



Future Opportunity for PV-Storage Peakers in CAISO

ESIG Fall Workshop

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Project Goals

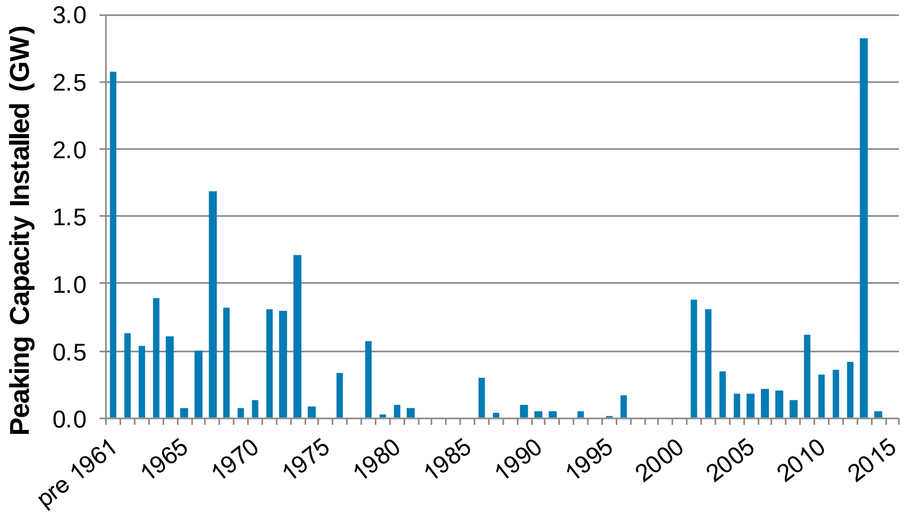
Study Goals

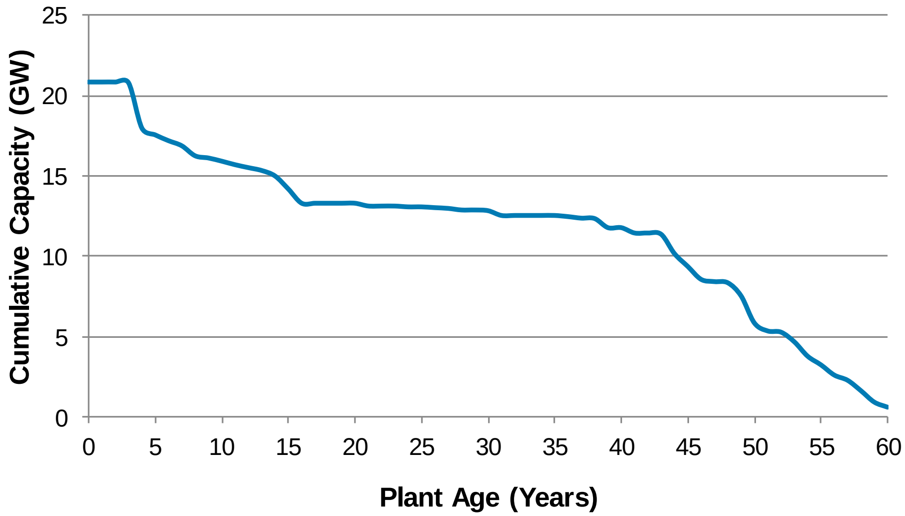
1. Evaluate the capacity credit of energy storage
2. Analyze the ability of storage to replace conventional peaking capacity
3. Examine how PV changes 1 and 2

Why is this Important?

- Peaking capacity is a potentially larger market for energy storage.

- About 13 GW of California's peak capacity could retire over the next 20 years, based only on age.



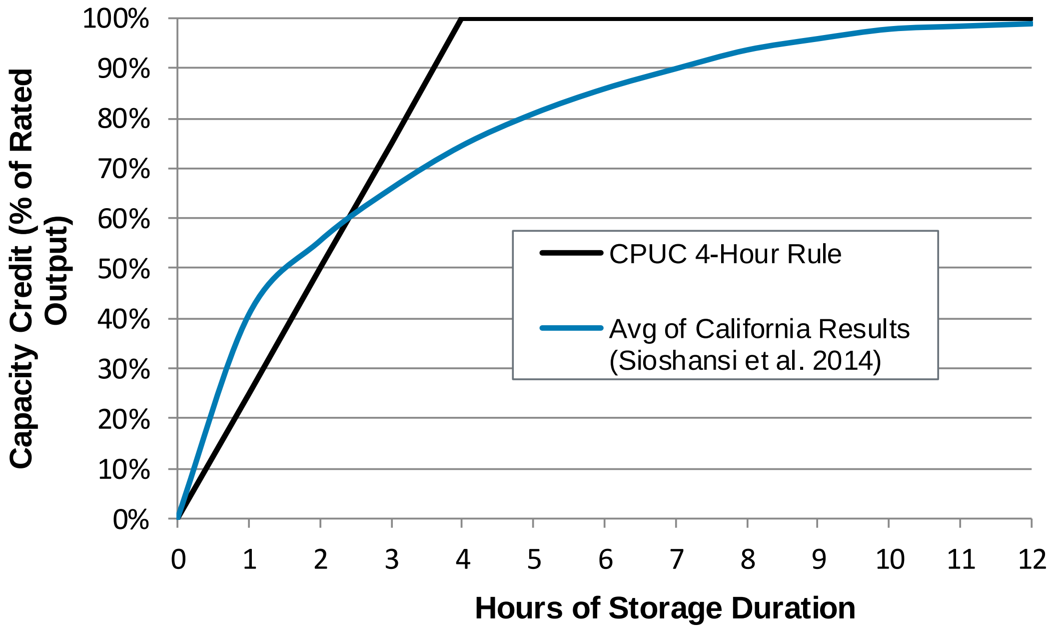


Installation date (left) and cumulative capacity by age (right, as of summer 2017) for peaking capacity in California. About 12 GW of capacity are at least 40 years of age.

