The Future of Energy Storage: A Pathway to 100+ GW of Deployment

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U.S. Department of Energy Electricity Advisory Committee

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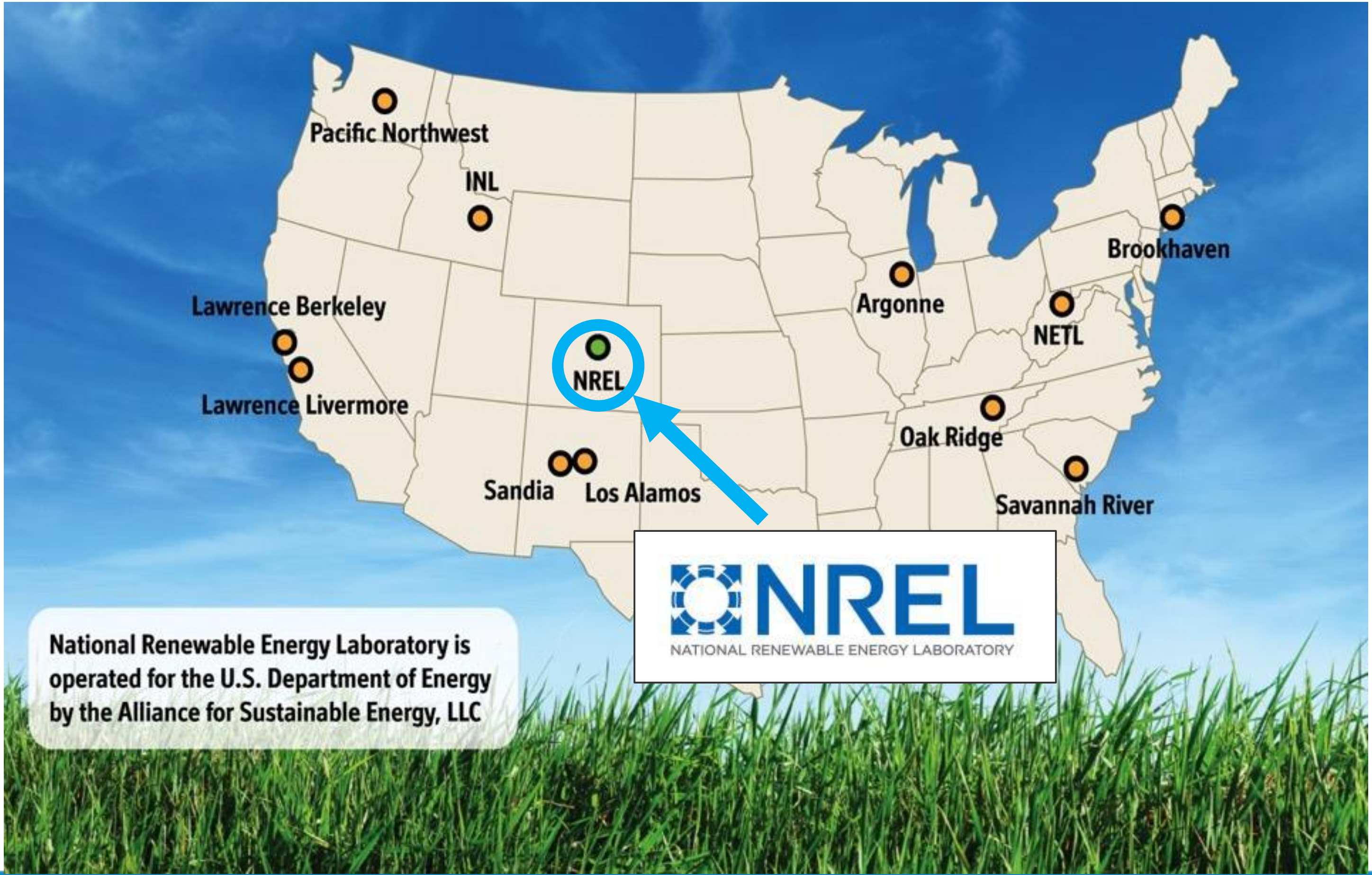
Where I Work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Outline / Conclusions

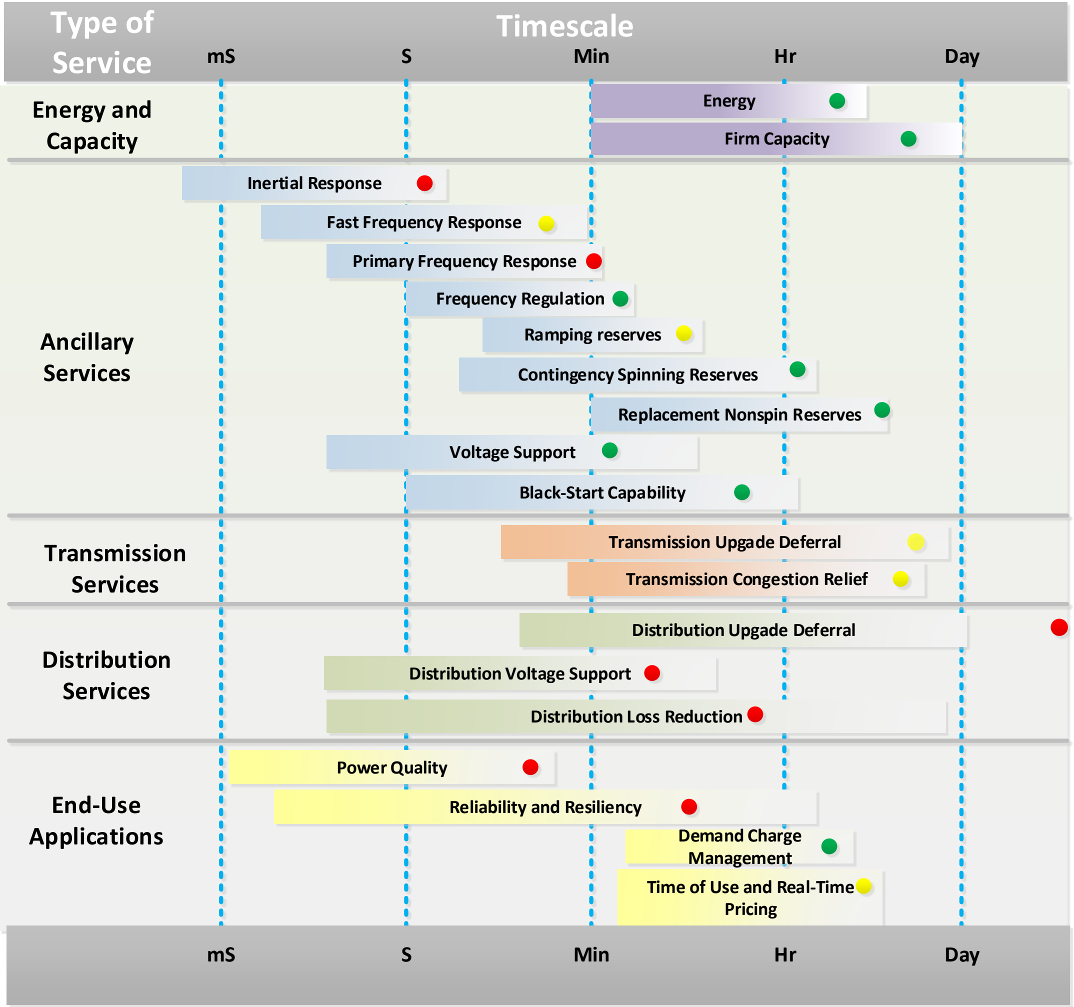
1. **The “Obsession” of Value Stacking?**
2. **But declining costs make single applications increasingly cost effective**
3. **Early focus on operating reserves**
4. **Transition to storage as peaking capacity**
5. **Analysis and a pathway to 100+ GW of storage deployment**
6. **Conclusions and caveats**

Value Stacking?

