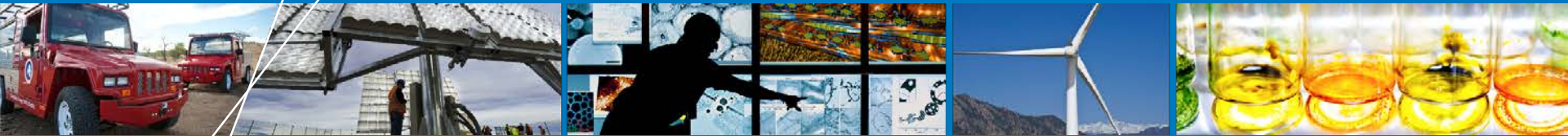


Batteries and Storage: Truly a Game Changer?



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Storage

- **The holy grail, paradigm shifting, silver bullet that will arbitrage, firm and shape renewables and serve up duck la 'orange**
- **But can you actually make any money?**

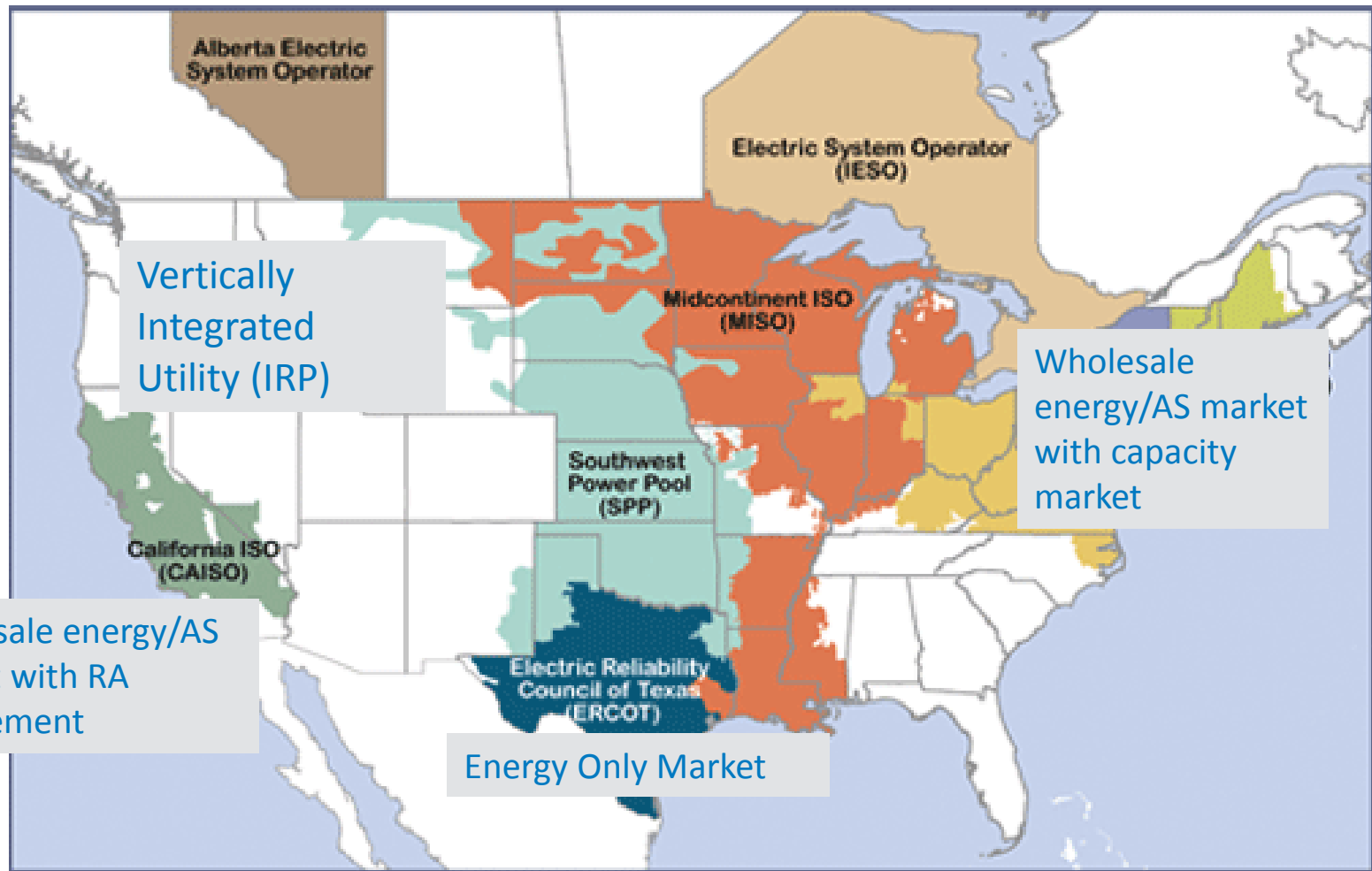
Applications of Utility-Scale Energy Storage

