NREL
Transforming ENERGY

Storage Futures Study: Grid Operational Impacts of Widespread Storage Deployment

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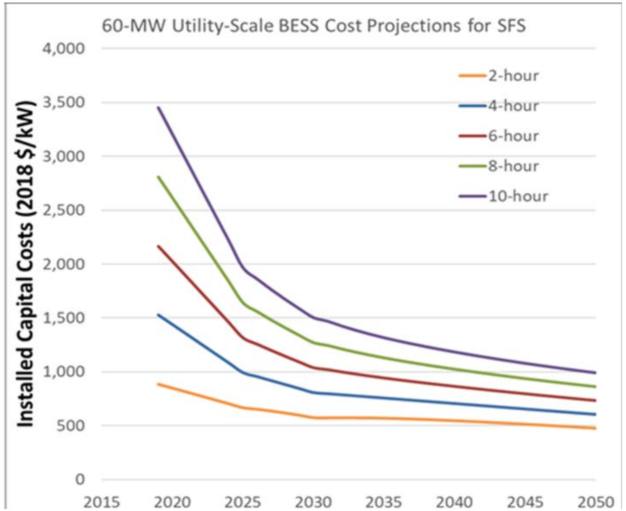
Storage Futures Study

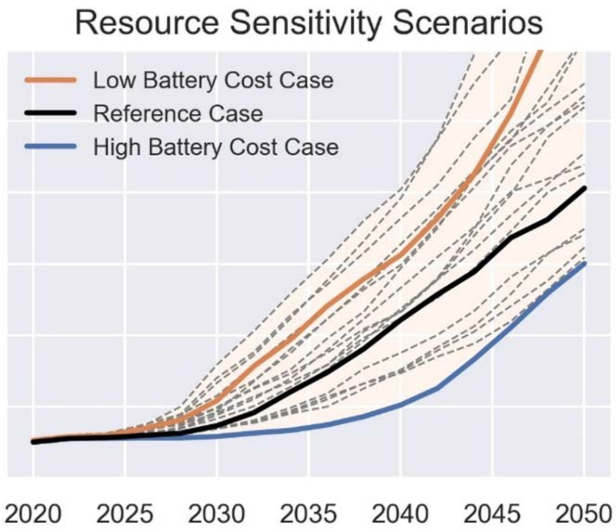
NREL is analyzing the rapidly increasing role of energy storage in the electrical grid through 2050.

- "Four Phases" - theoretical framework driving storage deployment
- Techno-Economic Analysis of Storage Technologies
- Deep dive on future costs of distributed and grid batteries
- Various cost-driven grid scenarios to 2050
- Distributed PV + storage adoption analysis
- Grid operational modeling of high-levels of storage

One Key Conclusion: Under all scenarios, dramatic growth in grid energy storage is the least cost option.

https://www.nrel.gov/analysis/storage-futures.html





The Storage Futures Study

✓ = discussed in detail today

The Four Phases of Storage Deployment: This report examines the framework developed around energy storage deployment and value in the electrical grid.

Storage Technology Modeling Input Data Report: A report on a broad set of storage technologies along with current and future costs for all modeled storage technologies including batteries, CSP, and pumped hydropower storage.

Grid-Scale Diurnal Storage Scenarios: A report on the various future capacity expansion scenarios and results developed through this project. These scenarios are modeled in the ReEDS model.

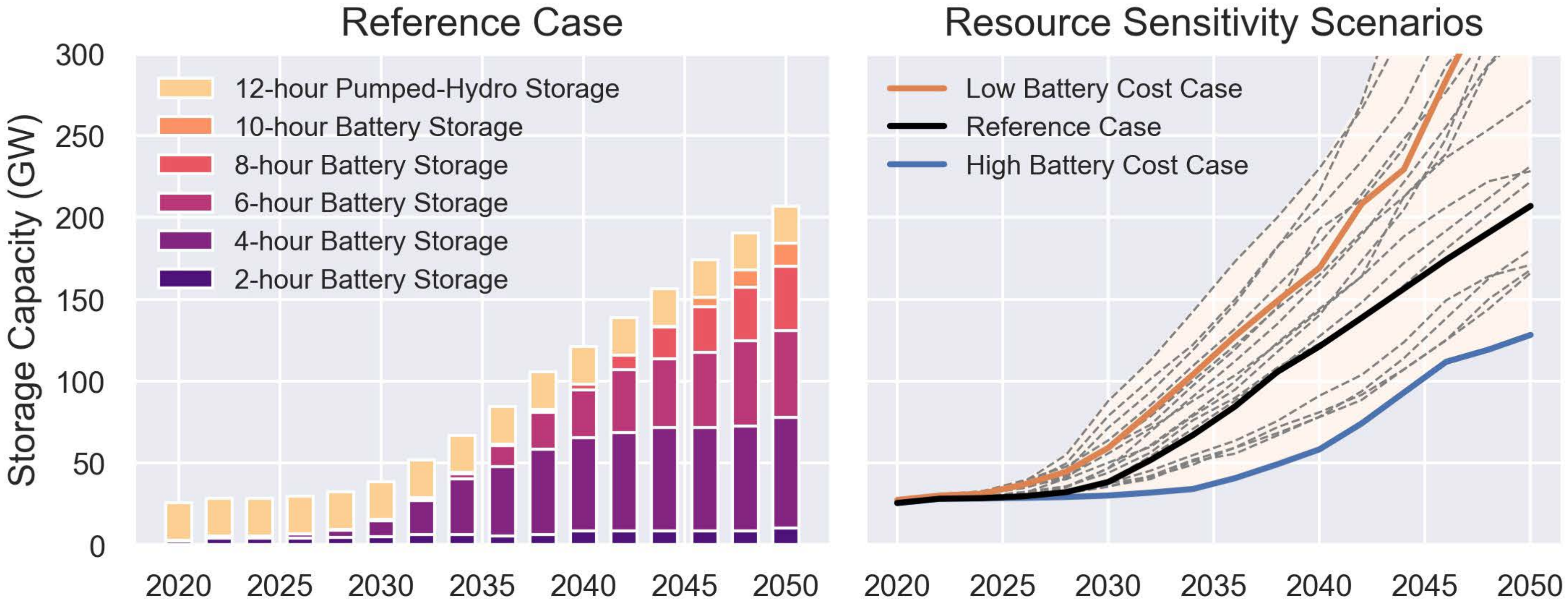
Distributed Storage Adoption Scenarios: A report on the various future distributed storage capacity adoption scenarios and results and implications. These scenarios reflect significant model development and analysis in the dGen model.

The Challenge of Defining Long-Duration Storage: Thought piece describing the challenge of a single uniform definition for long-duration energy storage to reflect both duration and application of the stored energy.

✓ **Grid Operational Impacts of Storage:** A report on the operational characteristics of energy storage, validation of ReEDS scenarios on capturing value streams for energy storage as well as impacts of seasonal storage on grid operations. Released January 2022

Synthesis Report: A final summary report that draws on all prior reports, generates key conclusions and summarizes the entire activity. Estimated release - February 2022