Yes, storage can do all this stuff.

And yes, storage needs a level playing field

But what happens when storage becomes cost-effective for a single, or more limited number of services?

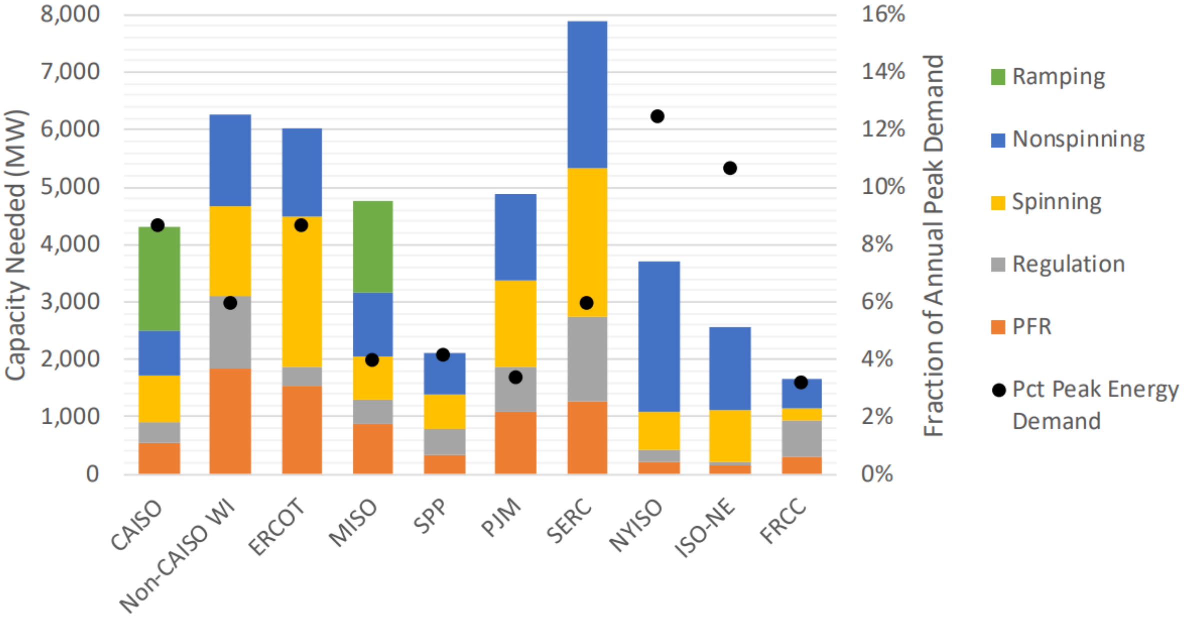


Services currently valued in some markets

Proposed or early adoption services

Currently not valued services

Early Focus of Energy Storage Applications…



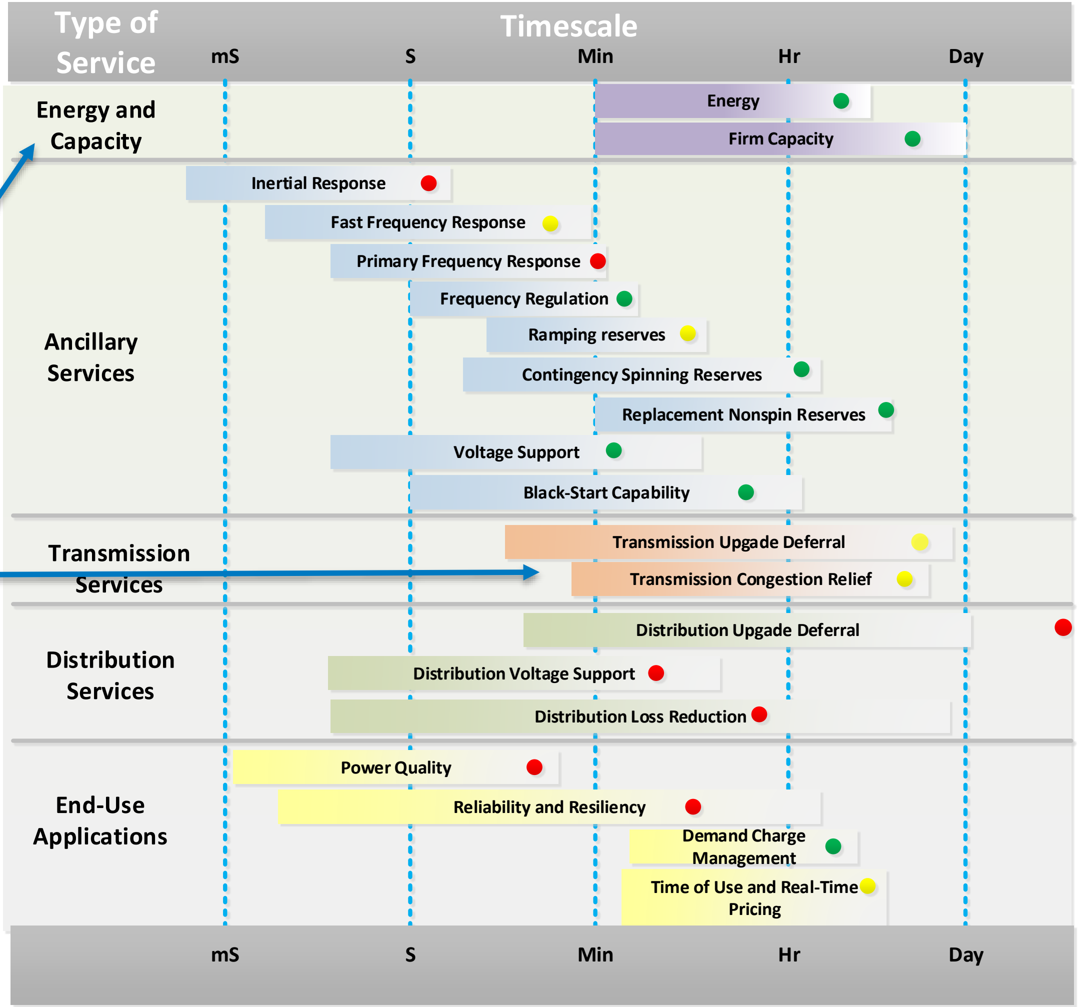
Source: Denholm et al. (2019). An Introduction to Grid Services: Concepts, Technical Requirements, and Provision from Wind. https://www.nrel.gov/docs/fy19osti/74184.pdf

- Much of the storage installed to date has targeted ancillary services such as frequency regulation
- However, these markets are limited
- The total size of the frequency regulation market in U.S. ISO/RTO markets (covering about 75% of U.S. demand) is about 2.5 GW

Value Stacking?