What is the capacity credit of energy storage?

- Anecdotally and historically utilities give 8 hr+ pumped storage full capacity credit (although I cant find any underlying justification)

- More recently, some utility and academic work



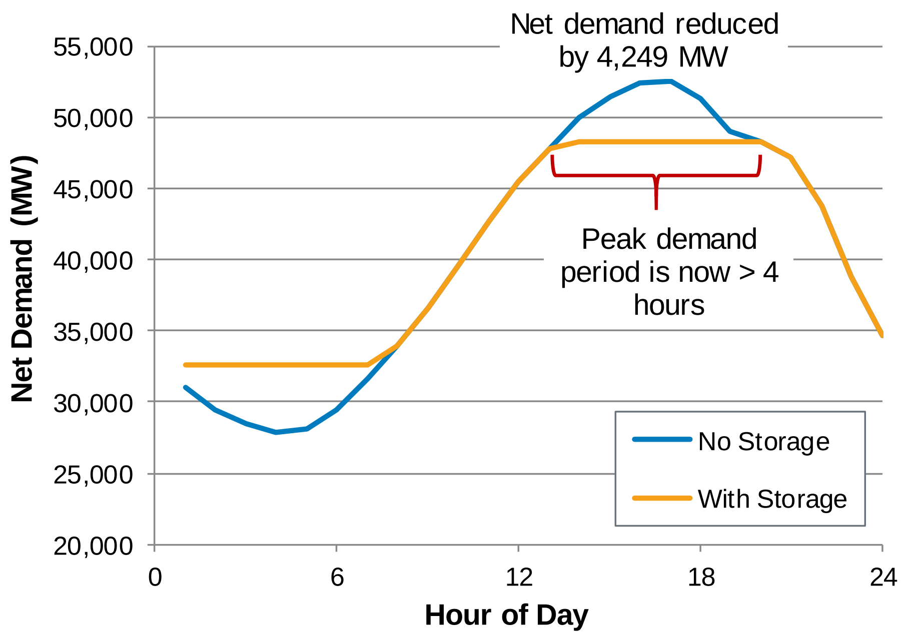
Capacity credit of storage as a function of hours of storage. Under California Public Utilities Commission (CPUC) rules, eligible storage must have "the ability to operate for at least four consecutive hours at maximum power output"—the "4-hour rule."

But this is still difficult

- Classical LOLE/LOLP tools don’t have chronology
- Adding full chronology to a LOLE tool is difficult. Need to assign an objective function to storage dispatch
  - You cant run production cost models a gazillion times to solve the problem
  - Arbitrage alone isn't quite the right function, so you need to use an objective function that minimizes LOLP, although that’s not how merchant storage gets paid…
- Some tools now do all this: SERVM, others
- Still need all the underlying assumptions about power system with all the messy EFOR data etc.

You Can Most of the Way There with Geometry

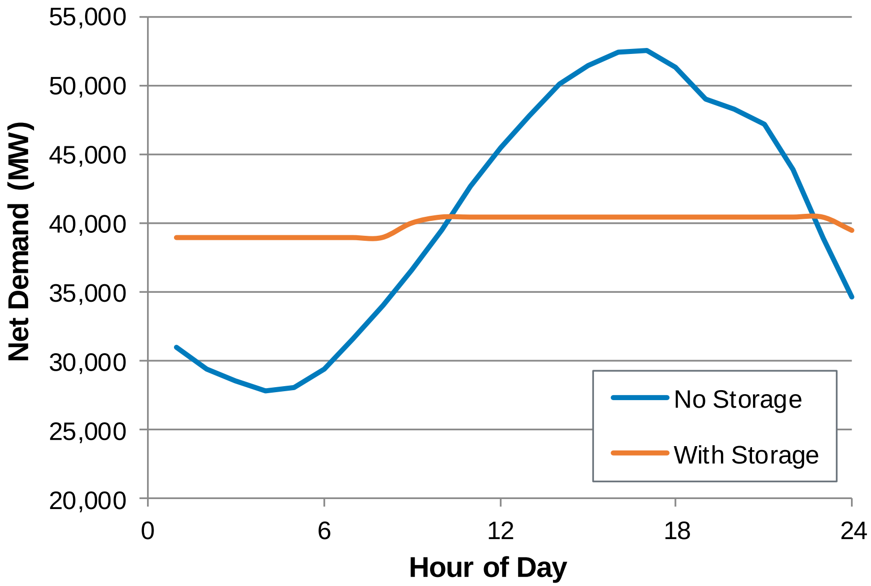
- To approximate capacity credit, storage is incrementally added (assuming full discharge) until adding 1 MW of storage cannot reduce net demand by 1 MW.
- Here 4,249 MW of 4-hour storage reduces peak demand by an amount equal to the power rating (4,249 MW), but more storage has a "peak demand reduction credit" less than 100%.