Storage is poised for rapid growth…

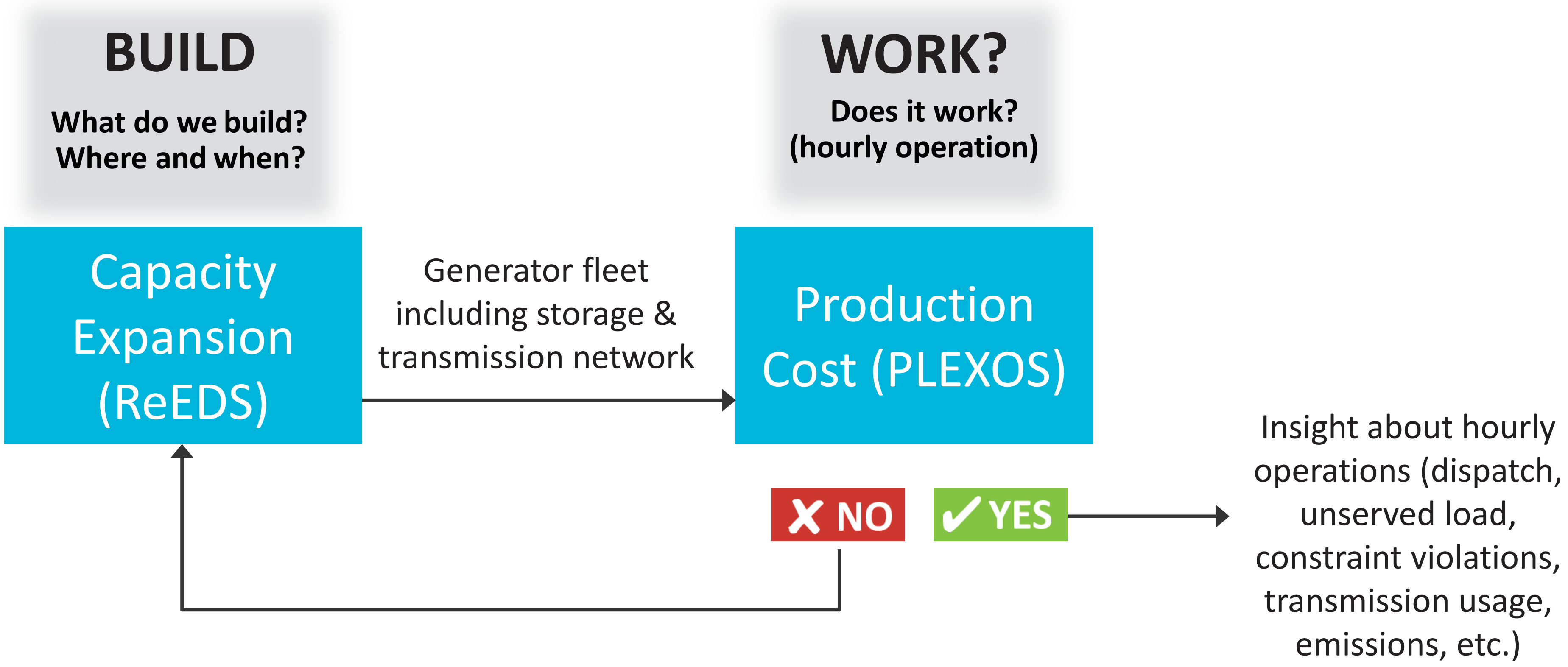


Source: Frazier, et al. Grid-Scale Diurnal Storage Scenarios, 2021.

…Questions about grid operations under such futures remain

- Can capacity expansion models (such as ReEDS) capture the realities of grid operations with significant amounts of diurnal storage & variable generation in informing investment decisions?
- What role does storage play in day-to-day and hour-to-hour operations of the electric power system?
- How does storage interact with wind and PV generation?
- Does storage impact the operation of other power system assets such as transmission and thermal generators and what are the implications?