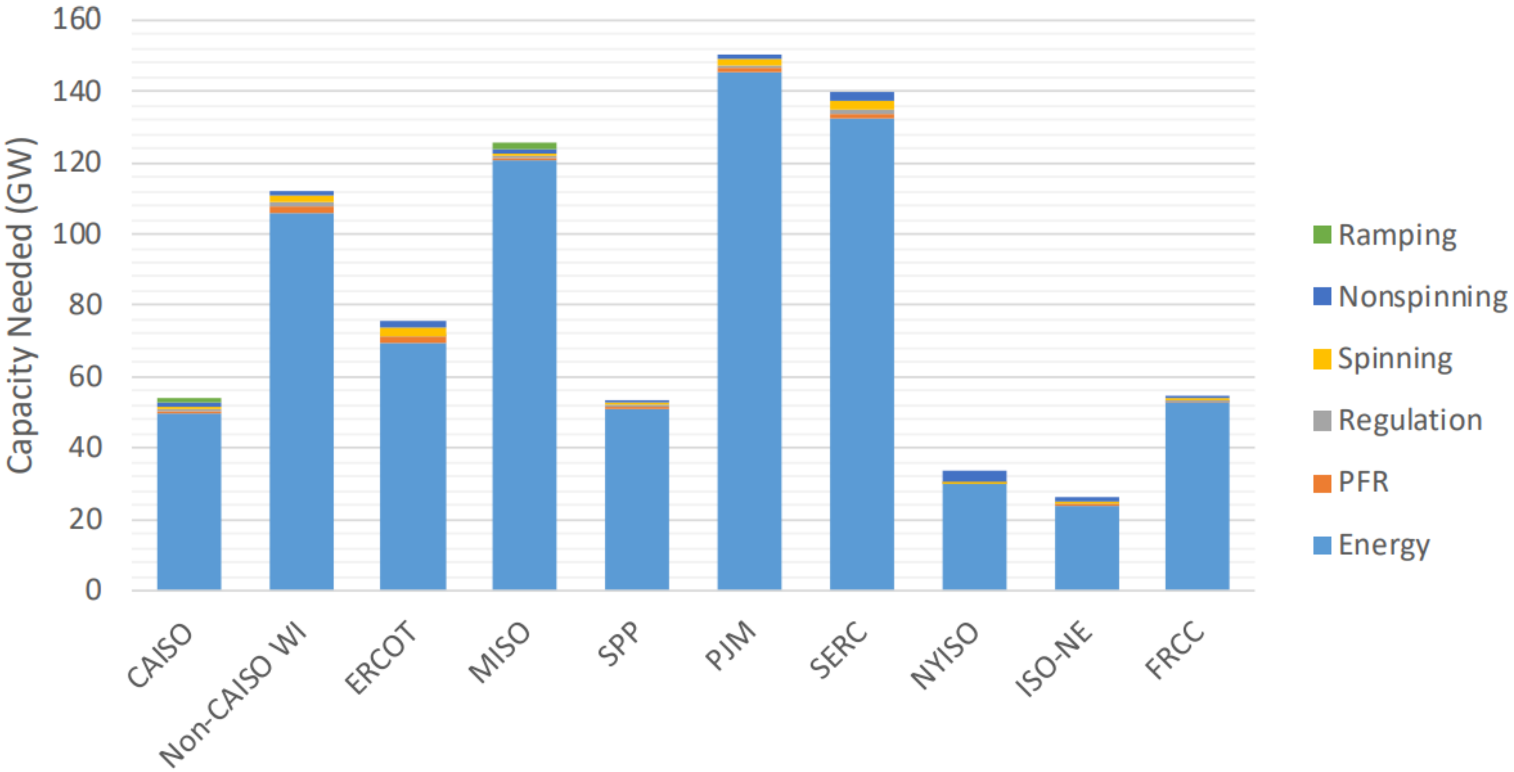
What if storage is cost effective if it can just do this?

(And maybe a little of this)



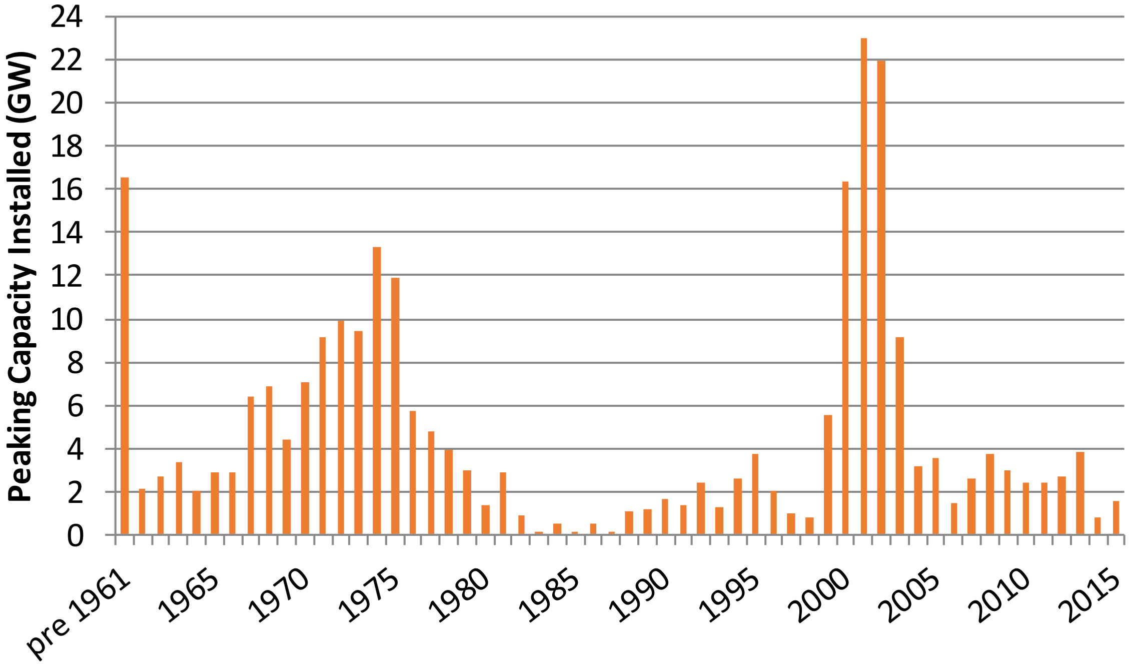
- Services currently valued in some markets
- Proposed or early adoption services
- Currently not valued services

Grid Capacity Requirements



Source: Denholm et al. (2019). An Introduction to Grid Services: Concepts, Technical Requirements, and Provision from Wind. https://www.nrel.gov/docs/fy19osti/74184.pdf