Impact of 4-hour storage dispatch on net demand on the peak demand day in 2011

Limits to Storage

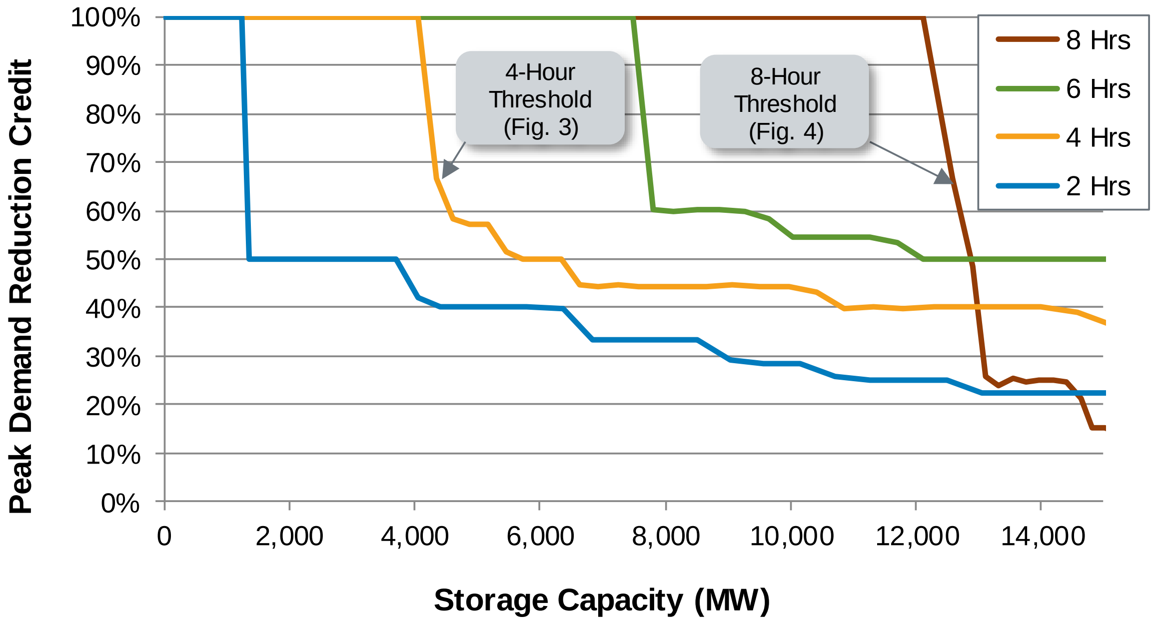
- Longer-duration storage reduces peak net demand further, with limits.
- With 8-hour storage, net demand is almost flat over 24 hours, but reducing peak demand further would require charging during a previous day, requiring much longer-duration storage and the ability to forecast net demand over extended periods.



Limits of 8-hour storage to reduce peak net demand due to limits in charging energy (peak demand day in 2011 shown)

Analysis Method

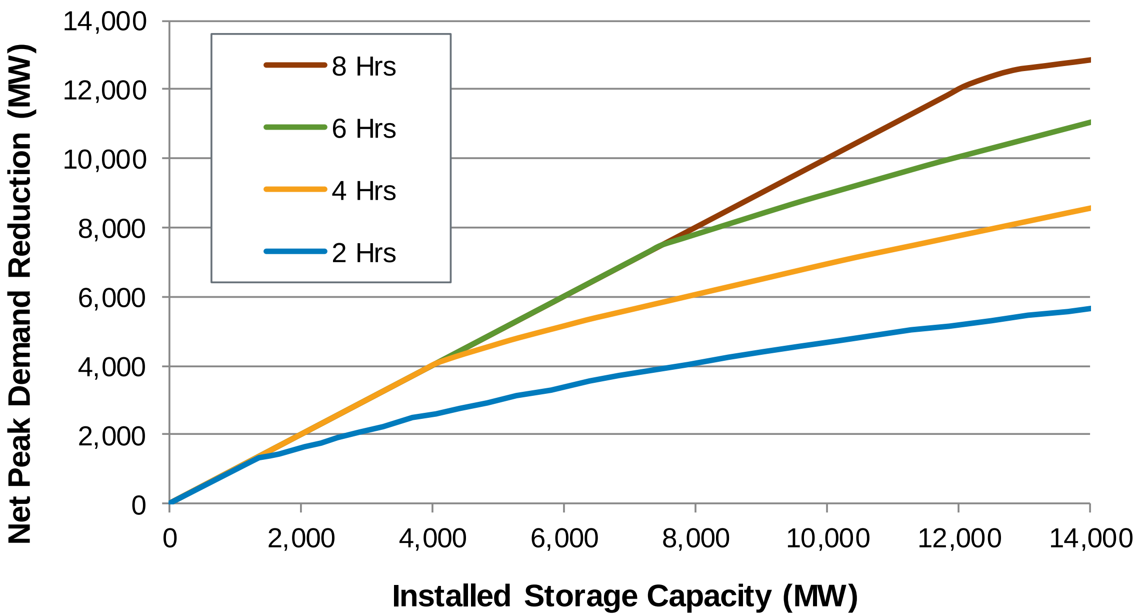
- Process is repeated over various storage power capacities and fixed durations of 2, 4, 6, and 8 hours, with dispatch simulated using NREL's REFlex model (assuming 80% roundtrip efficiency and no storage outages) and hourly load data for 2007–2015.
- In 2011 the 4-hour storage peak demand reduction credit falls below 100% at 4,249 MW; the 8-hour threshold is 12,559 MW.