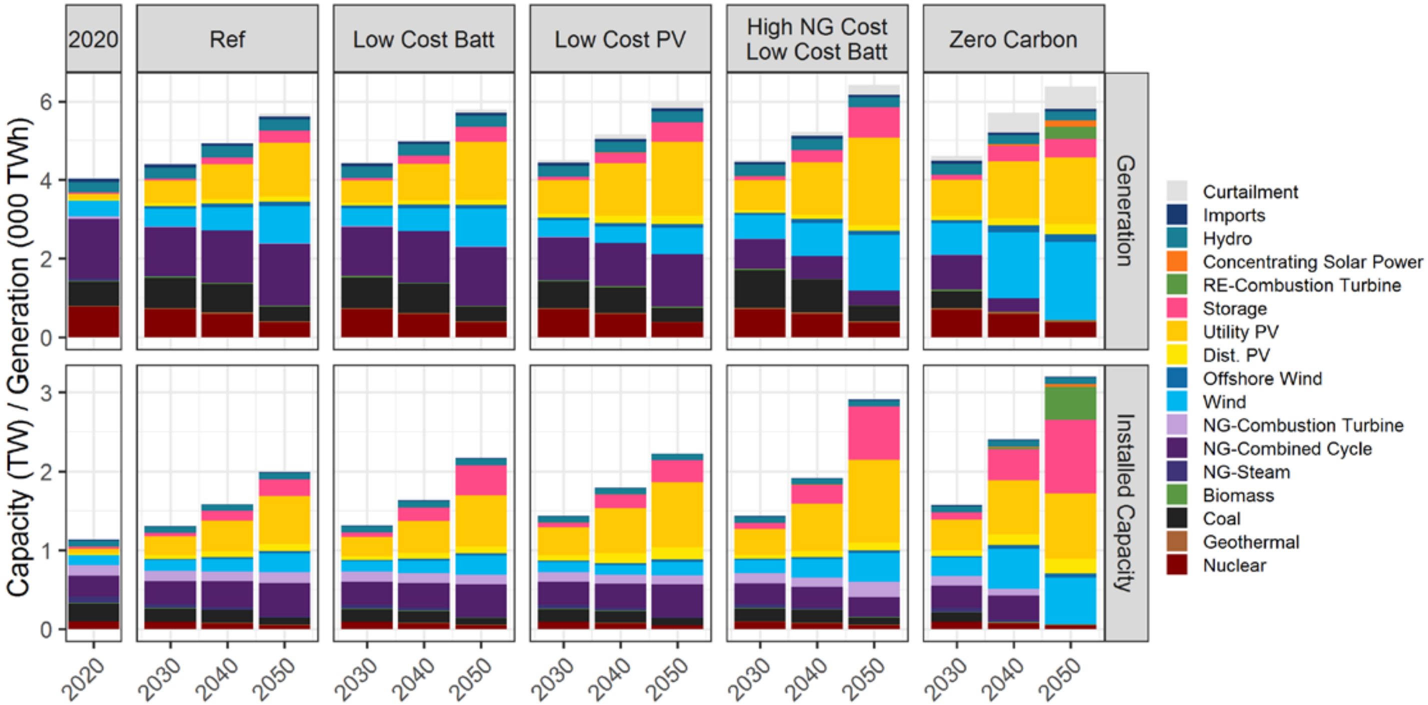
Modeling Framework – Bulk Power System



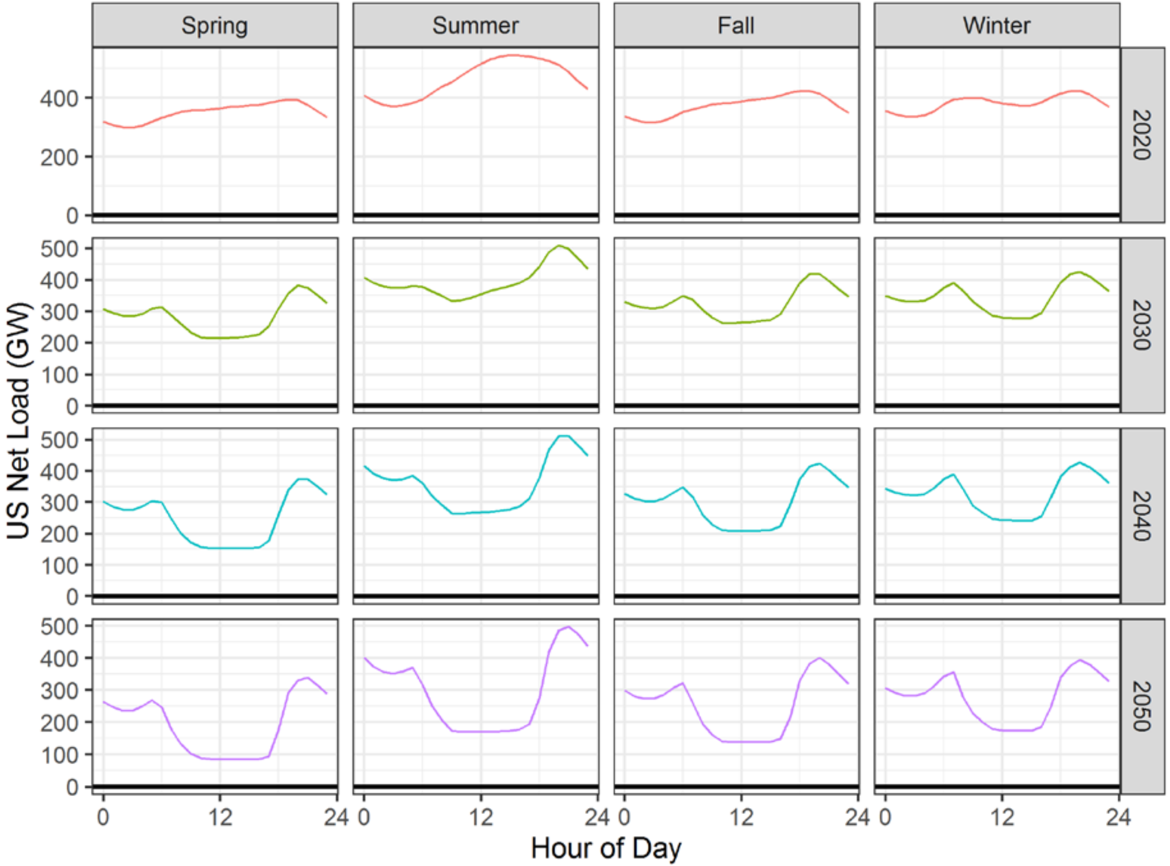
Scenario Framework

Less aggressive 2050 (200 GW storage, 20% wind, 28% solar)

Most aggressive 2050 (930 GW storage, 37% wind, 33% solar)

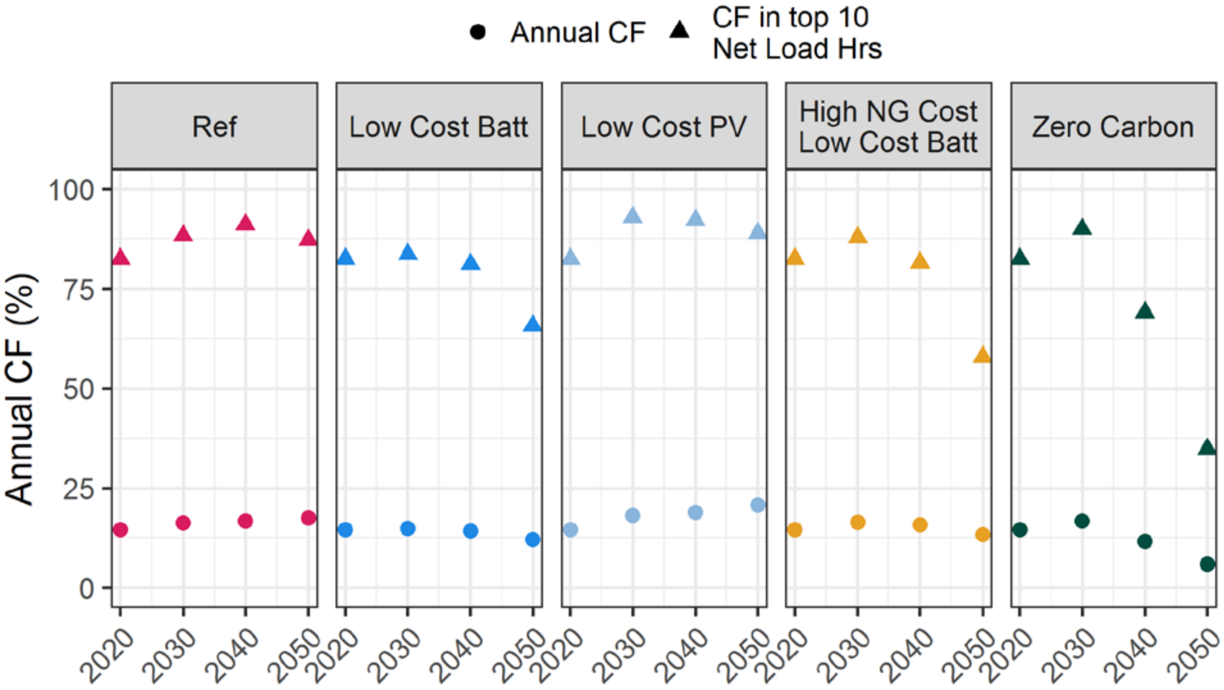


Conclusion #1: All scenarios (2020 – 2050) showed no unserved energy, and low reserve violations



- Example net load shapes from the High NG Cost Low PV Cost Case shows dramatic change in all seasons
- But, improvements made to ReEDS to better consider chronology was overall successful to envision high VG/storage systems that can balance on an hour-by-hour basis
  - Contribution from PV & Wind for the 2050 scenarios varied from 49-74%

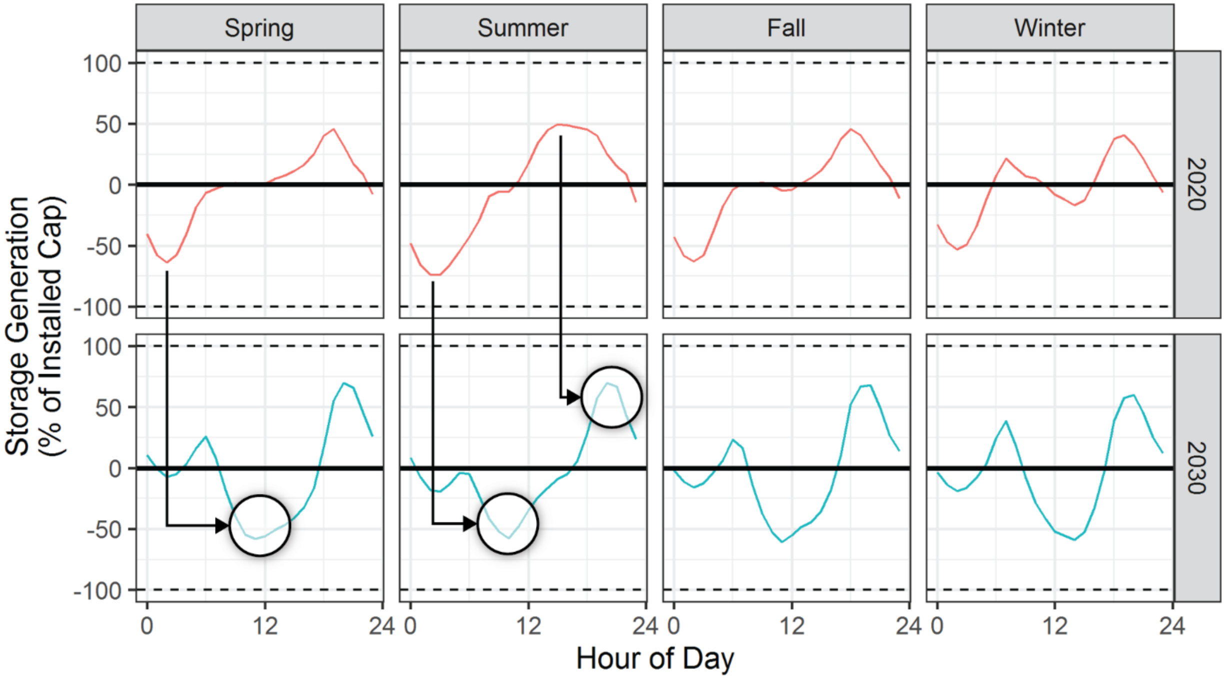
Conclusion #2: Storage plays a big role in shifting energy – even if annual usage is low



- Capacity Factor (CF) of storage is inherently limited by its need to charge, as well as efficiency loss
- Dots indicate CF < 25% in all scenarios, and even below 10%
- Triangles show that storage contributes a lot during the top 10 net load hours of the year – providing energy when it's most needed
- Utilization generally decreases as storage deployments rise