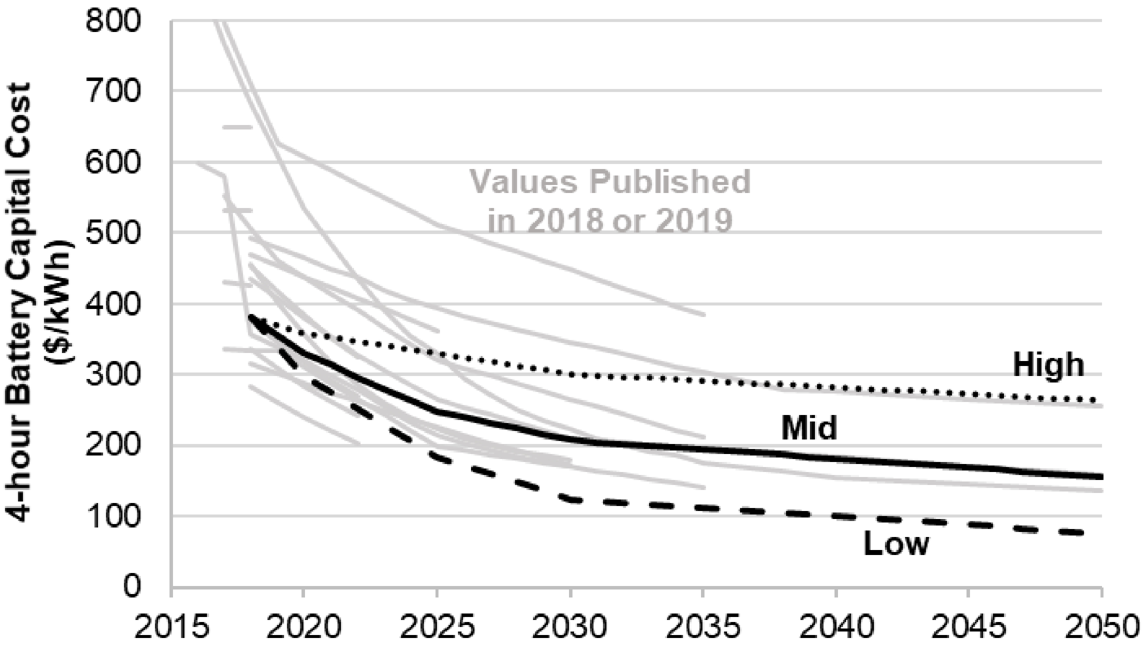
A Significant Amount of Peaking Capacity Will Be Retiring in the Next 20 Years



Installation dates of 261 GW of U.S. peaking capacity (non CHP CT, IC, oil/gas steam) (EIA 860)

Over the next 20 years, we expect about 150 GW of peaking capacity to retire

Storage Costs Are Projected to Decline



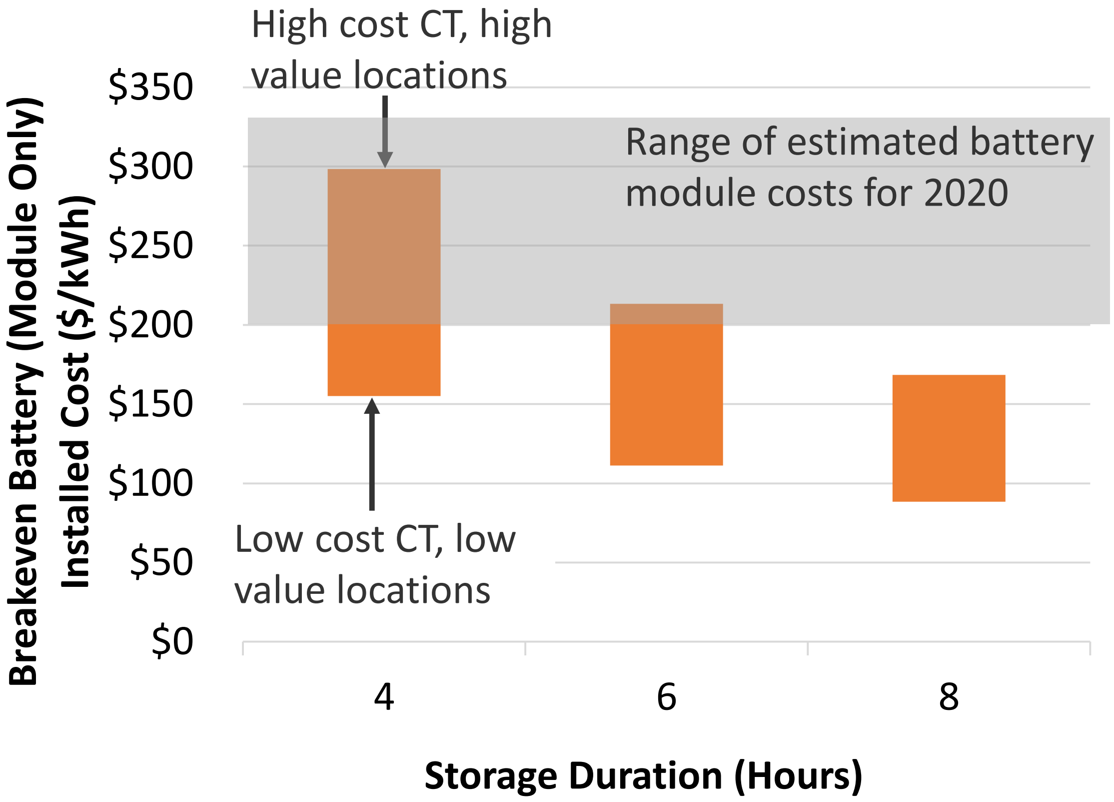
Cost declines (from 2018) range from 21% to 67% by 2030

Source: W. Cole and W. Frazier (2019). Cost Projections for Utility-Scale Battery Storage. https://www.nrel.gov/docs/fy19osti/73222.pdf

How to Compare Costs of a New CT vs Energy Storage?

- Difficult for storage compete purely on overnight capital cost
- CT: \$700/kW (frame) - \$1200/kW (aeroderivative)
- Translates to \$75 to \$200/kWh for battery module if we assume \$400/kW BOS
  - Assumes 4 hour duration
  - And before accounting for limited lifetime
- But storage provides other values that can be captured either a market or in a vertically integrated utility (least cost IRP) even without ancillary services
  - ***As long as capacity is needed and money isn't missing***

4-Hour Storage Approaching Wide-Scale Competitive Costs with CTs



Assuming Power and BOS costs of ~$400/kW

But Can Battery Storage Replace Peaking Capacity?

- Storage is inherently energy limited
- Can it replace traditional resources that can run many hours of even weeks without stopping?
- Utilities have historically relied on pumped storage plants for peaking capacity—but these plants often have 8 hours or more of capacity
- We need to determine the capacity credit of storage with various amounts of energy capacity (number of hours)

