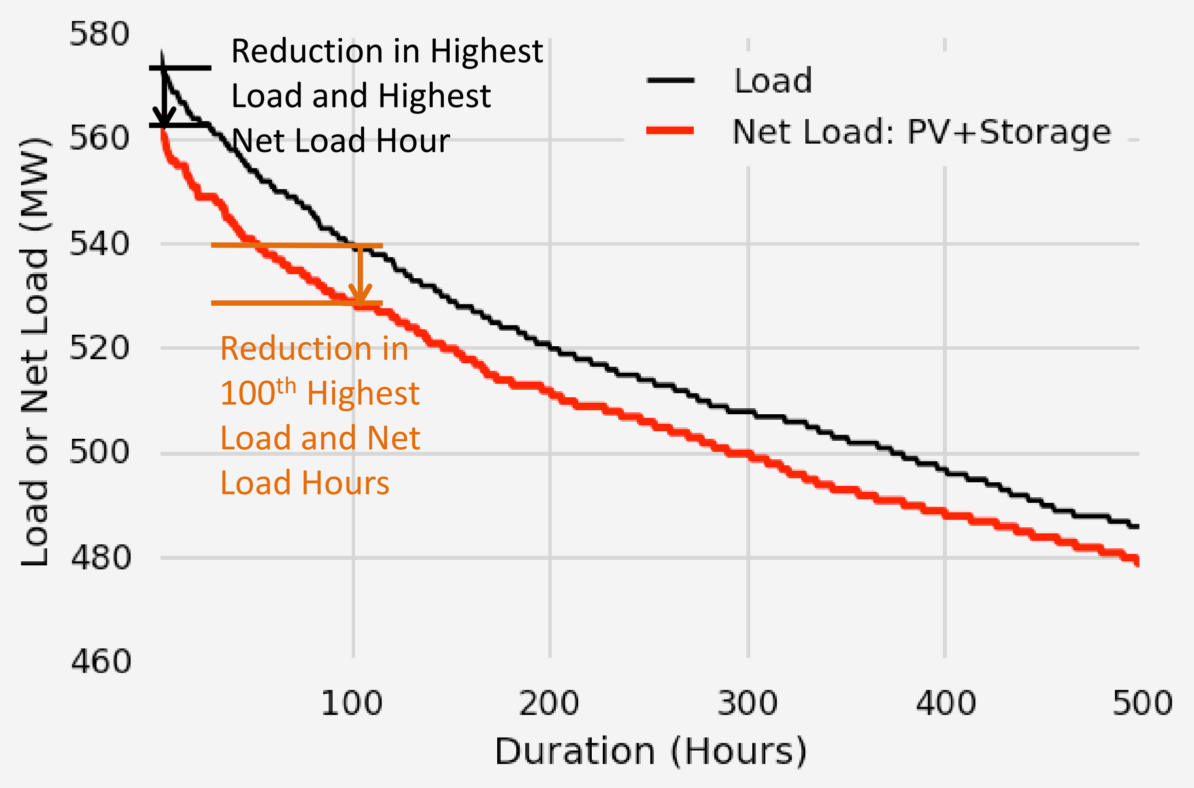
Net Load Duration Curve with 10 MW of PV and 40 MWh Storage: Resort from Highest Net Load to Lowest Net Load