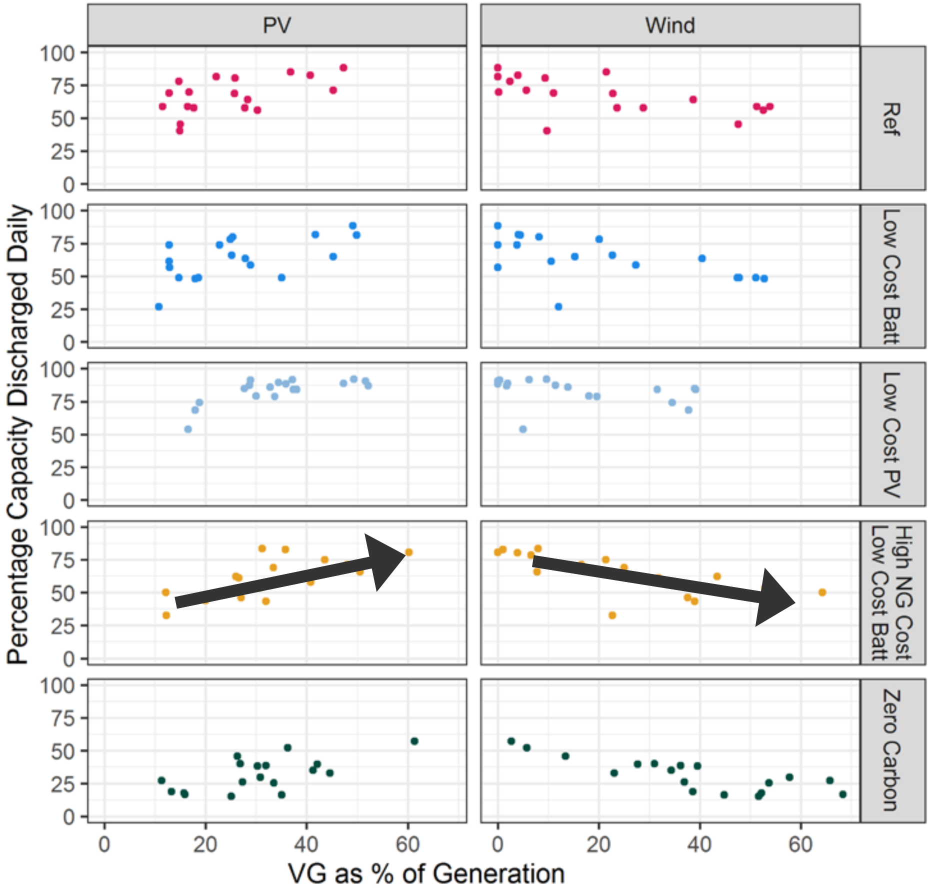
Conclusion #3: On an operational basis, storage and PV are better together

Storage operation – 2020 (top) and 2030 (bottom)



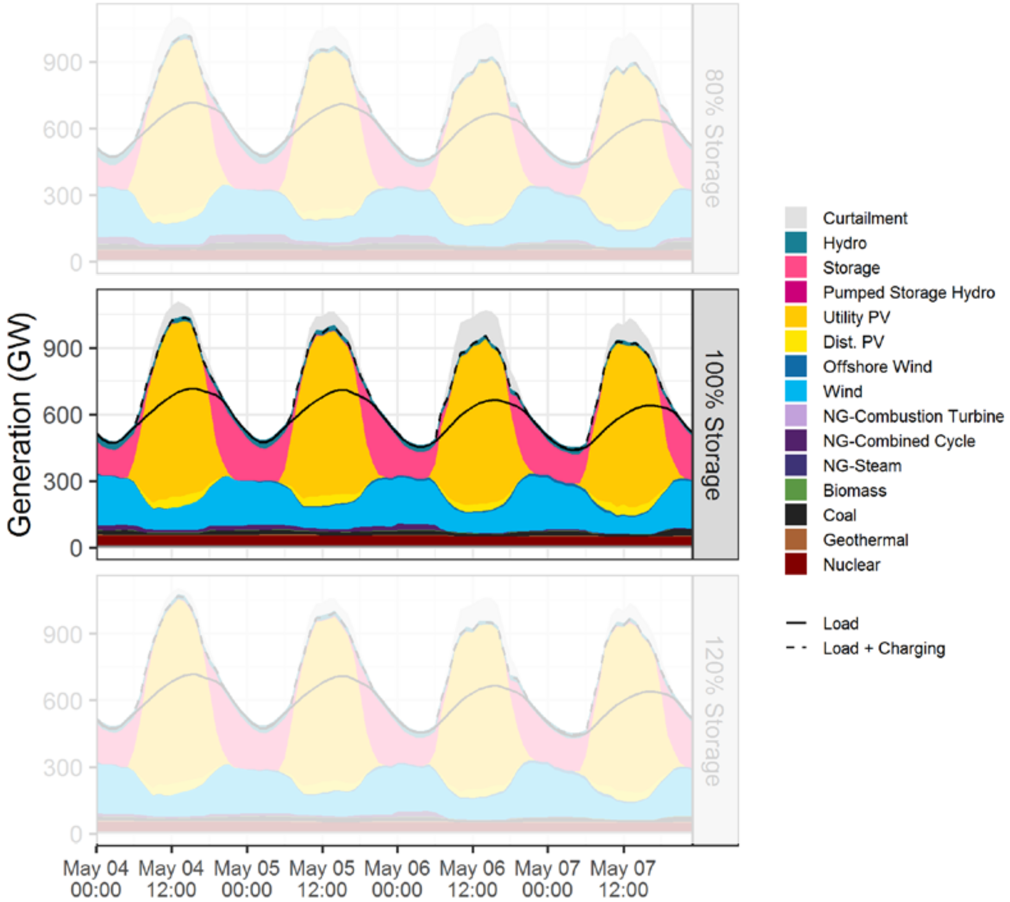
- Storage operation changes over time
  - 2020: charging overnight on "cheap" wind or coal
  - 2030: charging during the day on solar
  - Still discharging during evening peak (and lesser extent during morning peak)
- During the 2020 summer peak, storage must discharge for longer. During 2030 peak, storage can discharge at closer to full output (on average) due to narrower peak

Conclusion #3: On an operational basis, storage and PV are better together



- Number of daily cycles for storage (or % capacity discharged daily, where 100% would be one cycle)
- Regions with more PV exhibit higher amounts discharged on a daily basis, but the opposite trend for wind
  - With PV, an increased need for daily cycling
  - Wind overgeneration generally occurs for longer periods – diurnal storage is limited by duration in how much it can absorb

Conclusion #4: Storage makes better use of other grid assets too (not only excess VG)



Sensitivities varying the amount of storage illustrate the role it plays in changing load shape, reducing overgeneration, reducing gas generation, etc.