Incremental peak demand reduction credit vs. storage capacity in California (2011 data)

Analysis Method

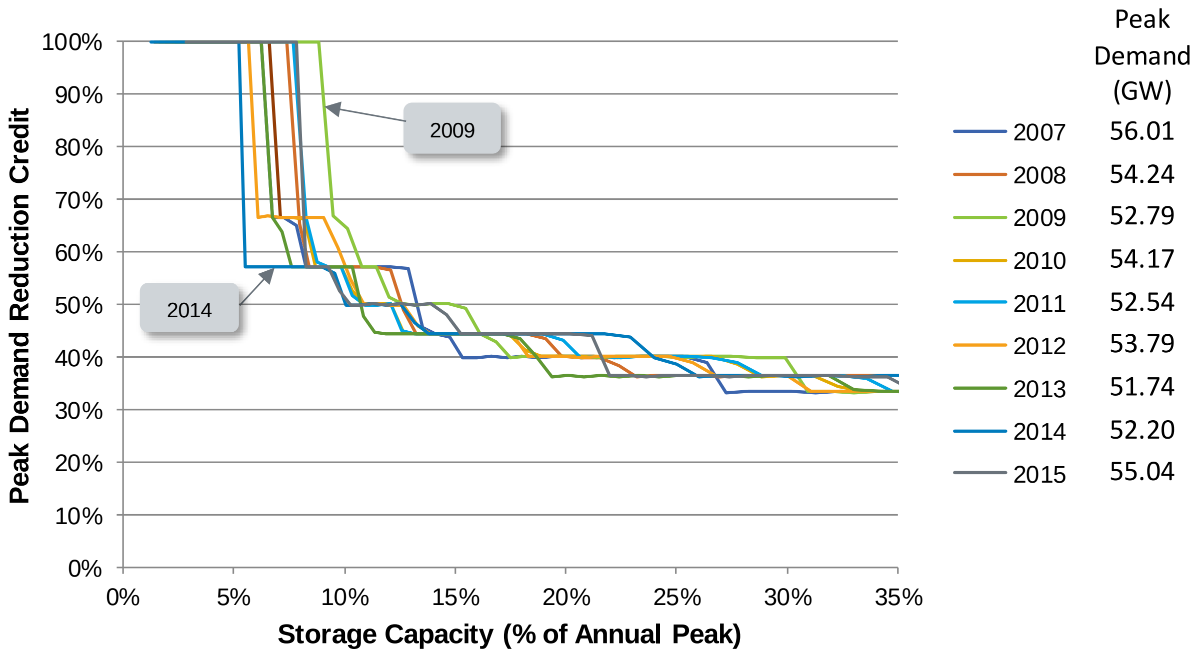
- When the peak demand reduction credit is 100%, the relation between net peak demand reduction and installed storage capacity is linear, but below 100% there are diminishing returns.
- Here about 4 GW of 4-hour storage reduce peak net demand by 4 GW, but reducing peak net demand by another 4 GW requires an additional 9 GW of 4-hour storage.



Total net peak demand reduction vs. storage capacity in California (2011 data)

Results with No PV

- Relationships between peak demand reduction credit and installed storage capacity vary by year, e.g., 4-hour storage could reduce annual peak demand by 9% at 100% credit using 2009 data, but only by 6% using 2014 data.
- To estimate storage's potential to meet peak demand in 2020 (~54 GW), the lowest credit values across all years are used.



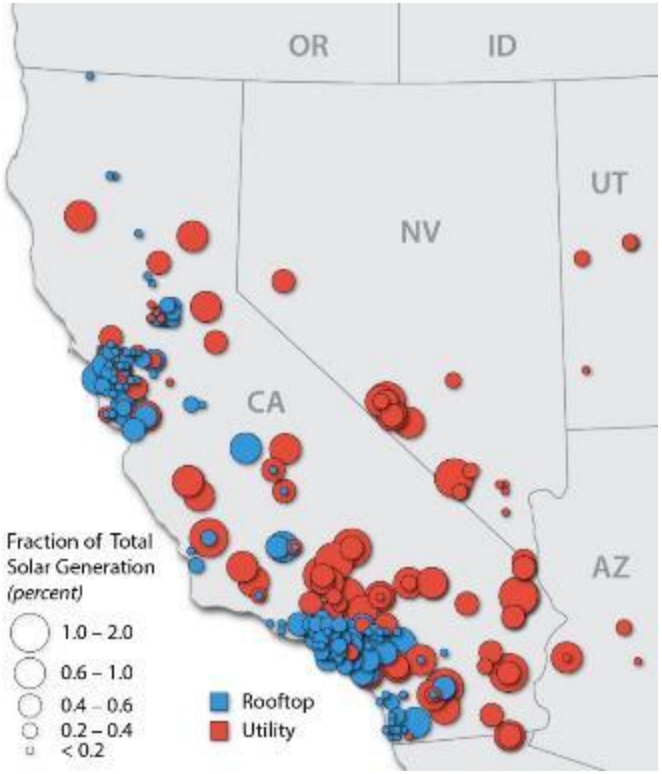
Peak demand reduction credit vs. 4-hour storage capacity in California (2007–2015 data)

Adding PV

- Previous results (no PV) are sort of useless. In 2017, California already provided about 11% of total electricity demand with PV

- PV energy penetrations up to 30% are simulated for 2007–2015.