Methods – Capacity Credit of Storage

Full Effective Load Carrying Capability

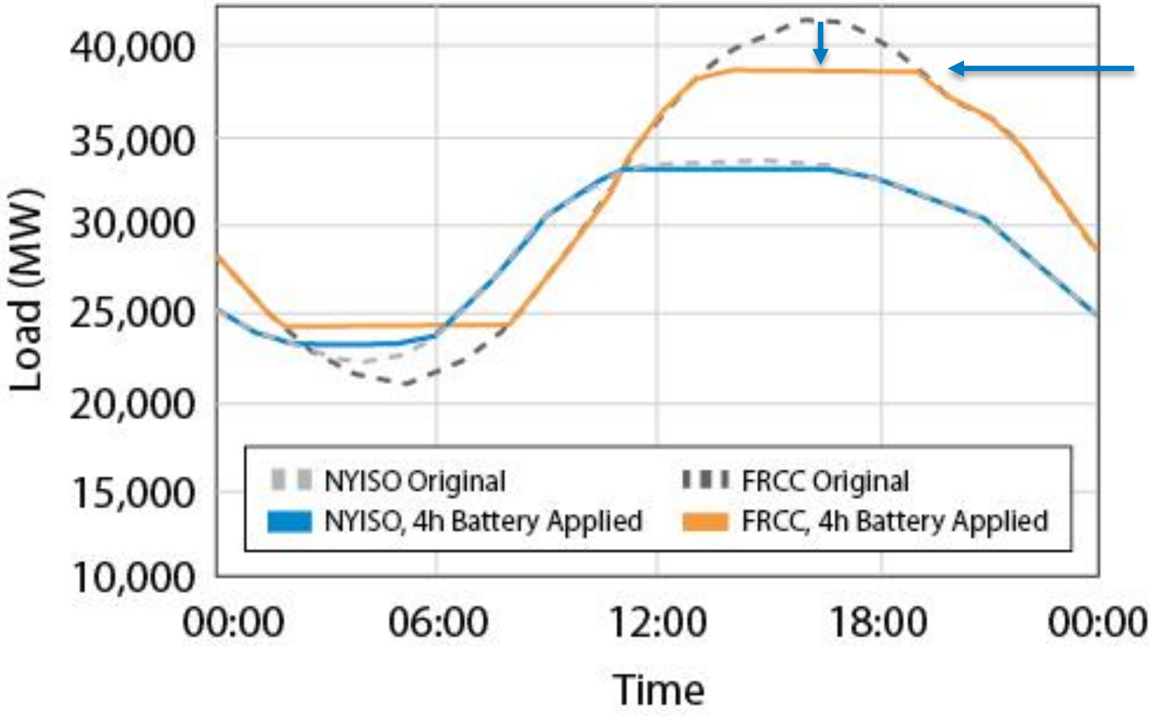
- The most robust way to determine the ability of storage to provide reliable replacement of peaking capacity
- Requires detailed simulations of the system
- Multiple years requires normalizing power system data, which is time consuming and expensive
- Can be computationally intensive
- Techniques are still maturing without consensus on best methods to simulate storage
- In the past year, only a few locations have been analyzed using this approach (example is Astrape analysis of PJM)

Methods – Capacity Credit of Storage

Approximation Approaches

- Examine production from storage during periods of peak demand
- Historically applied to wind and solar
- Much easier, requires much less data (primarily load)

Our Approach – Peak Net Demand Reduction



Measure the reduction in peak demand for storage of different power and energy capacity

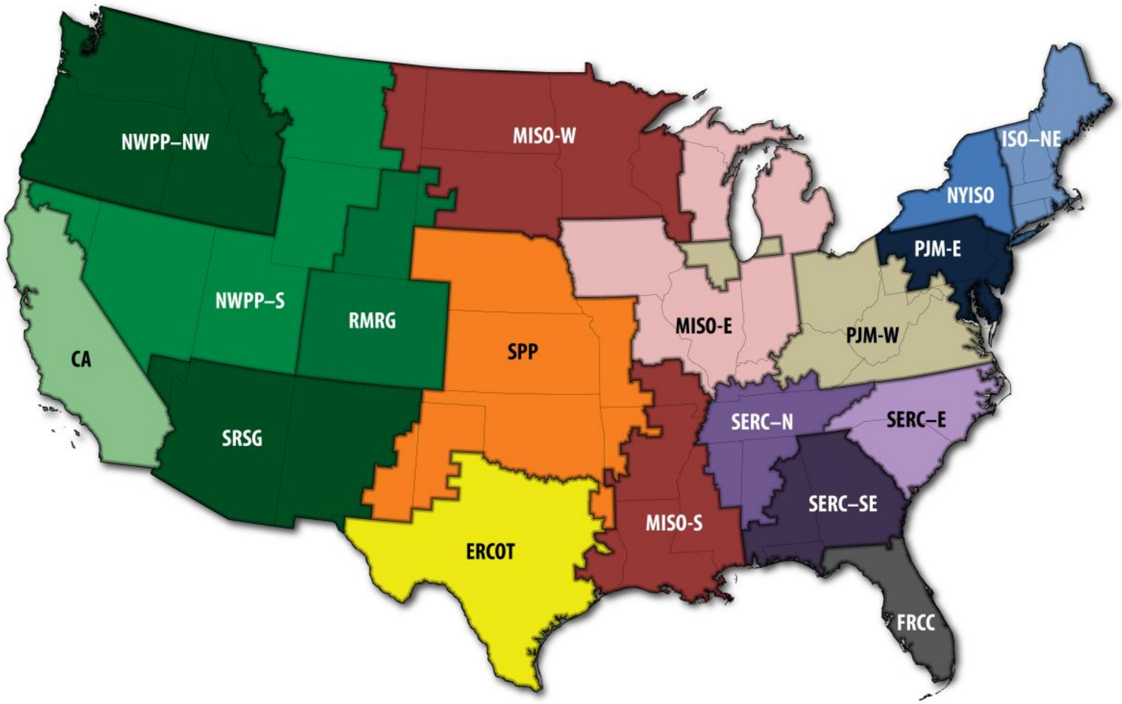
Ability of 4-hour storage to reduce peak demand drops as net demand shape widens

Our Approach

- Calculate Peak Demand Reduction Credit (PDRC)
  - Reduction in peak demand (MW) per MW of storage capacity
  - We define “practical potential” as the point at which the PDRC falls below 100%
- Simulate 4, 6, and 8 hours of storage
- Analyze all 8,760 hours of the year (not just the peak day) to capture shifts in peak demand
- Use most conservative value of simulations across 7 years of data (2007-2013) (except NWPP-NW – see report)
- Focus on 4-hour results due to near-term cost competitiveness and “4-hour” resource adequacy requirement in California