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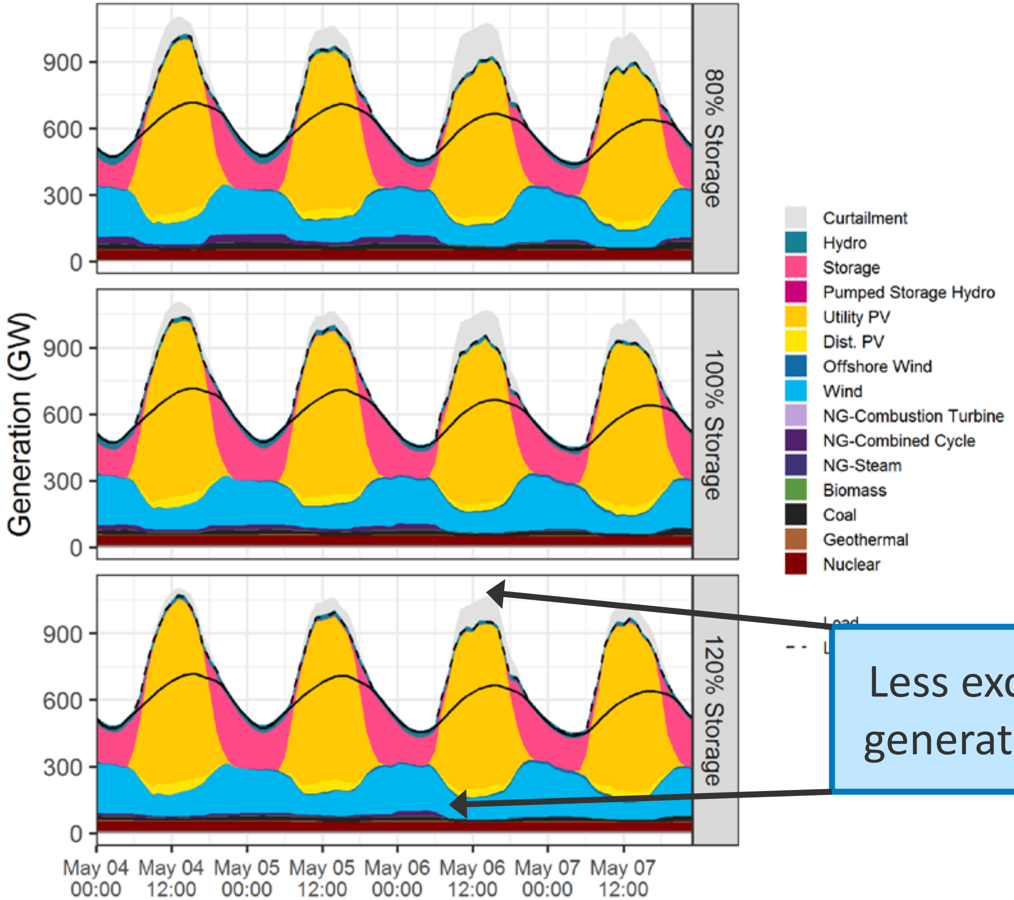

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Less excess PV, gas CC generation goes down

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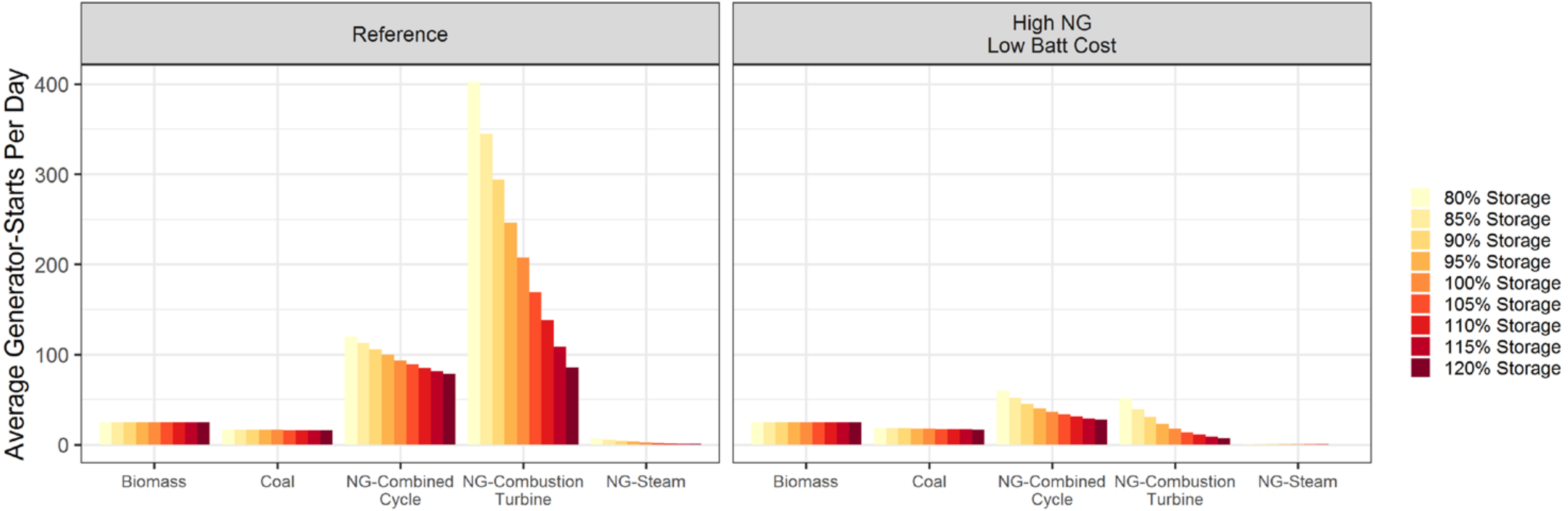

Storage reduces the average number of generator starts per day, dramatically in some categories – reducing cost and emissions

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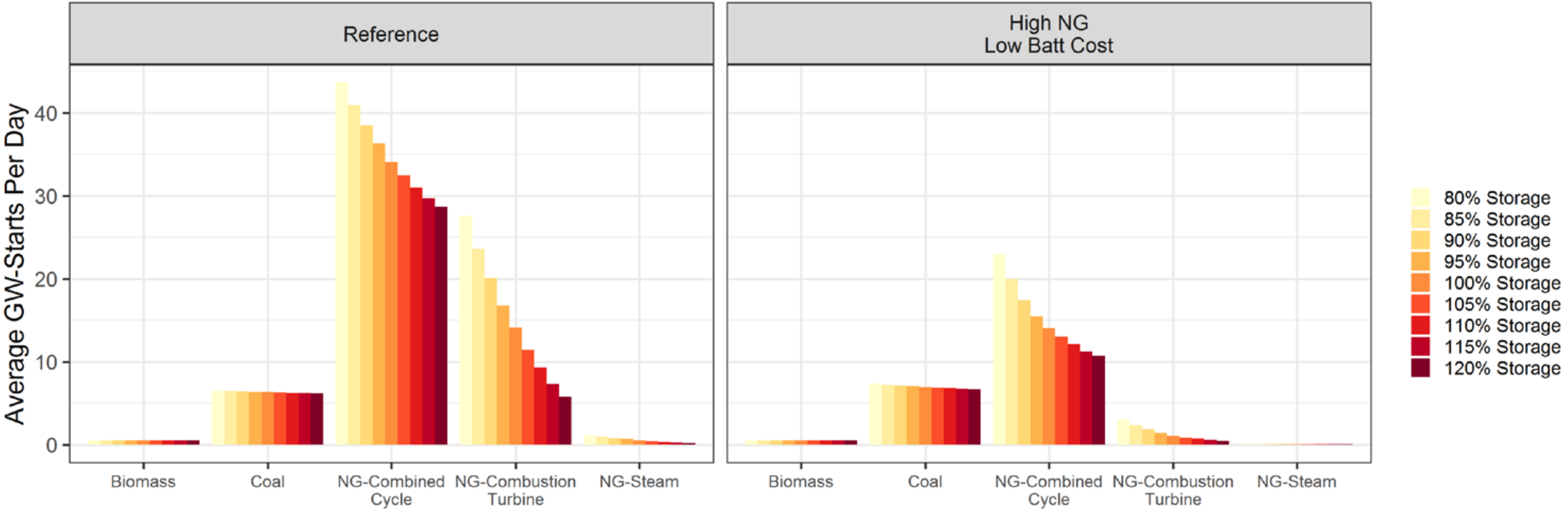
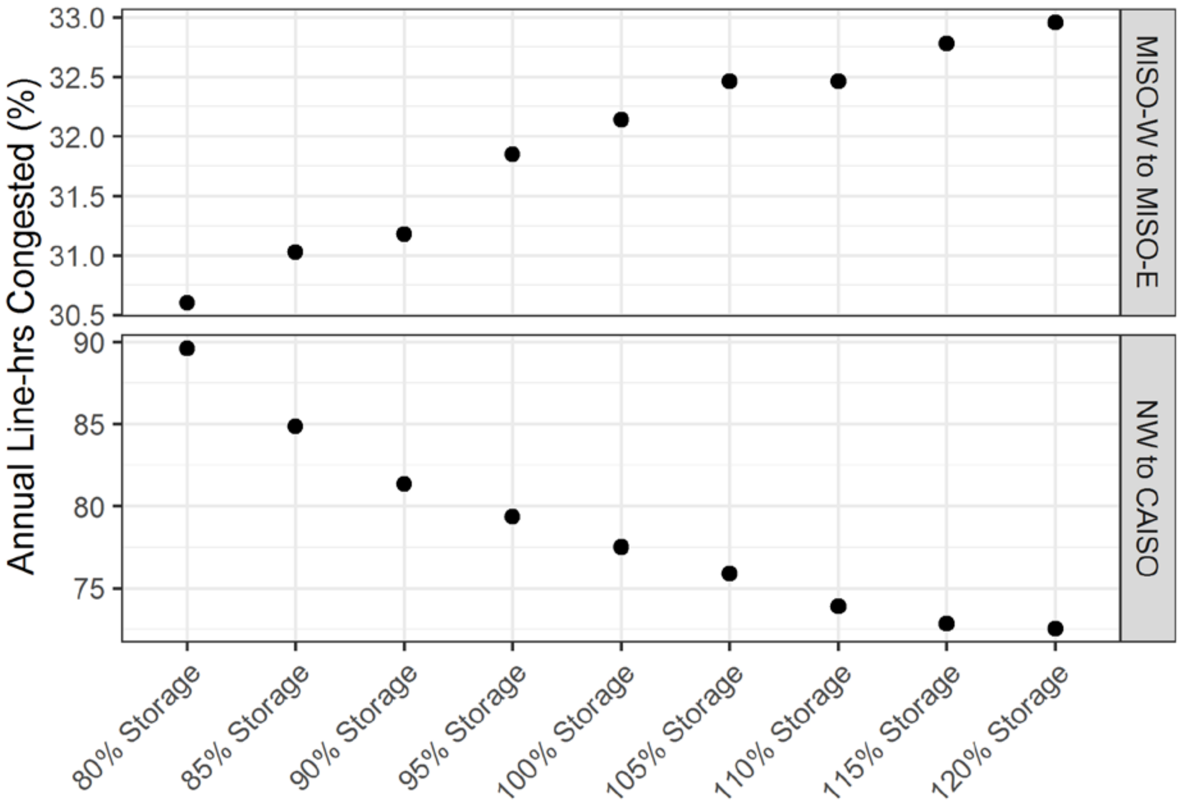