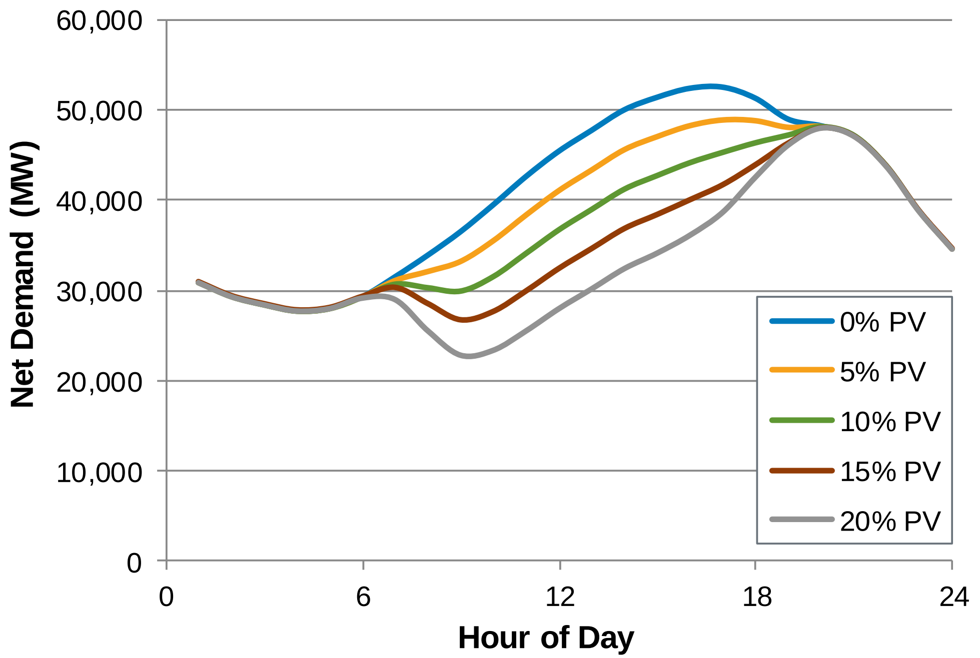
- Generation profiles were simulated using NREL's System Advisor Model assuming a mix of utility-scale and rooftop PV



Distribution of simulated PV sites

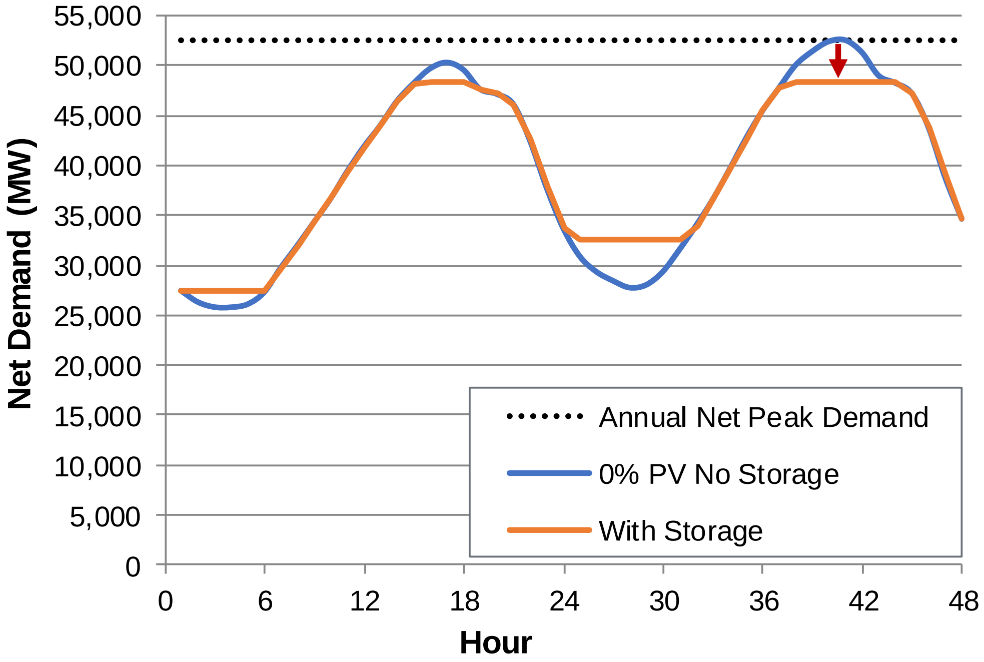
Results with PV

- Increasing levels of PV change the net load shape: at low penetration, PV reduces and flattens the peak demand. As PV penetration increases, PV's impact on reducing peak demand diminishes, while it increases the "peakiness" (narrows the width) of the net peak demand.