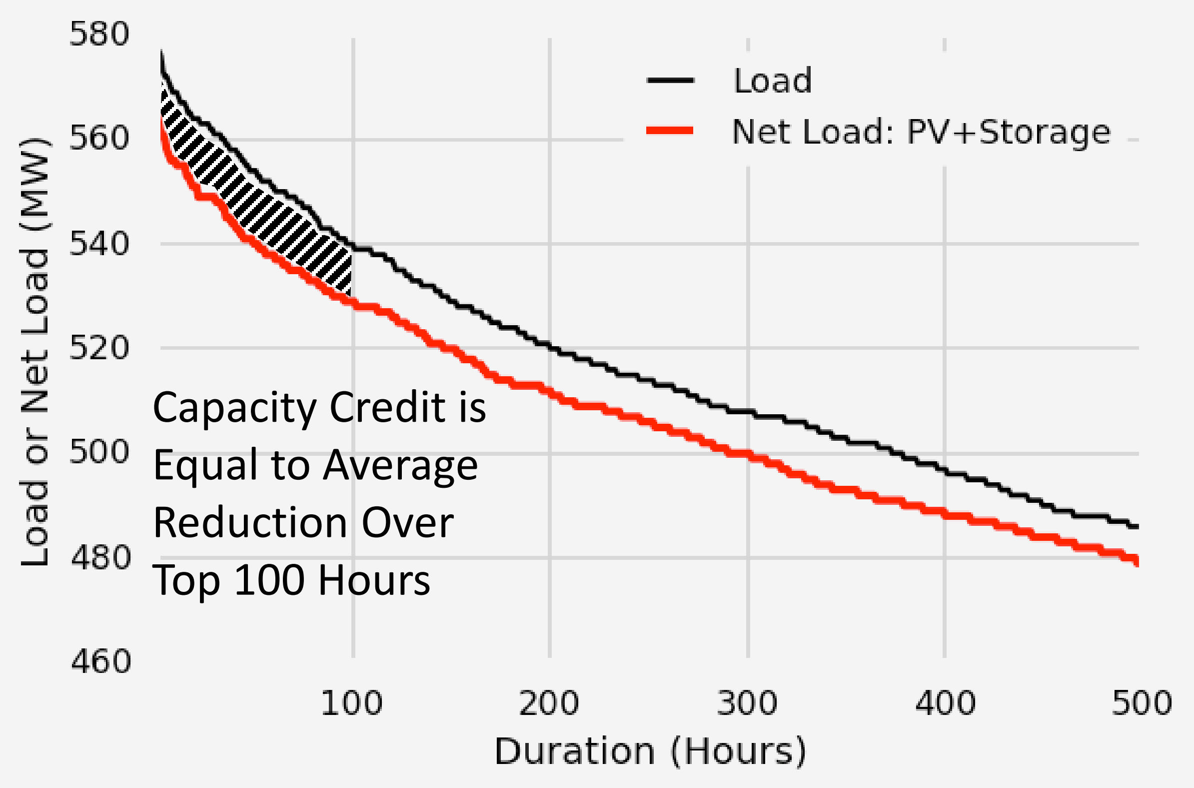


Top 100 Hours of Load and Net Load Duration Curve

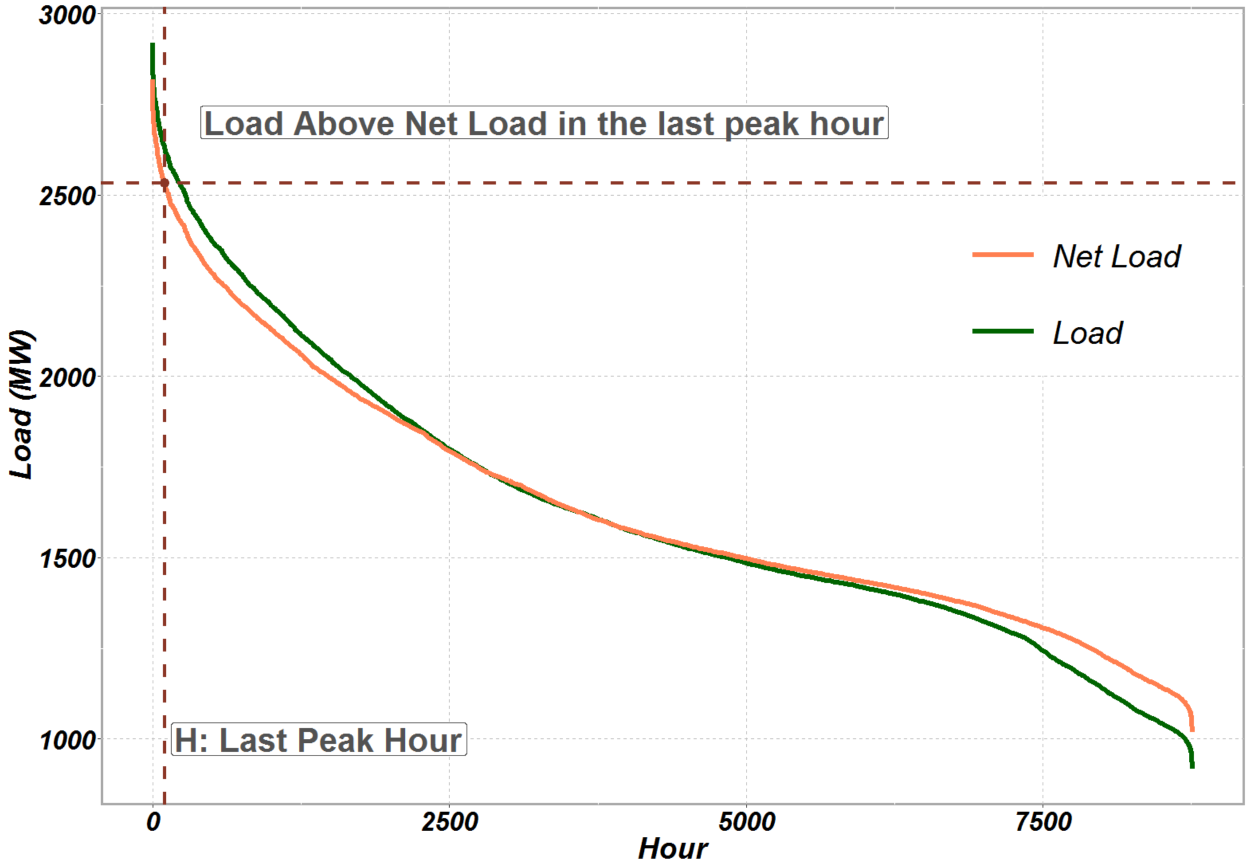


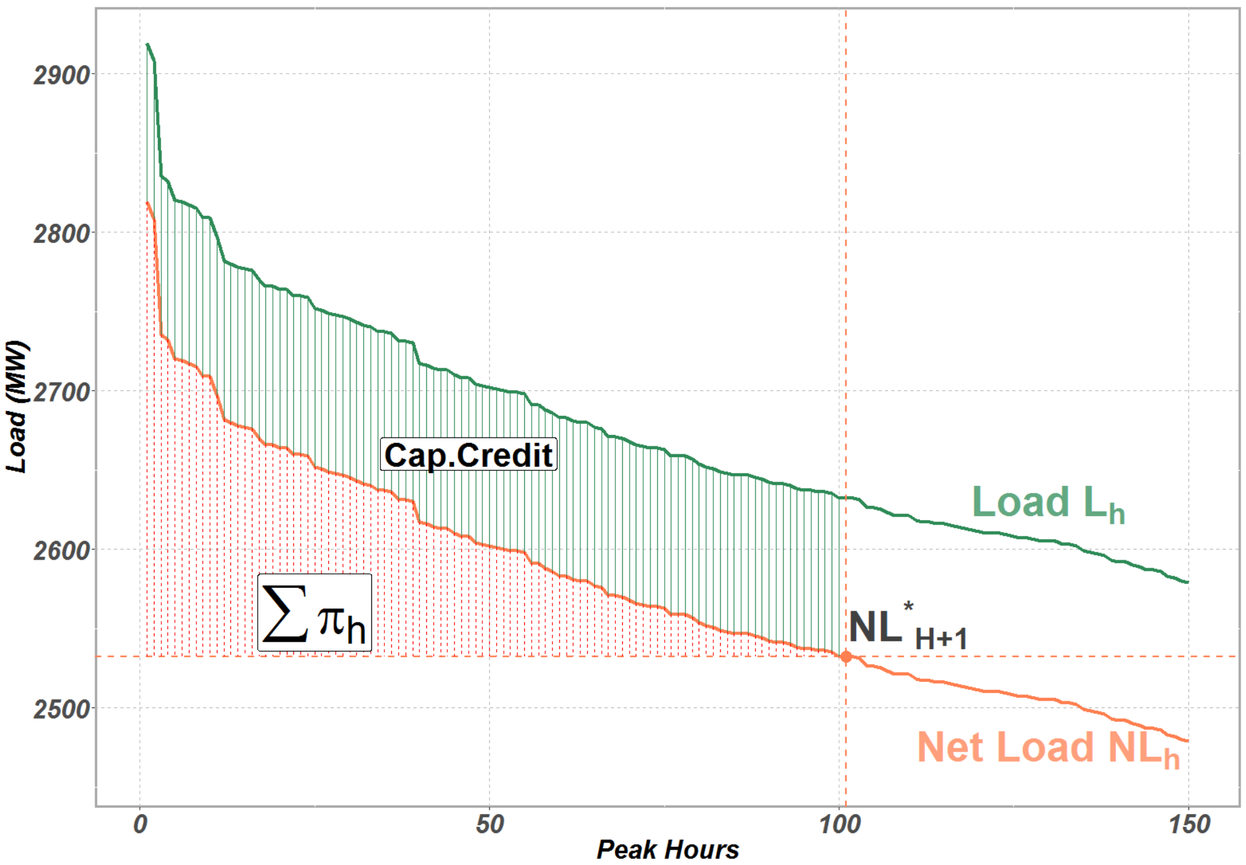
Capacity Credit Based on Method Used in NREL's Resource Planning Model





Storage Dispatch to Maximize Capacity Credit of Storage





Define capacity credit similar to NREL's "Resource Planning Model": difference