In the High NG Low Batt Cost case, GHG emissions are reduced 5% between the 80% Storage case and the 100% Storage case (and another 3% between the 100% Storage case and the 120% Storage case).

Conclusion #5: The interaction of storage and transmission is not always intuitive



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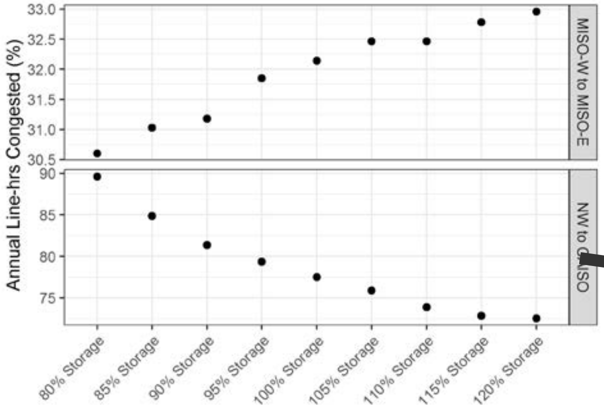
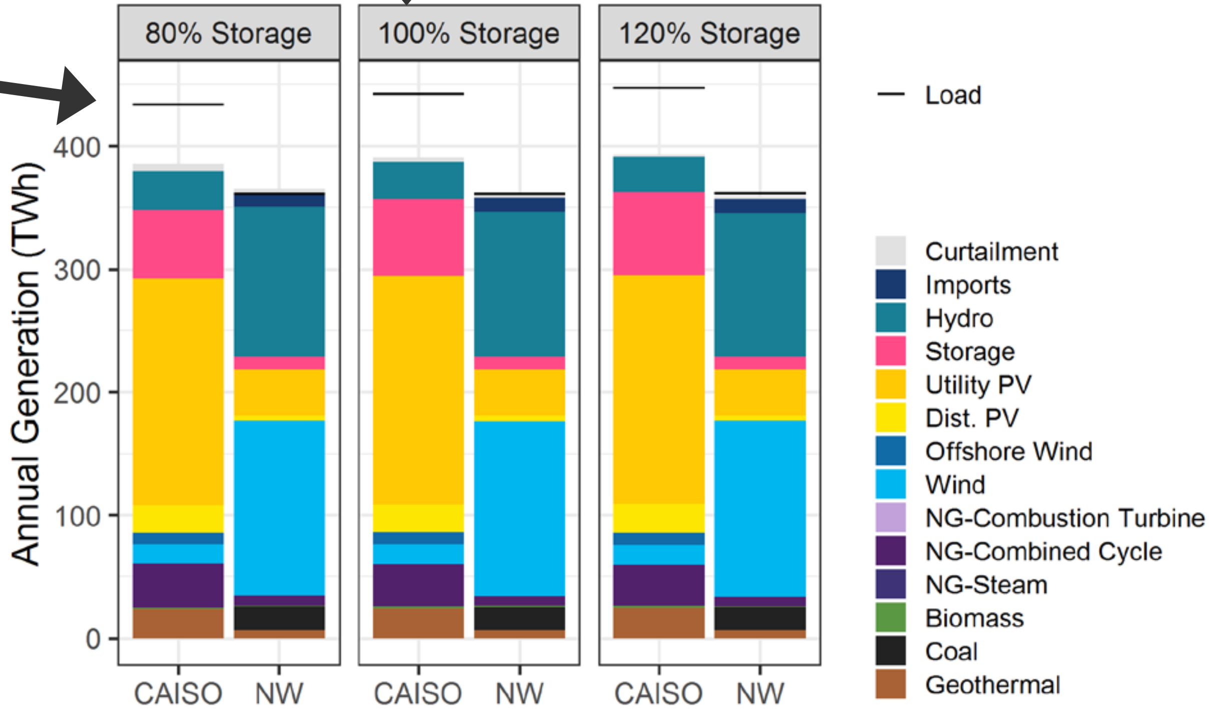


CAISO region is a heavy net importer



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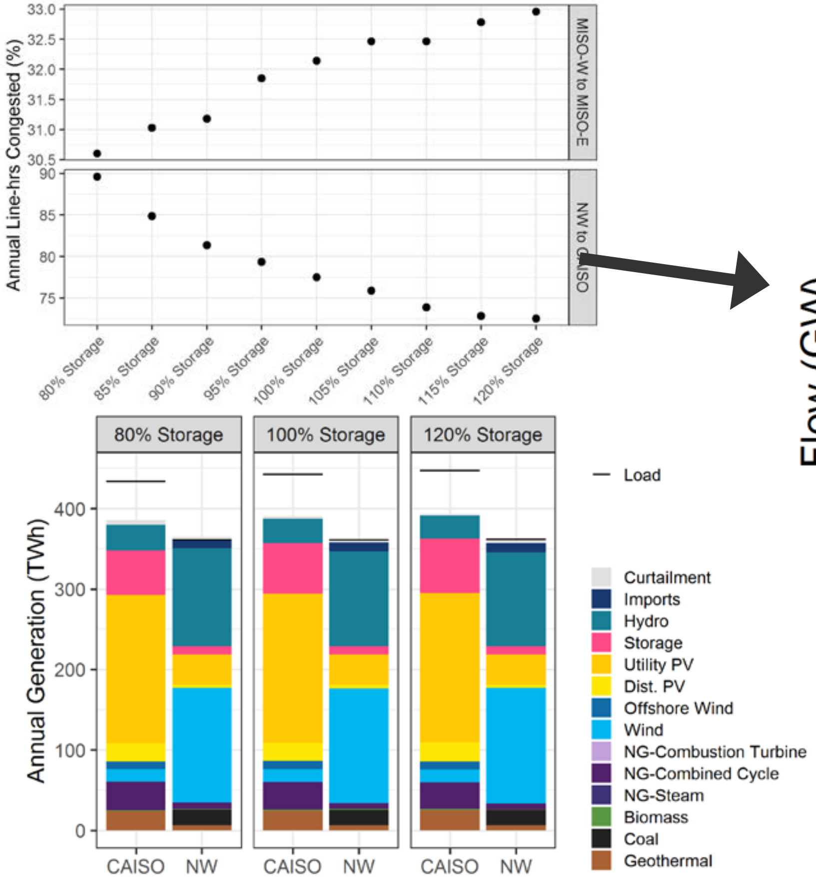