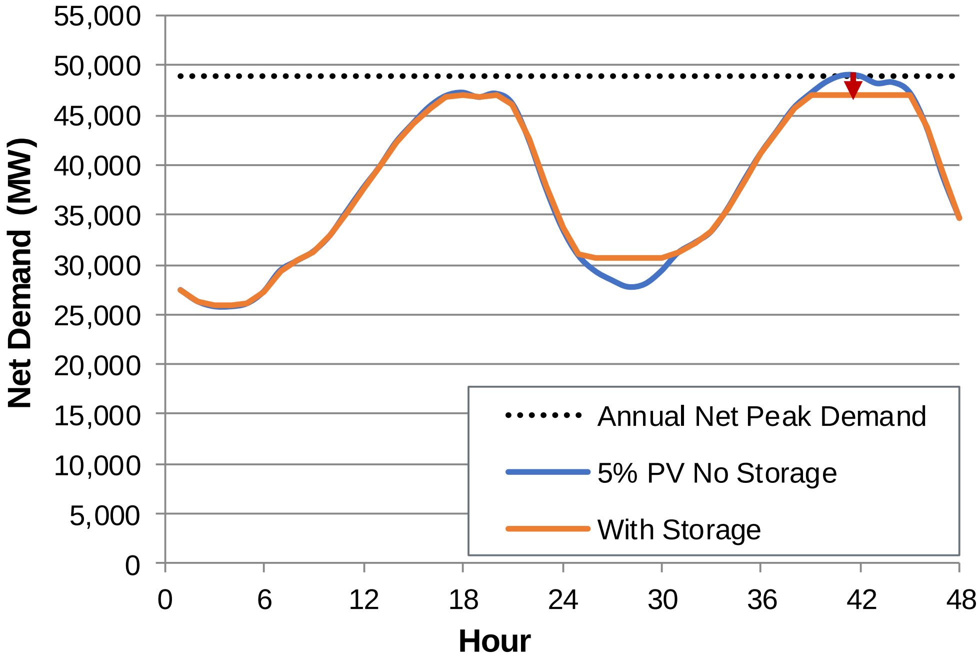
Simulated change in California net load shape due to PV on a peak demand day in September 2011

Supplement: Peak Day With and Without Storage (0% PV)



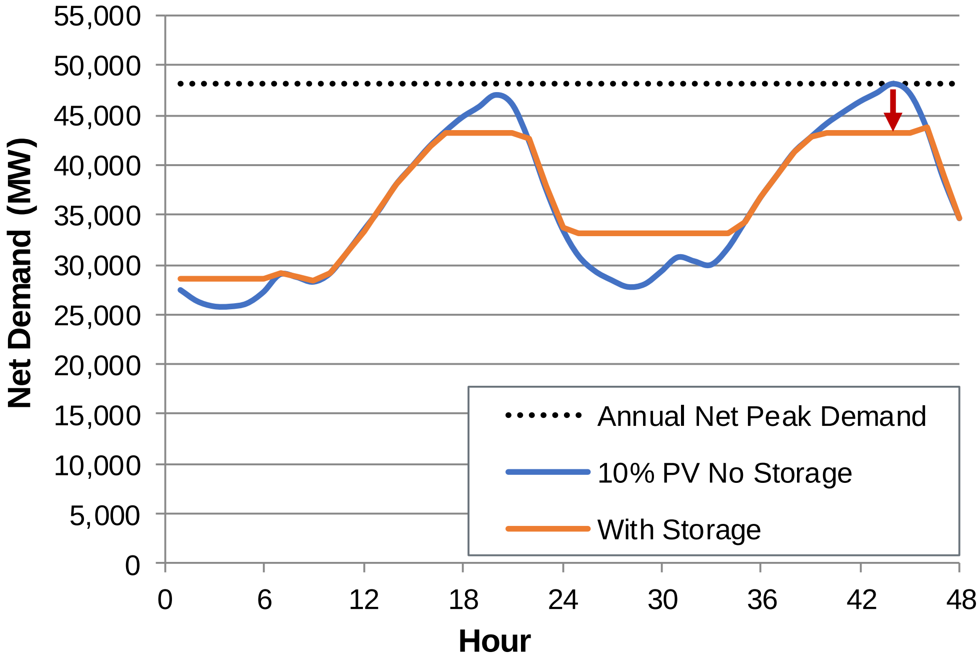
Zero PV. Peak demand occurs on September 6 (day 2) and is 52,540 MW. Peak demand reduction with 4-hr storage at 100% credit is 4,249 MW. Annual net peak demand is reduced to 48,292 MW. Storage is not completely utilized on day one so could have had additional charge/discharge for greater price arbitrage.