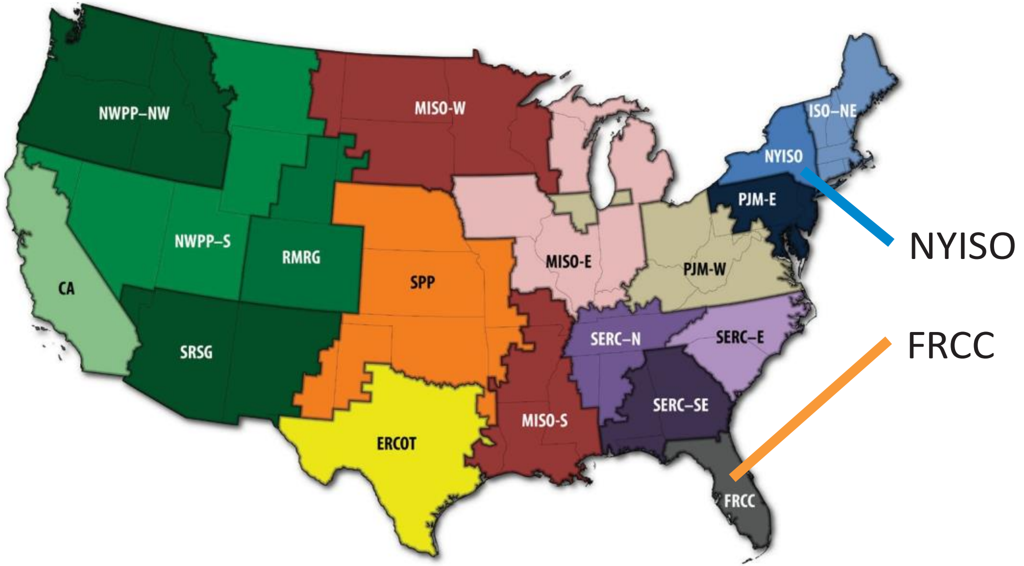
Regions Analyzed

All regions generally summer peaking, except NWPP-NW

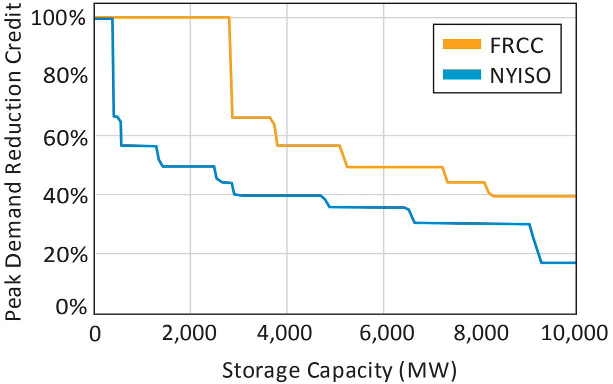


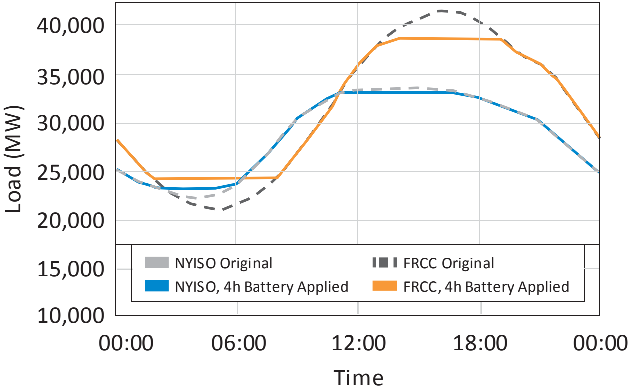
Roughly conforms to North American Electric Reliability Corporation (NERC) Assessment Areas
Larger regions split to capture impact of different demand patterns

Peaking Capacity Potential



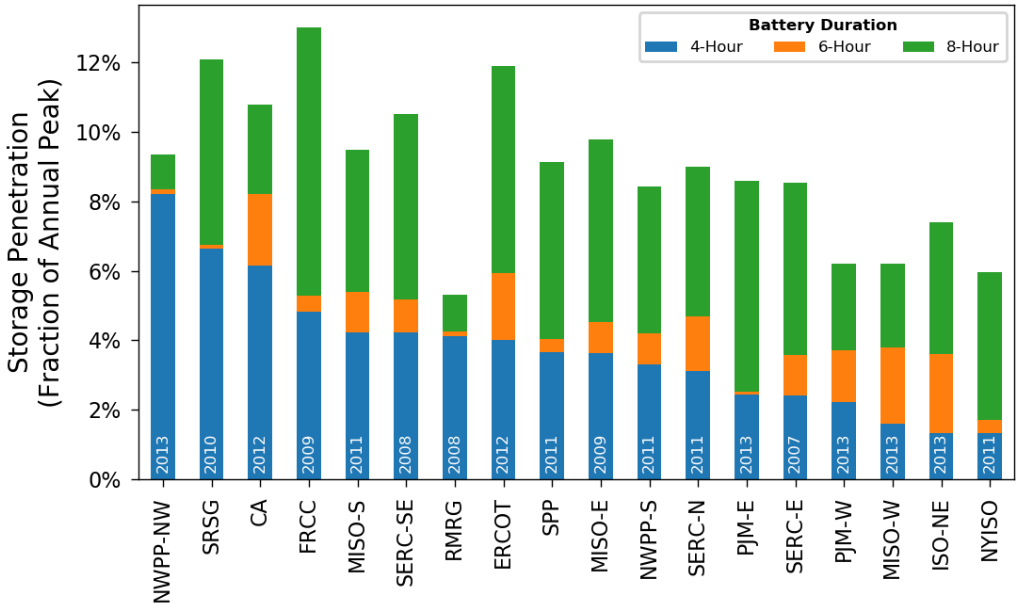
- The peaking capacity potential is a function of a region’s load shape
- Florida has narrower peaks – so 4-hour storage works better in Florida than in New York





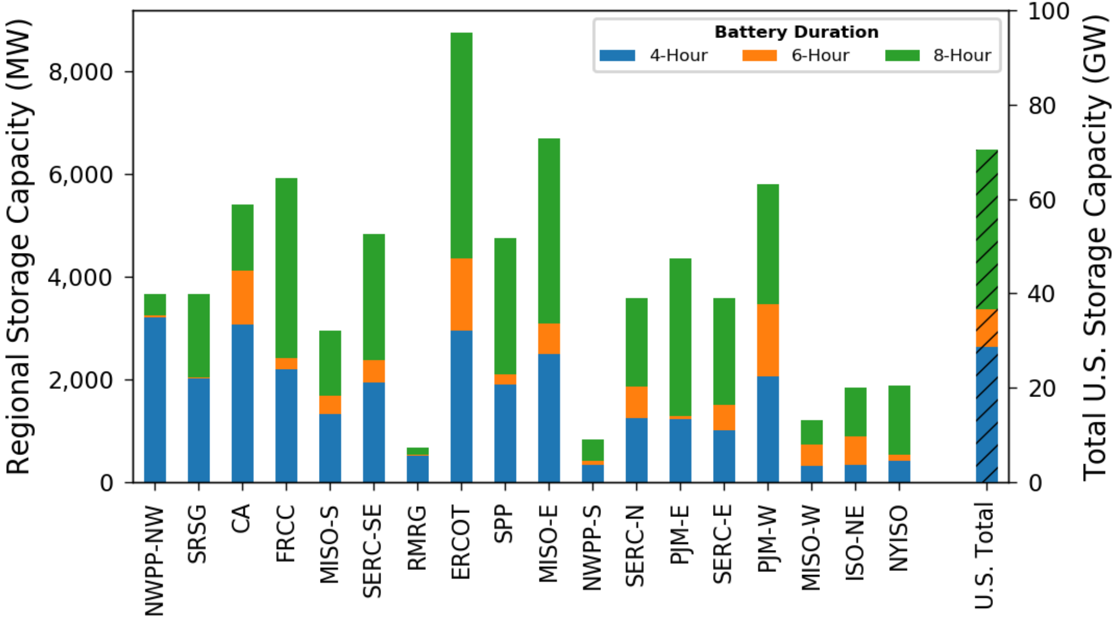
2020 Practical Peaking Capacity Potential

- Results are normalized as a fraction of 2020 peak demand for comparison
- 4-hour storage typically works best in strongly summer peaking systems with narrow peaks



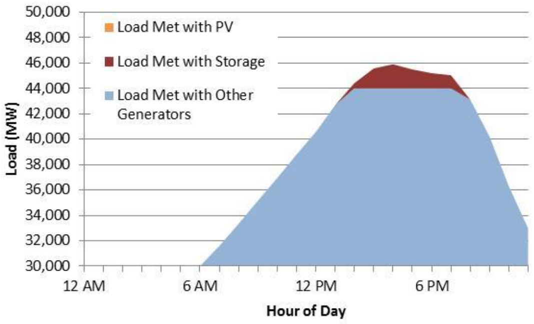
2020 Practical Peaking Capacity Potential

- Regional variations driven by size (peak demand) as well as demand characteristics
- National practical potential for 4-hour storage is about 28 GW

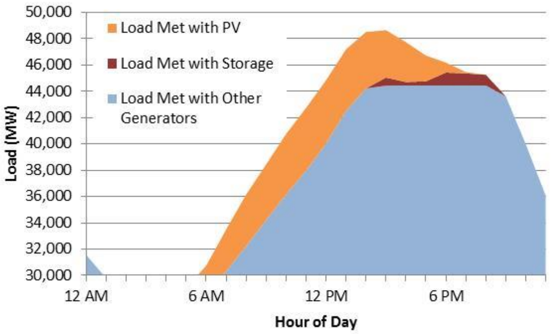


What Happens When We Add RE?