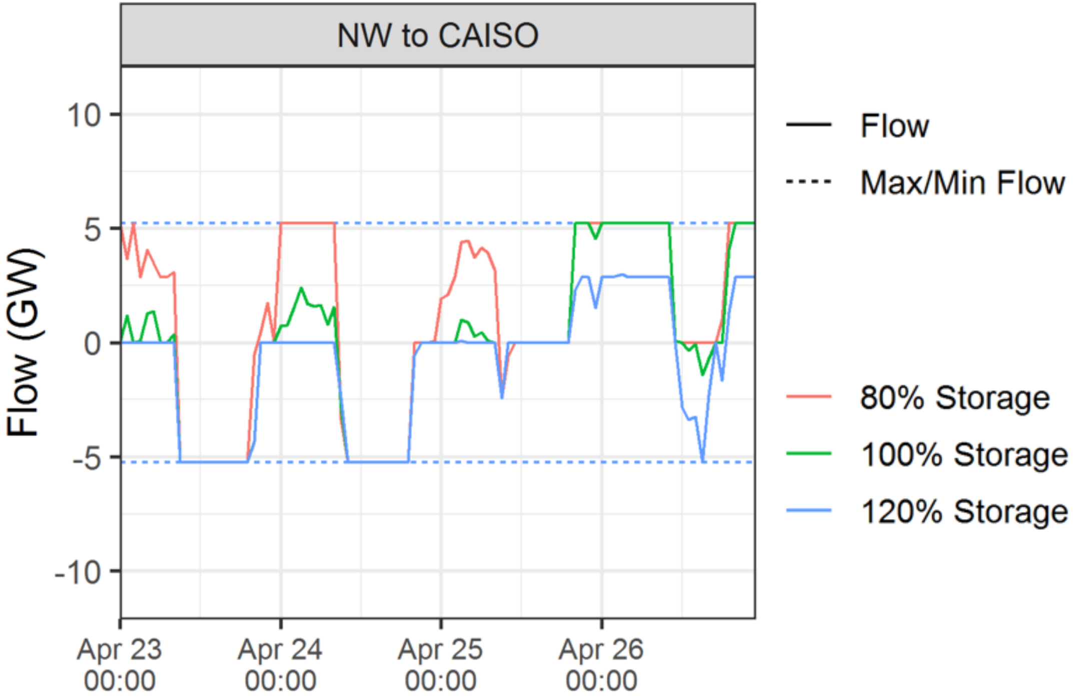

In non-solar hours, CAISO *imports* energy. As storage deployment increases, CAISO needs to import less since it can store more solar

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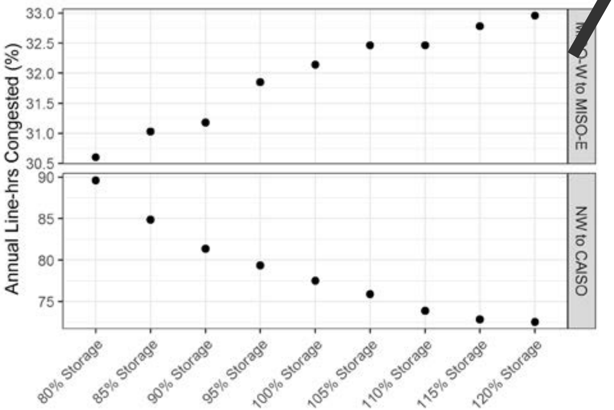

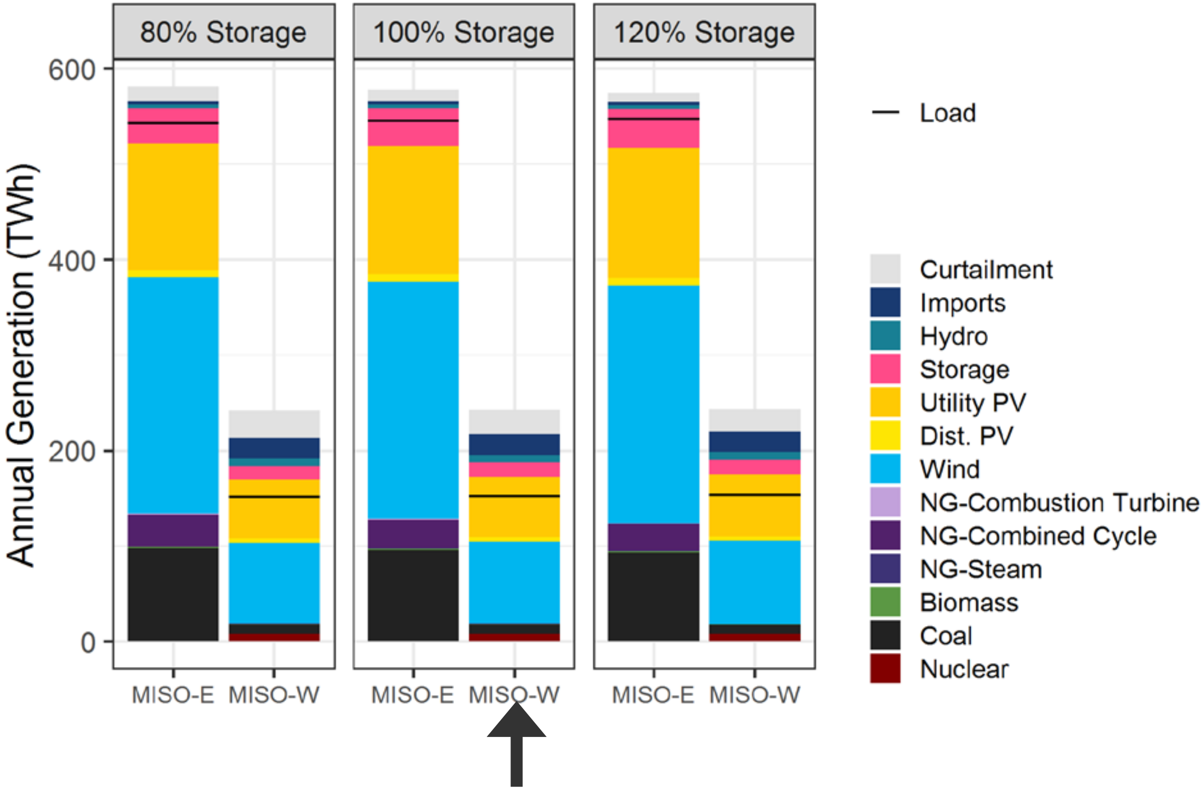

MISO-W region is a heavy net exporter with excess generation

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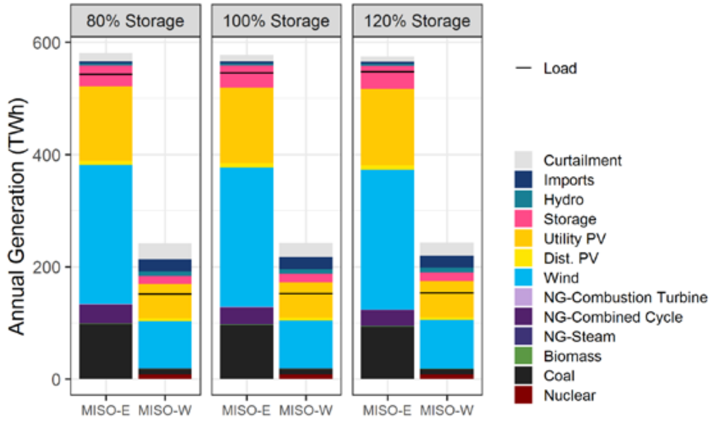