of the highest peak load hours and highest peak net load hours. Use a simple linear model to find the storage dispatch that maximizes this capacity credit.

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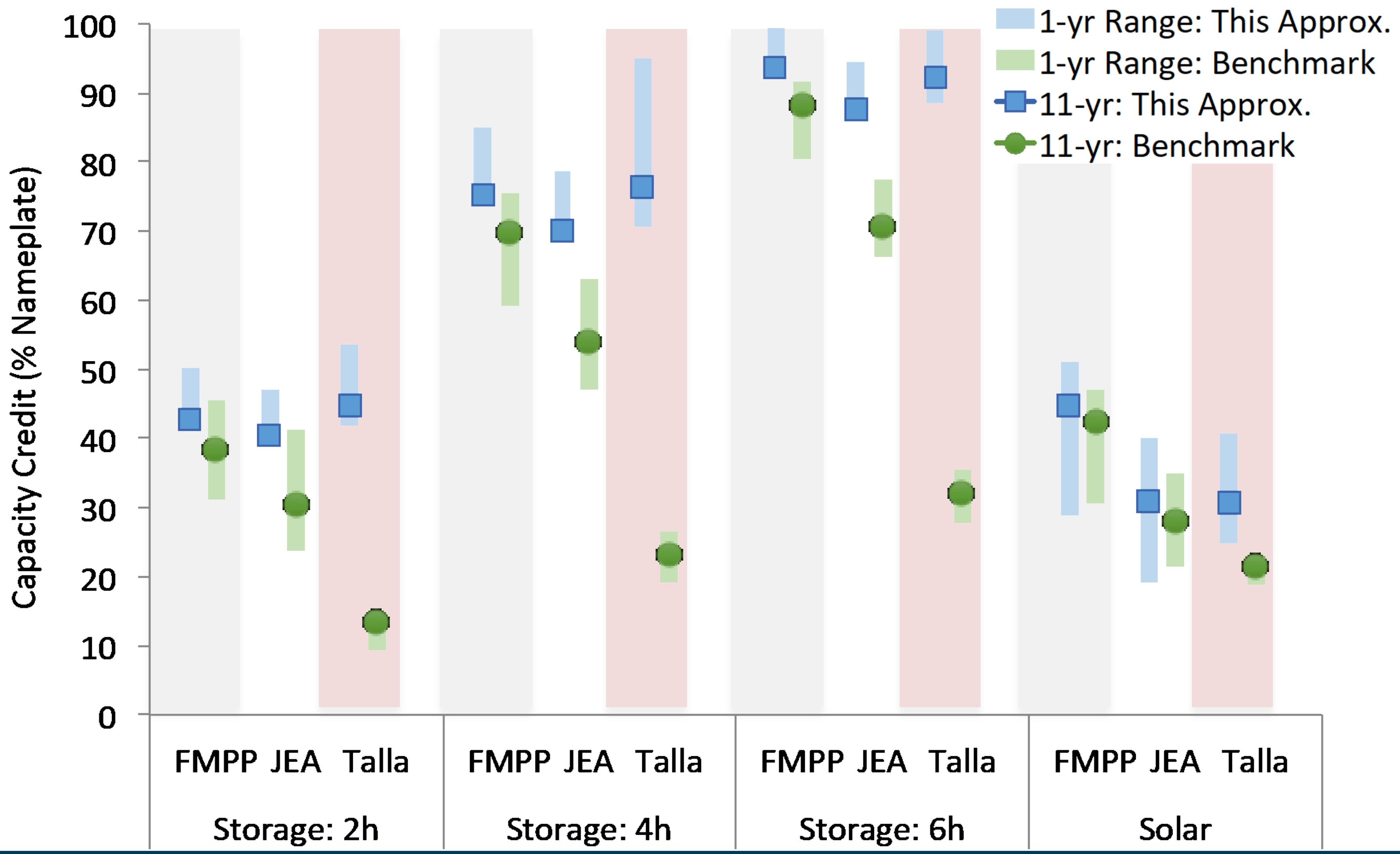
Capacity Credit Calculated with Simplified Method is Consistent with Probabilistic Benchmark Except for Very Small Utilities