Supplement: Peak Day With and Without Storage (5% PV)



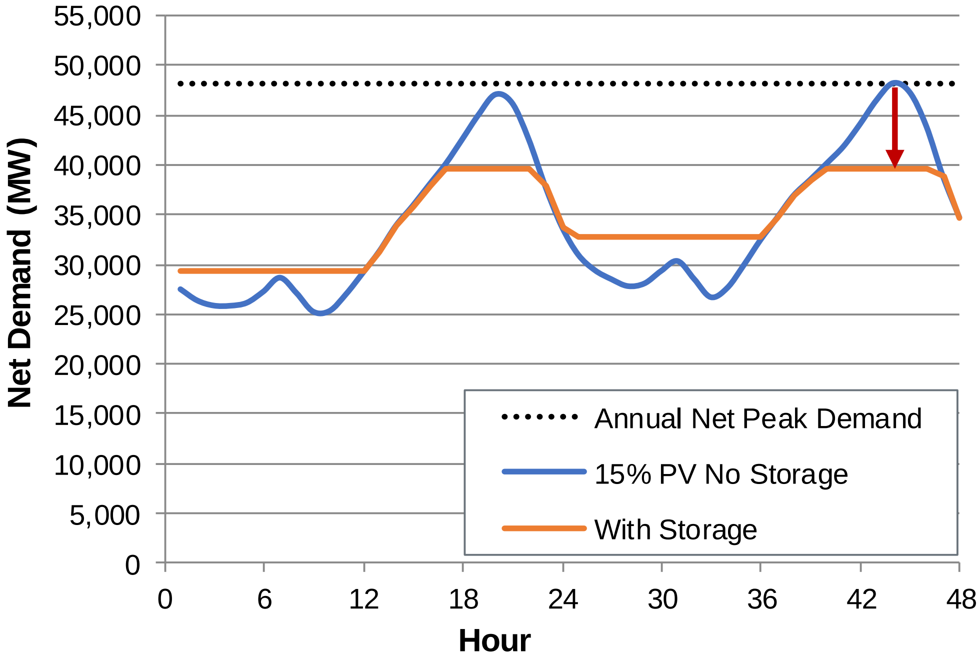
5% PV. PV generation has reduced net peak demand has been reduced to 48,940 MW. The peak shape is clipped (flattened) compared to zero PV case. Peak demand reduction of 4-hr storage at 100% credit is 1,937 MW (less than with zero PV).

Supplement: Peak Day With and Without Storage (10% PV)



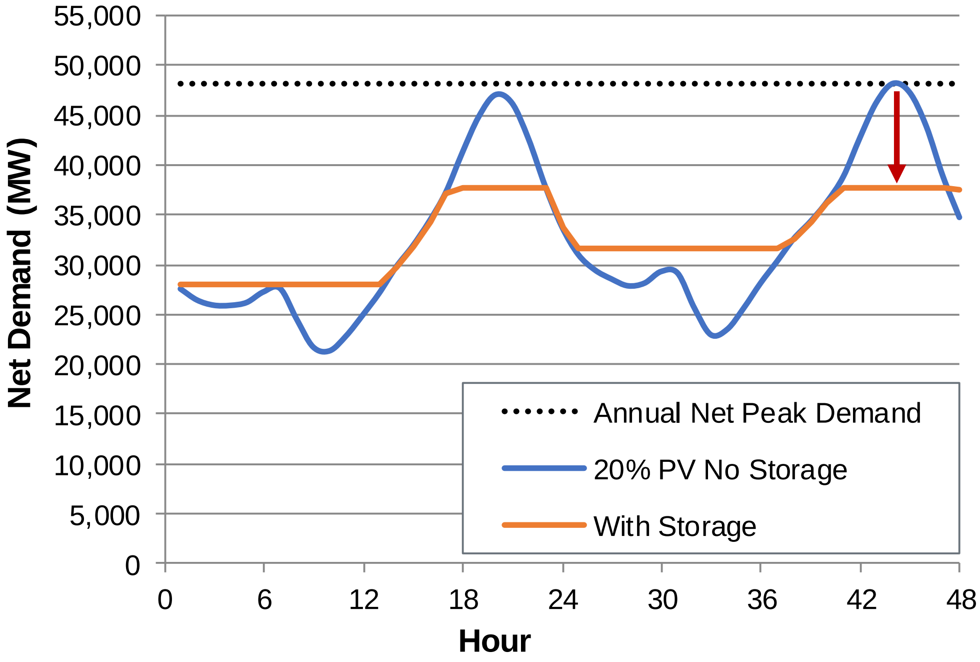
10% PV. PV generation has reduced net peak demand has been reduced to 48,172 MW. Peak demand shape has been narrowed relative to previous cases. Peak demand reduction with 4-hr storage at 100% credit has increased to 4,935 MW, a small increase relative to the zero PV case.

Supplement: Peak Day With and Without Storage (15% PV)



15% PV. PV generation has reduced net peak demand has been reduced to 48,123 MW. Net demand peak now occurs during period of low solar output and incremental capacity credit of PV is approaching zero. Peak shape has been significantly narrowed. Peak demand reduction with 4-hr storage at 100% credit is 8,462 MW, or about double the zero PV case.