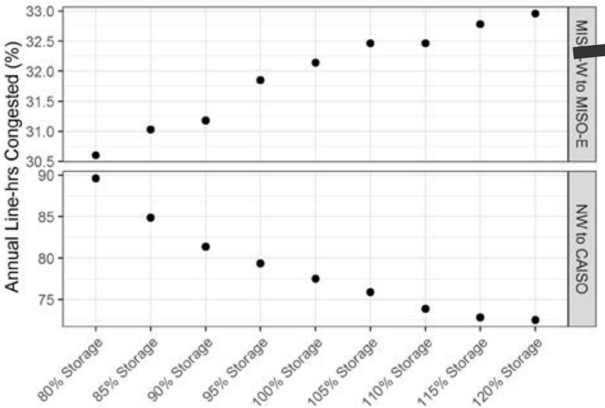

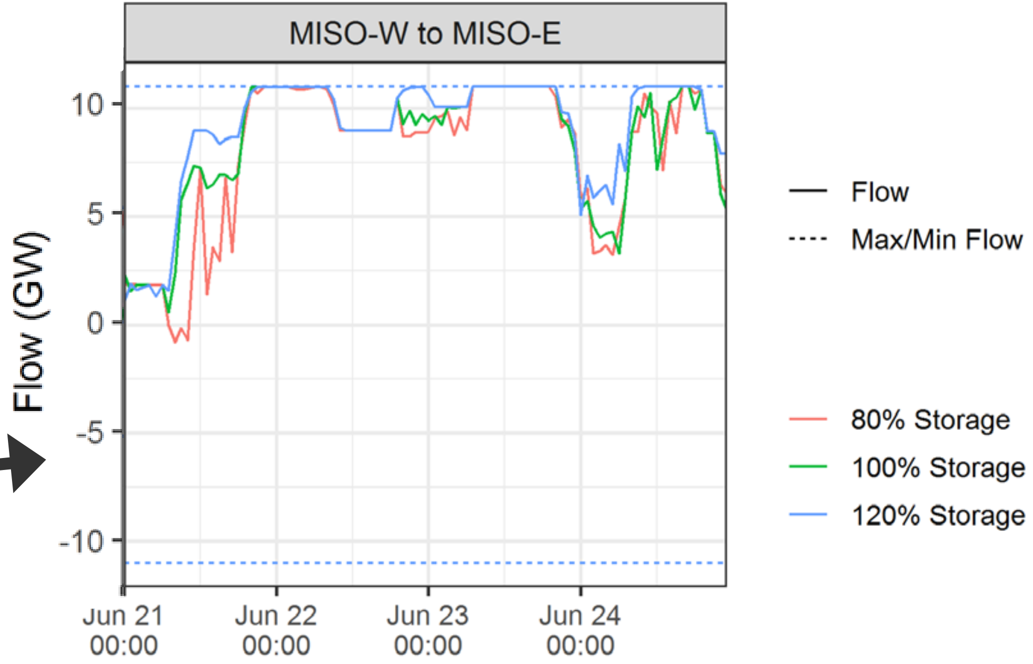

With extra storage, MISO-W has limited opportunities for arbitrage in its own region so it effectively arbitrages in the neighboring region – *increasing* congestion between these regions

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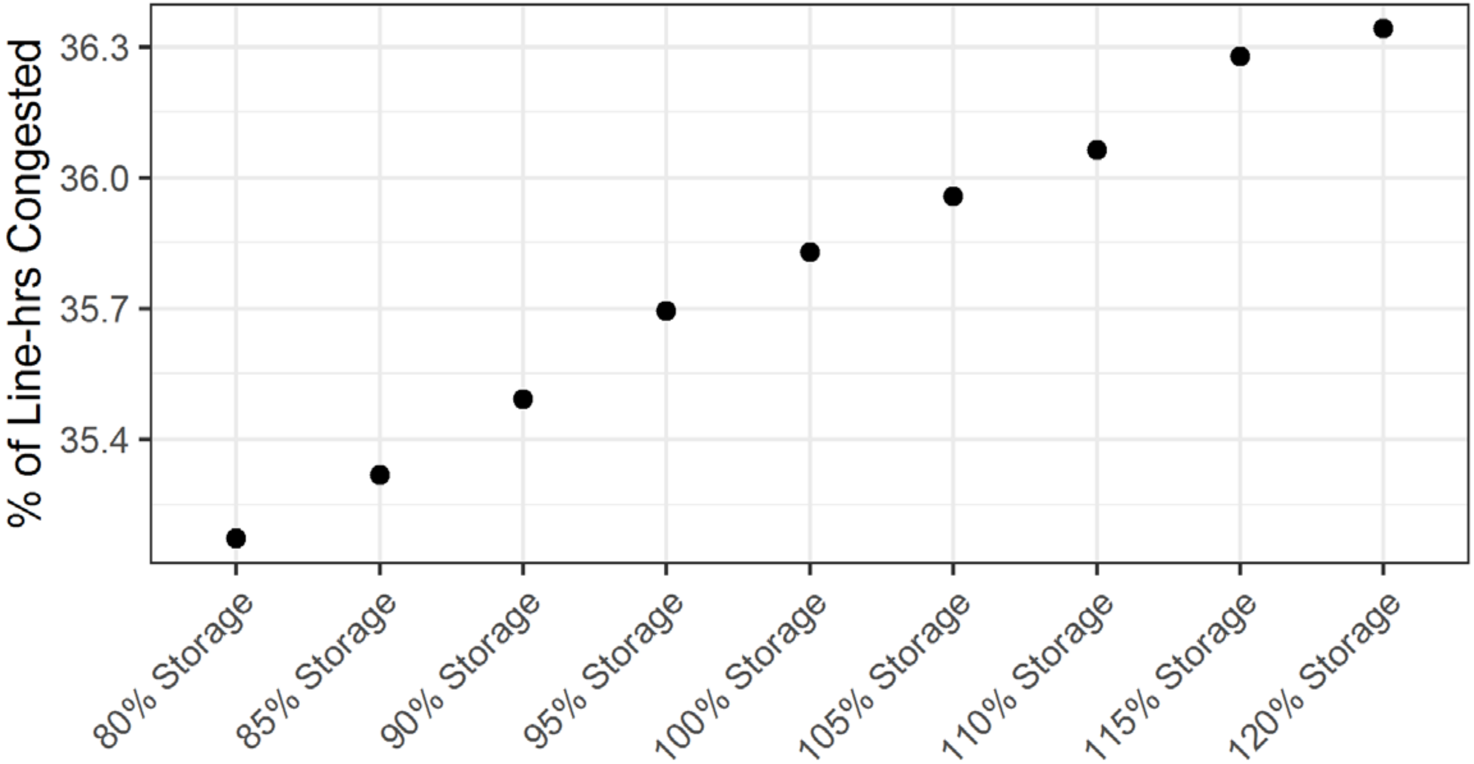

Insights from the Storage Futures Study

“**Collectively, the results of this and previous Storage Futures Study analysis show the growing opportunity for diurnal storage (that is, storage with up to 12 hours of duration) to play an important role in future power systems.** We find that the high storage (and often high variable generation) power system scenarios envisioned in ReEDS can successfully operate, showing no concerns about hourly load balancing through the end of 2050. Future work could examine the role of longer-duration storage resources, especially under highly decarbonized grid conditions, such as those approaching 100% clean energy.”

Keep an eye out for our final synthesis report and webinar covering the entire study – coming soon!

Thank you!

www.nrel.gov

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Read the full report.

Learn more about the Storage Futures Study.

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