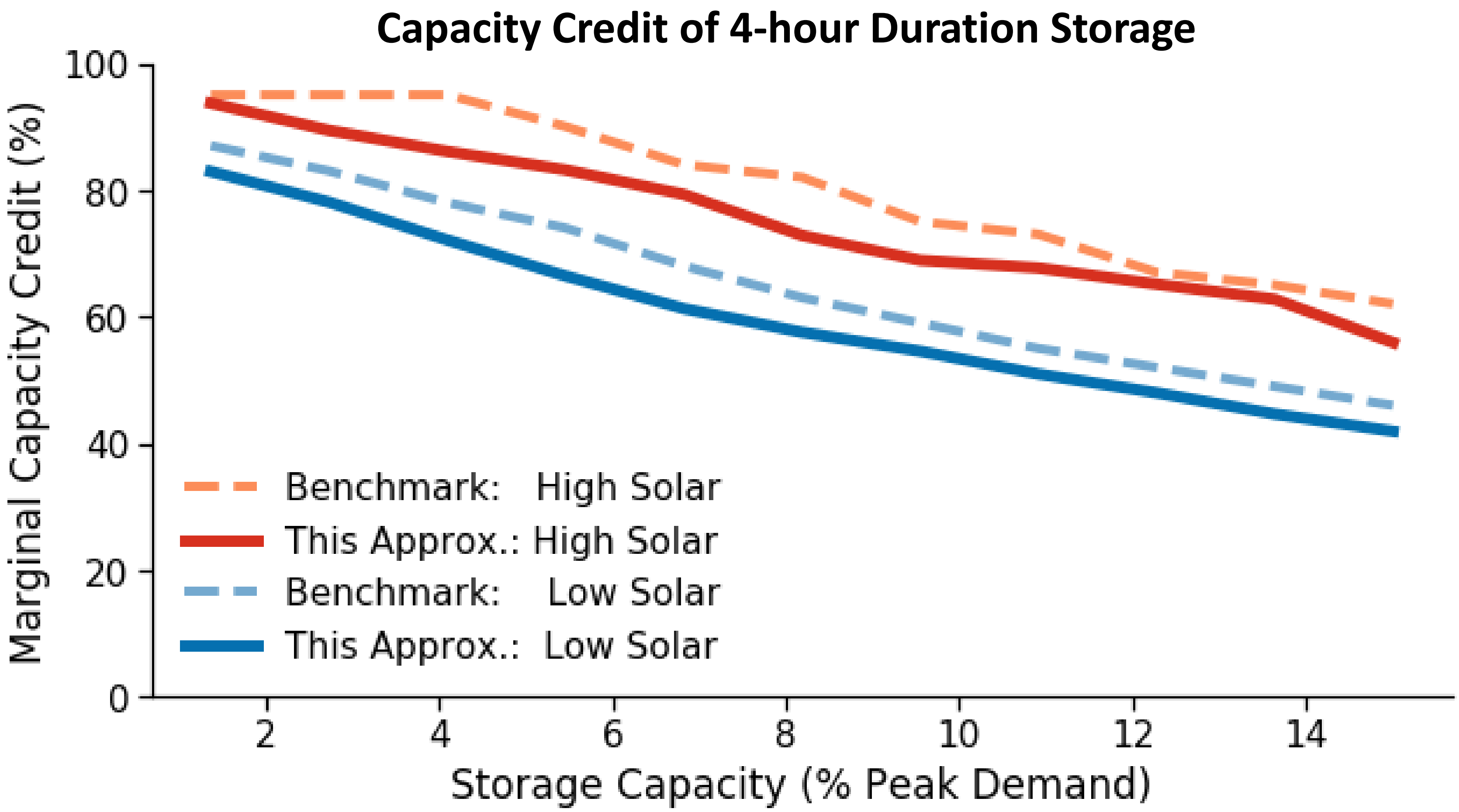


Probabilistic benchmark uses a simple Loss of Load Probability model to calculate the Effective Load Carrying Capability (ELCC).

ELCC represents the amount that the demand can be increased after a resource is added to the generation mix while maintaining the same level of overall reliability (2.4 LOLH/yr).

Approximation method only performs poorly for a small utility with a large generator (Talla).

Approximation Also Validated With a Probabilistic Benchmark from a Utility in the Western US



Probabilistic benchmark is a detailed Loss of Load Probability model used by the utility for planning.

The Benchmark shows the utility's estimated ELCC of 4-hour duration storage with a reliability criteria of 2.4 LOLH/yr.