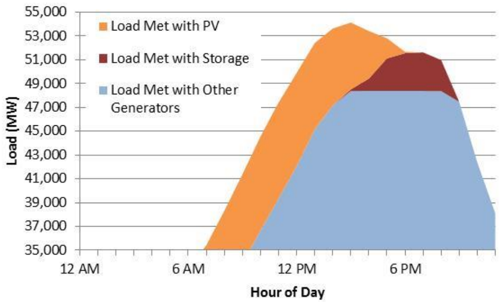
Base case does not consider changes in load shapes that occur with wind and solar



Zero PV



5% PV



10% PV

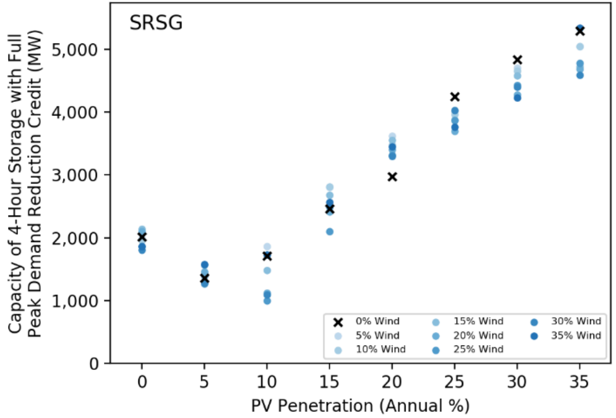
Adding solar tends to narrow period of peak demand, potentially increasing the ability of 4-hour storage to act as peaking capacity

Our Approach

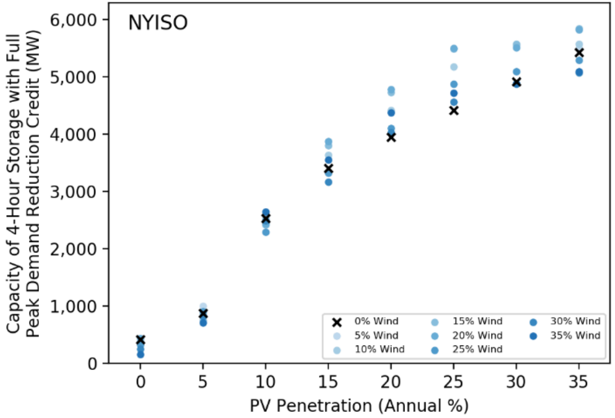
- Add cases with up to 35% annual contribution from wind and solar (or up to 70% total)
- Sites derived from the Regional Energy Deployment System (ReEDS) capacity expansion model
  - All generation from within the evaluated region except in locations with insufficient wind
- Generation profiles for all 7 years from the National Solar Resource Database and the WIND Toolkit

Practical Potential of 4-Hour Storage Increases as PV Is Added

The practical potential of 4-hour storage increases as a function of PV deployment in all regions, but with a variety of regional patterns



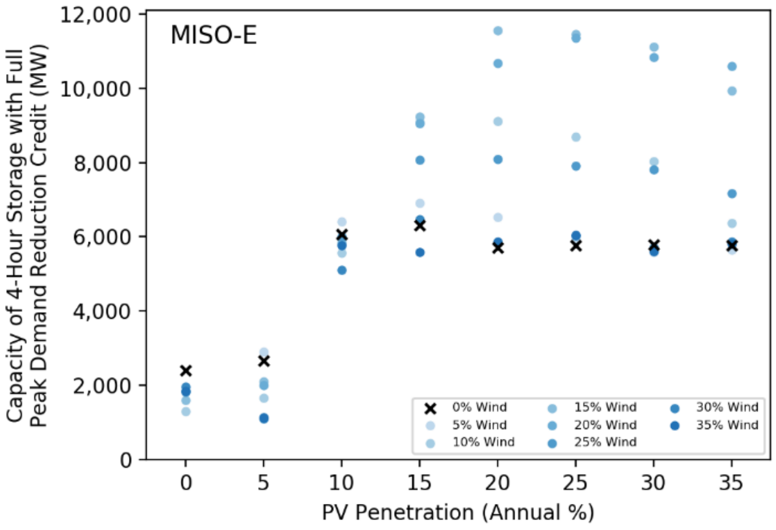
Some regions drop at first, then steadily increase (California, Southwest). This is because at low penetration, PV clips the peak and makes the net demand wider.

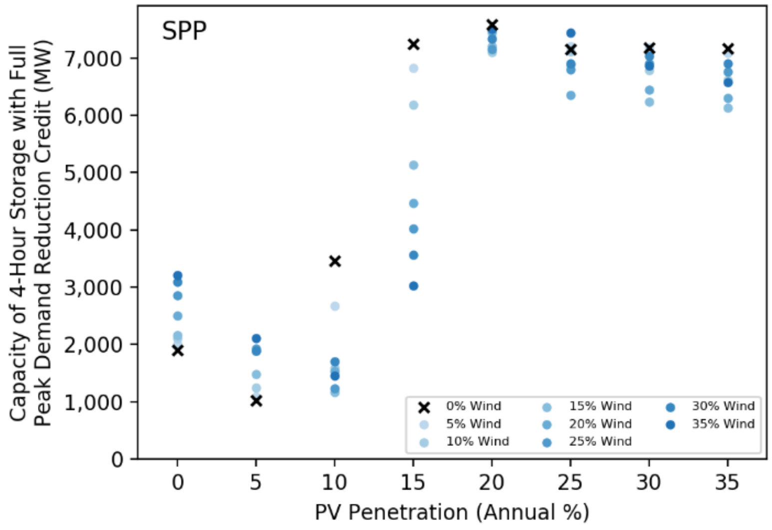


Some regions show a consistent increase up to the penetrations evaluated.

Some Regions Saturate

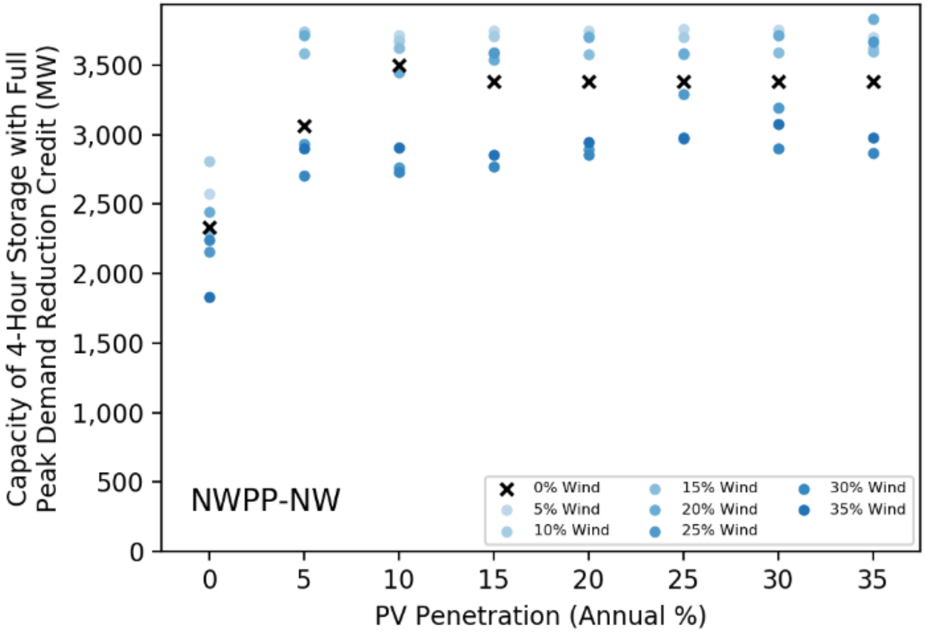
- Some regions show significant increase, but saturate at modest penetration
- This can occur when the peak demand shifts to winter