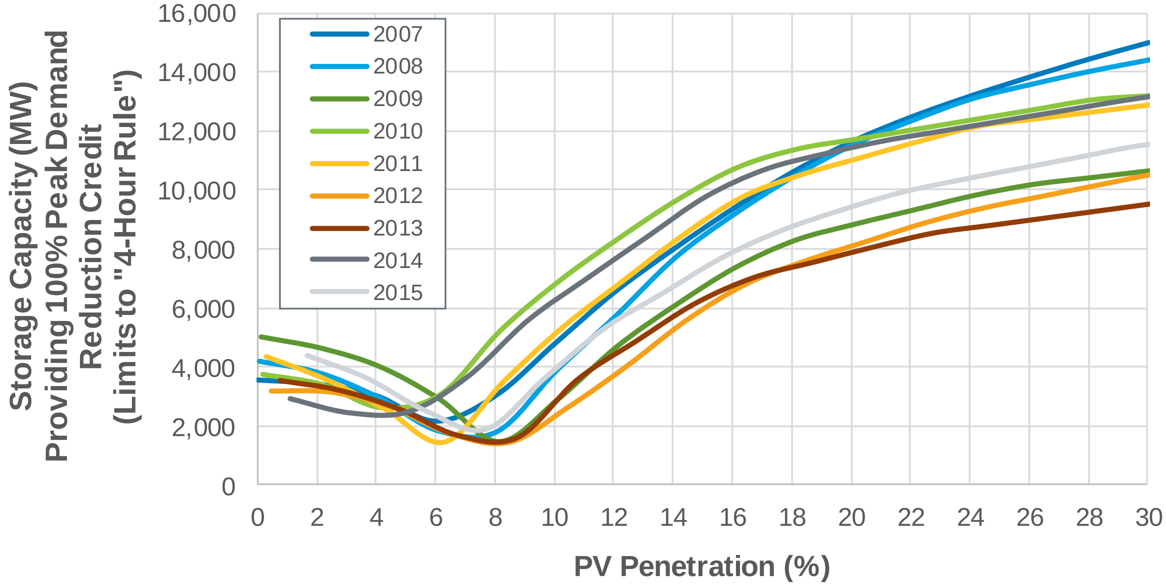
Supplement: Peak Day With and Without Storage (20% PV)



20% PV. PV generation has reduced net peak demand to 48,117 MW. Essentially zero incremental capacity credit of PV. The peak continues to narrow. Peak demand reduction with 4-hr storage at 100% credit is 10,372 MW.

Results with PV

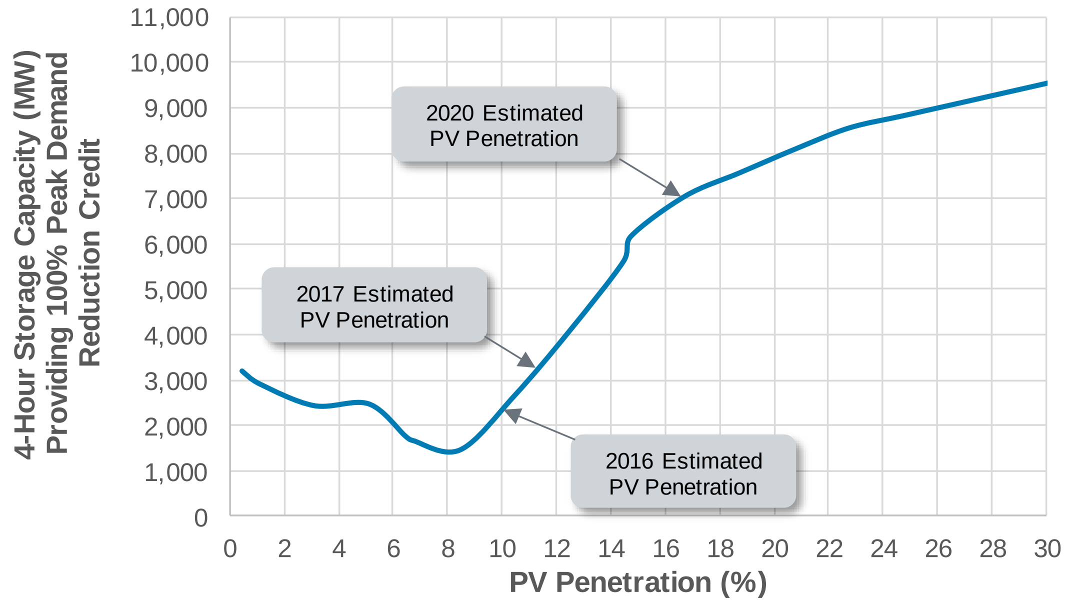
- For all years, from zero to about 5%–8% PV there is a decline in storage capacity that can receive a 100% peak demand reduction credit owing to the “flattening” effect of PV.
- At 5%–8% PV, the net peak demand begins to narrow, and at 7%–11% PV the storage capacity providing 100% peak demand reduction credit increases past its value at zero PV.



Threshold values for 100% peak demand reduction credit for 4-hour energy storage in each year, 2007–2015 (assuming a peak demand of 54 GW)

Results with PV

- Using the lowest credit values across all years, at 11% PV penetration optimally dispatched 4-hour storage could reduce California's net peak demand by about 3,000 MW, with full peak demand reduction credit—about the same as at zero PV.
- Assuming a 2020 PV penetration of 17%, the full-credit 4-hour storage capacity rises to 7,000 MW.



Threshold values for 100% peak demand reduction credit for 4-hour energy storage in 2020 (assuming a peak demand of 54 GW)

Conclusions

- **Storage's ability to reduce peak demand decreases with increasing installed storage capacity**.
- **Adding PV changes storage's ability to meet peak demand**
- **Synergy exists between storage and PV deployment**.

Ongoing Work

- Repeating for the whole U.S.
- Scenarios up to 60% VG
- Combination of wind and solar

For More Information

Download the report:

https://www.nrel.gov/docs/fy18osti/70905.pdf

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