Approximation method uses the utility's net load data to calculate the capacity credit of storage.

Both approaches show a declining capacity credit of 4-hour duration storage, and increase in capacity credit with high system-wide solar.

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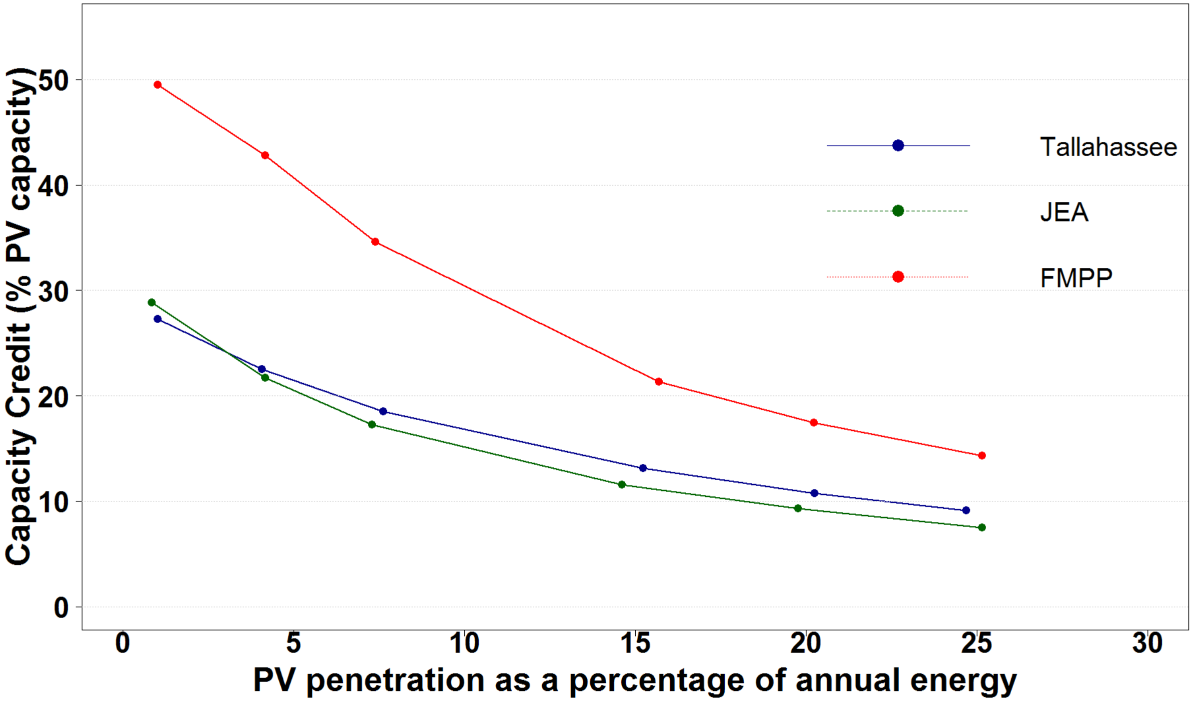
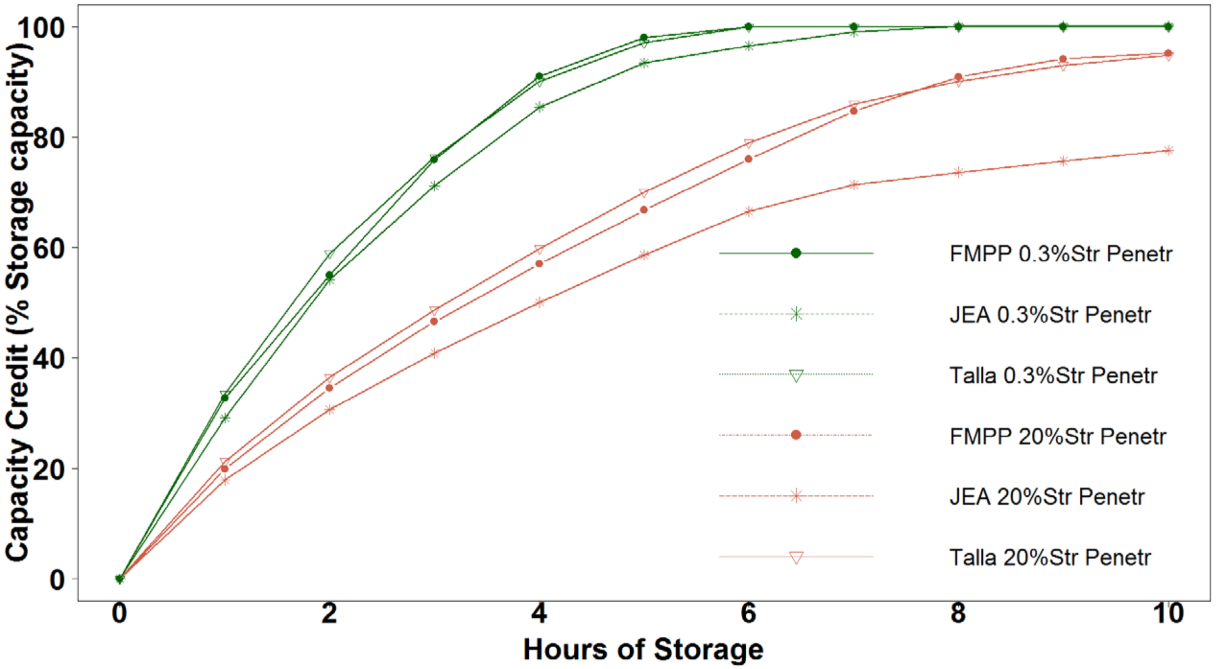
Analytical Approach

Configuration	Questions
PV Alone	• How does the capacity credit vary by site/utility combination? • How much does the capacity credit change depending on solar deployment?
Storage Alone	• How does the capacity credit of storage change with the size of the storage reservoir? • Does the capacity credit of storage change with storage deployment?
PV+Storage	• How does the capacity credit depend on the PV+storage configuration? • How do results change with the battery size relative to the PV size?