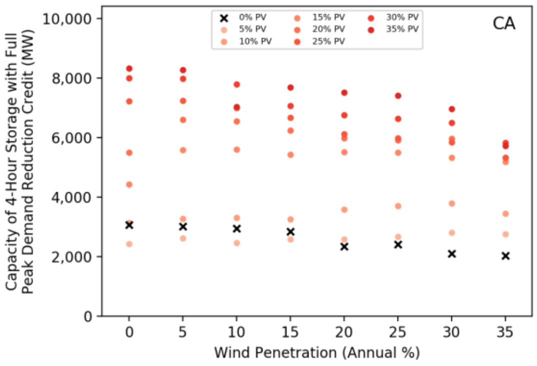


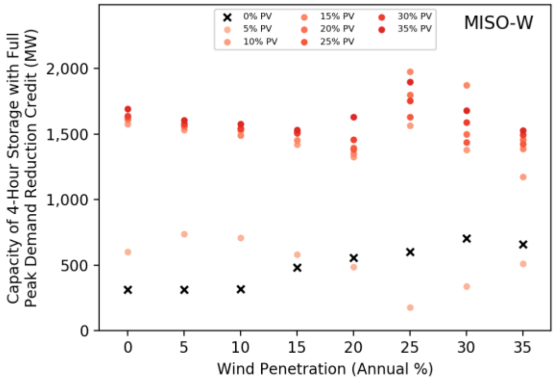
Winter Peaking Systems Show Fewer Benefits

- All regions except NWPP show significant increase in practical potential of 4-hours storage (more than double with between 10% and 25% annual PV contribution)
- NWPP (winter peaking) shows the least relative increase

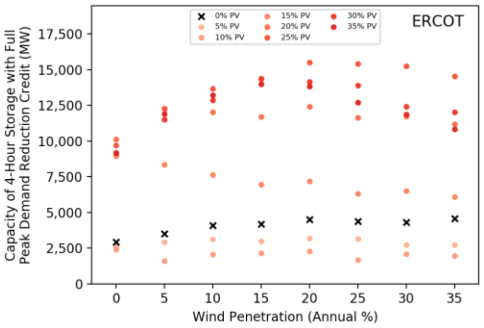


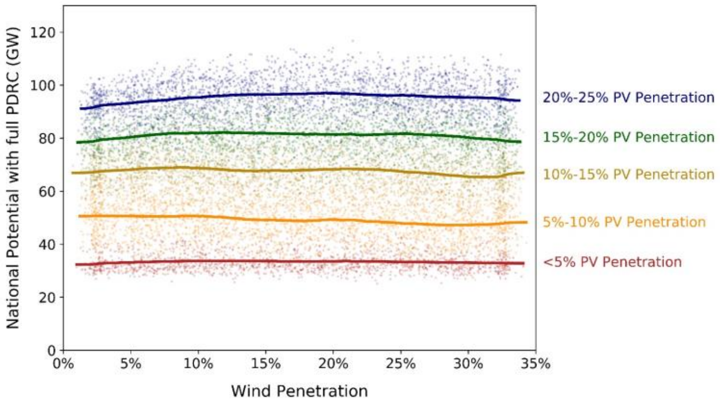
No Patterns in Peak Demand Reduction Potential as Wind Is Added





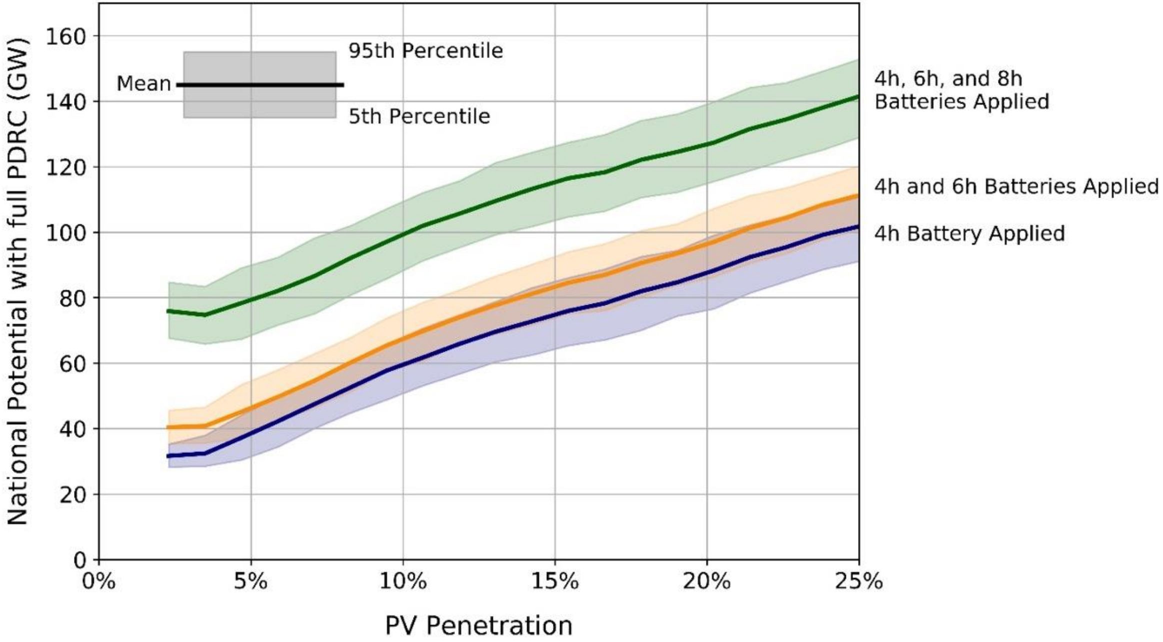
- Adding wind doesn’t consistently change demand patterns
- Essentially no real trend in wind patterns on hot summer days like there is with PV





National Results

National 2020 Practical Peaking Potential for 4-8 Hour Storage



Results from 20,000 combinations of VG penetration
Lower bound represents current PV deployment

- 4-hour storage potential doubles from ~0% PV to ~10% PV
- At 10% PV the potential for a mix of storage durations exceeds 100 GW.

Conclusions

- It appears that when properly scheduled, some amount of 4-hour storage can provide an alternative to conventional peaking capacity in regions throughout the United States
- This amount grows significantly with the addition of PV and demonstrates a pathway to 100+ GW of potential based on providing solely energy and capacity services for a mix of 4-8 hour devices
- Opportunities for 8+ hour storage are less explored.

Caveats

- These results are not a substitute for full ELCC analysis
- We do not consider the role of long-distance electricity trade
- This analysis uses historical demand patterns and does not consider changes in load patterns due to climate or electrification, including electric vehicles
- We assume perfect foresight of demand patterns

Much of this material is derived from https://www.nrel.gov/docs/fy19osti/74184.pdf

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