Capacity Credit of PV and Storage Alone

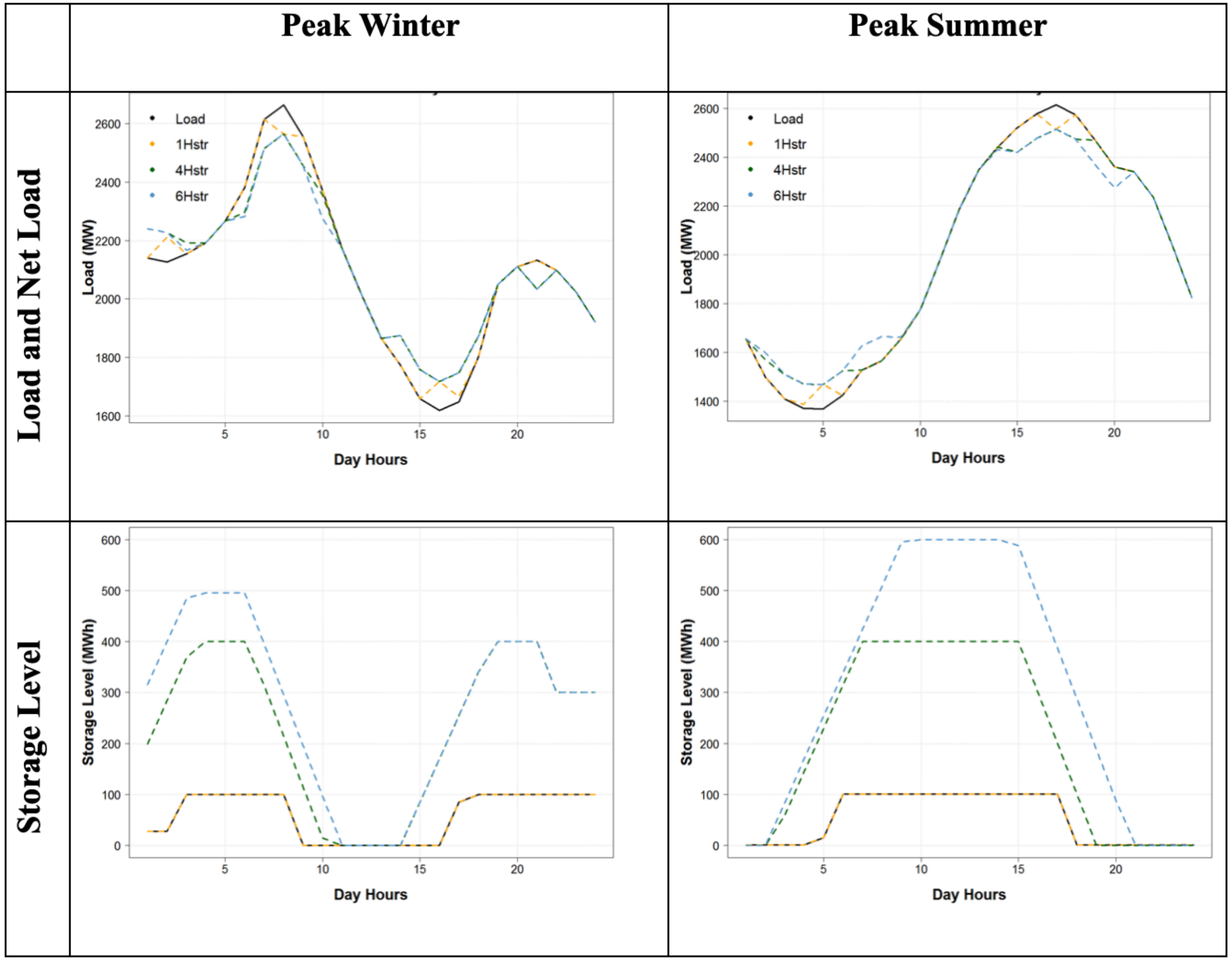




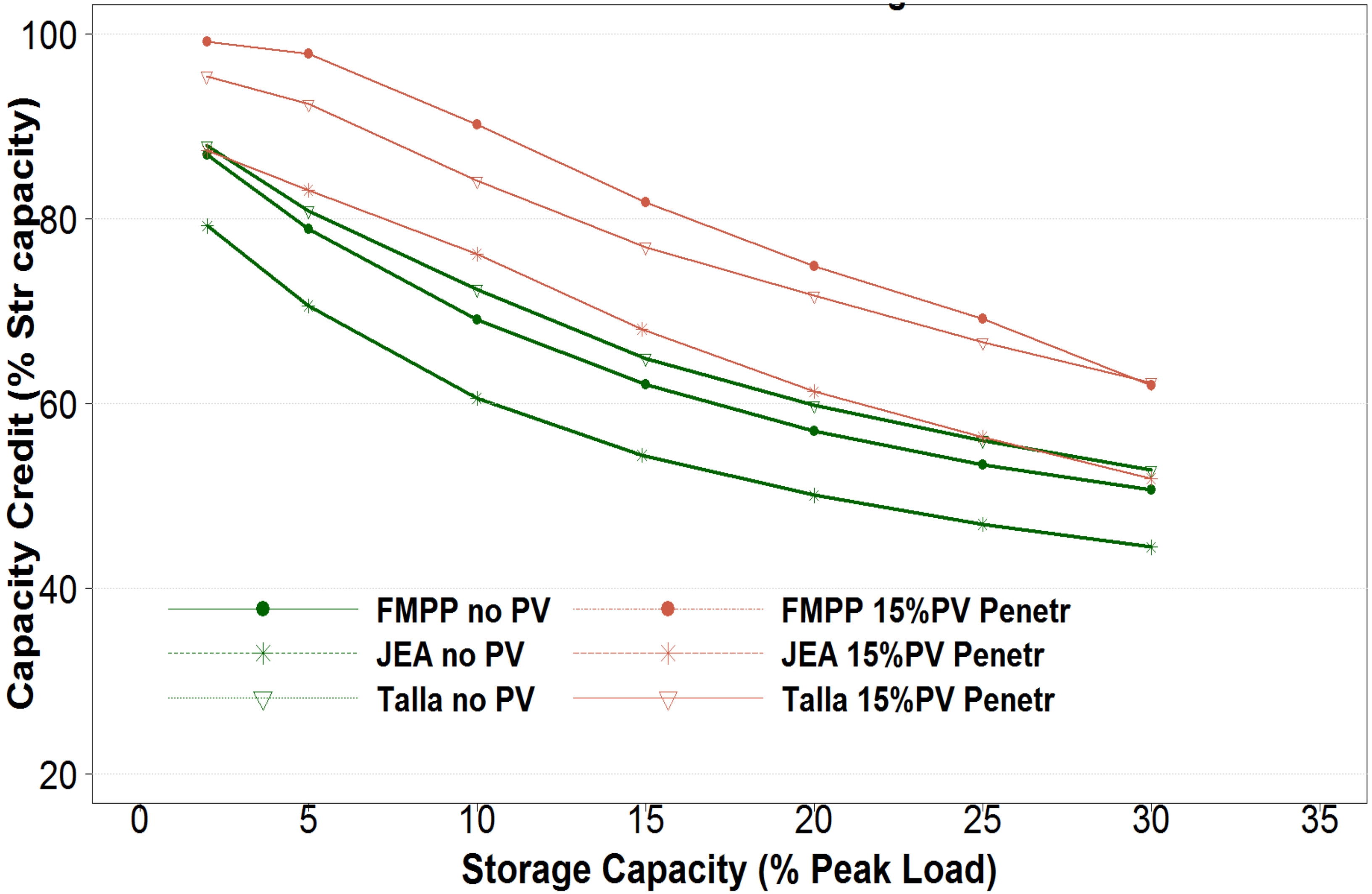
- Capacity credit of PV varies by utility, depending on how well correlated PV production is with peak load.
- Capacity credit of PV declines with increasing penetration.

- Capacity credit of storage depends on duration.
- Duration required to achieve near 100% capacity credit increases with storage deployment.

Impact of Storage Duration on Storage's Ability to Reduce Winter and Summer Peak Load Hours



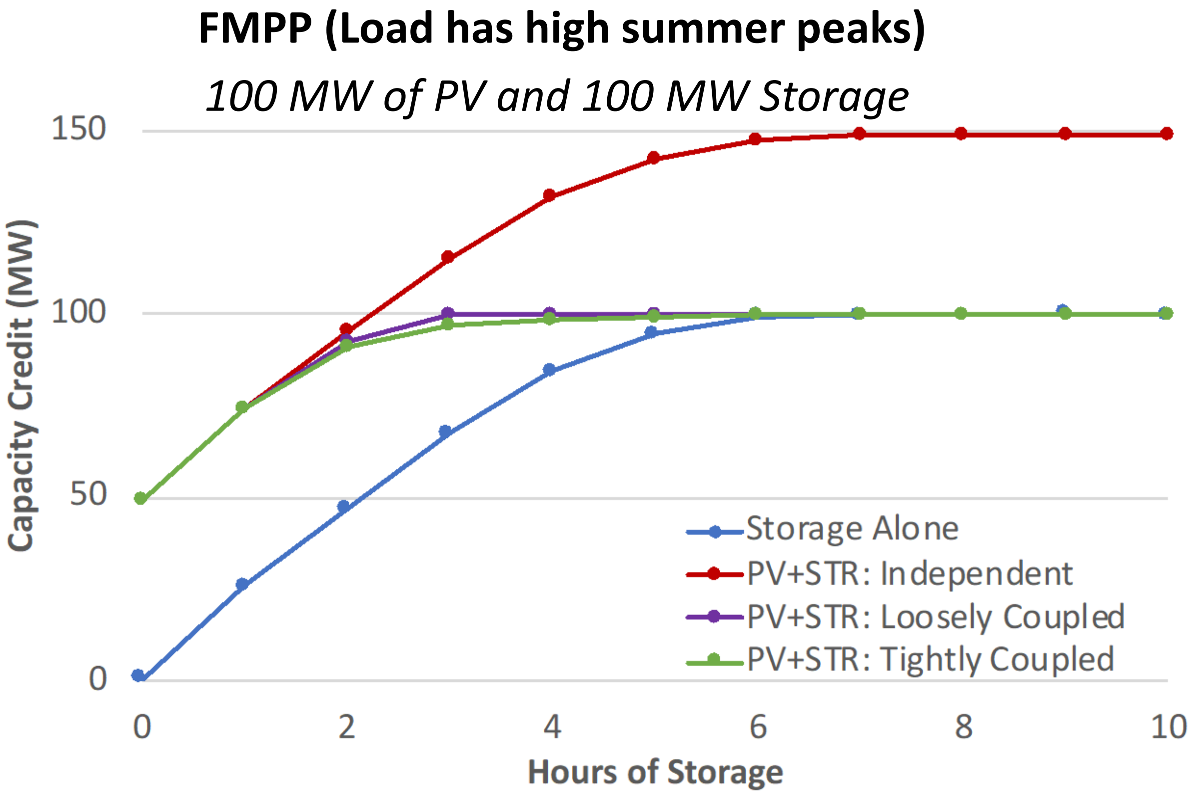
For a Fixed Storage Duration (4 hours), Capacity Credit Declines As More and More Storage is Deployed

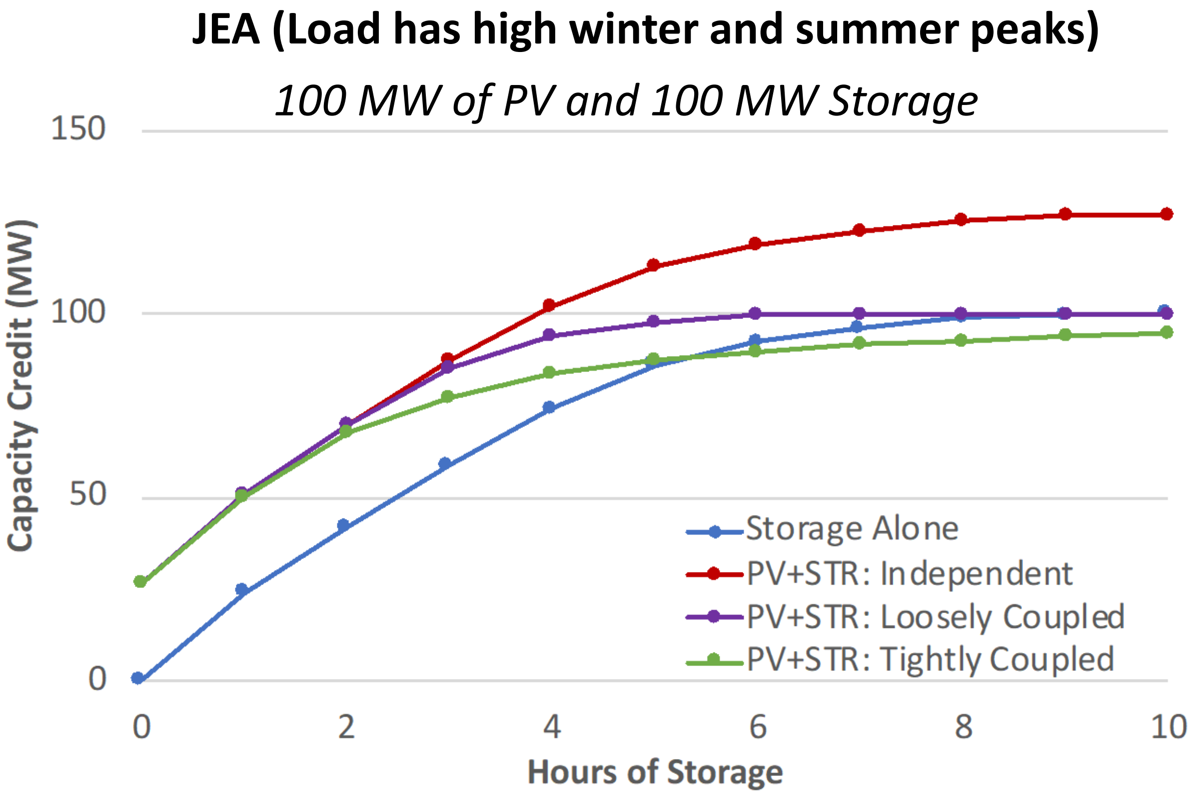


PV + Storage Configurations

Configuration	Description	Share Equipment?	Source of Electricity for Storage
Independent	PV and storage do not share equipment and storage is charged from the grid	No	Grid
Loosely Coupled	PV and storage both connect on the DC side of shared inverters, but storage can charge from storage or the grid	Shared Inverter	Grid or PV
Tightly Coupled	PV and storage connect on DC side of shared inverters, and storage can only charge from PV	Shared Inverter	Only PV

Capacity Credit of Solar+Storage Systems With Large Batteries Depends on Configuration





- Capacity credit of PV+Storage can be limited by the shared inverter when DC coupled
- No significant difference for loosely vs. tightly coupled

- For a load with high winter peaks, differences between loosely and tightly coupled are more important
- Restricting storage to charge only from solar can lead to a lower capacity credit than storage alone

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- Contribution of solar+storage to resource adequacy is important to planning and understanding the value proposition
- Capacity credit of solar varies by utility due to differences in load patterns; declines with higher penetration of solar
- Capacity credit of storage varies with storage duration; also declines with increased deployment of storage
- Capacity credit of solar+storage depends on the configuration
  - Can be limited by shared inverter or interconnection when batteries are large
  - Can be limited by requirements to charge storage only from solar

Questions?

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Mills, A.D., and P. Rodriguez. 2019. *Drivers of the Resource Adequacy Contribution of Solar and Storage for Florida Municipal Utilities*. Berkeley, CA: Lawrence Berkeley National Laboratory, October. https://escholarship.org/uc/item/9xz19063

Download all of our work at:

http://emp.lbl.gov/reports/re

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