Application	Description	Timescale of Operation
Load Leveling/ Arbitrage	Purchasing low-cost off-peak energy and selling it during periods of high prices.	Hours.
Firm Capacity	Provide reliable capacity to meet peak system demand.	4 + Hours
Operating Reserves		
Regulation	Fast response to random, unpredictable variations in demand.	15 minutes to 1 hour
Contingency Spinning	Fast response to respond to a contingency such as a generator failure.	30 minutes to 2 hours
Replacement/ Supplemental	Units brought on-line to replace spinning units.	Hours
Ramping/Load Following	Follow longer term (hourly) changes in electricity demand.	30 minutes to hours.
T&D Replacement and Deferral	Reduce loading on T&D system during peak times.	Hours
Black-Start	Units brought online to start system after a system-wide failure (blackout).	Hours

Value Capture?

- **The concept of stacked services is well documented**
- **But so are the challenges**
- **Depending on location these values are capture by 1-4 different entities under different regulatory framework.**
- **Can you actually get paid for all the wonderful things that storage can do?**

Market Regions



So where does that leave us?

- **I want a big market**
- **I want to stack a limited number of services within a single business entity**
- **I want to deal with a single market and jurisdiction**

Applications of Utility-Scale Energy Storage

Application	Valued in A Single Restructured Markets?
Load Leveling/ Arbitrage	Yes
Firm Capacity	Via scarcity pricing, combined scarcity plus capacity markets or through resource adequacy payments.
Regulation Reserves	Yes
Contingency Spinning Reserves	Yes
Replacement/Supplemental /Non-Spinning	Yes but values are very low
Primary Frequency Response / Inertia	No. Early stage proposals
Ramping/Load Following	No. Proposed in several markets
Transmission Replacement and Deferral	Only partially via congestion prices
All Distribution Specific Applications	No. Will likely remain cost of service through regulated entities
Renewable Integration	Captured through other services.

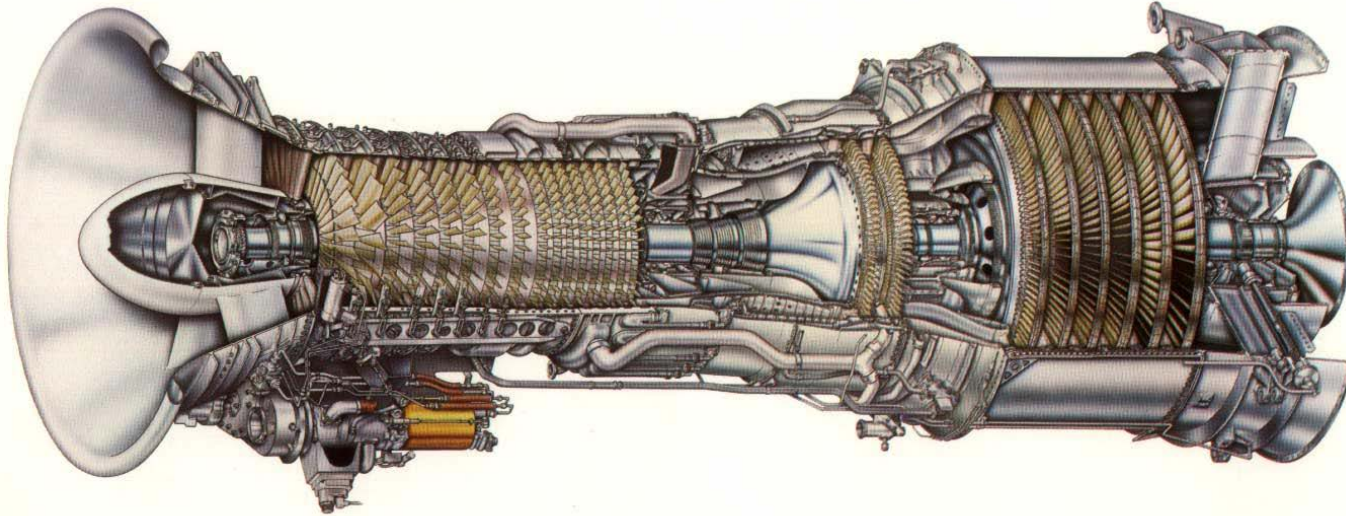
Ancillary Services?

- **Early markets for frequency regulation are close to saturation**
- **Total market for regulating reserves in all RTO/ISO markets is ~2.5 GW.**
- **Already have ~700 MW of new battery storage**
- **Much lower prices for spinning reserves**
 - Non-spin is basically worthless
- **Increased competition from DR**

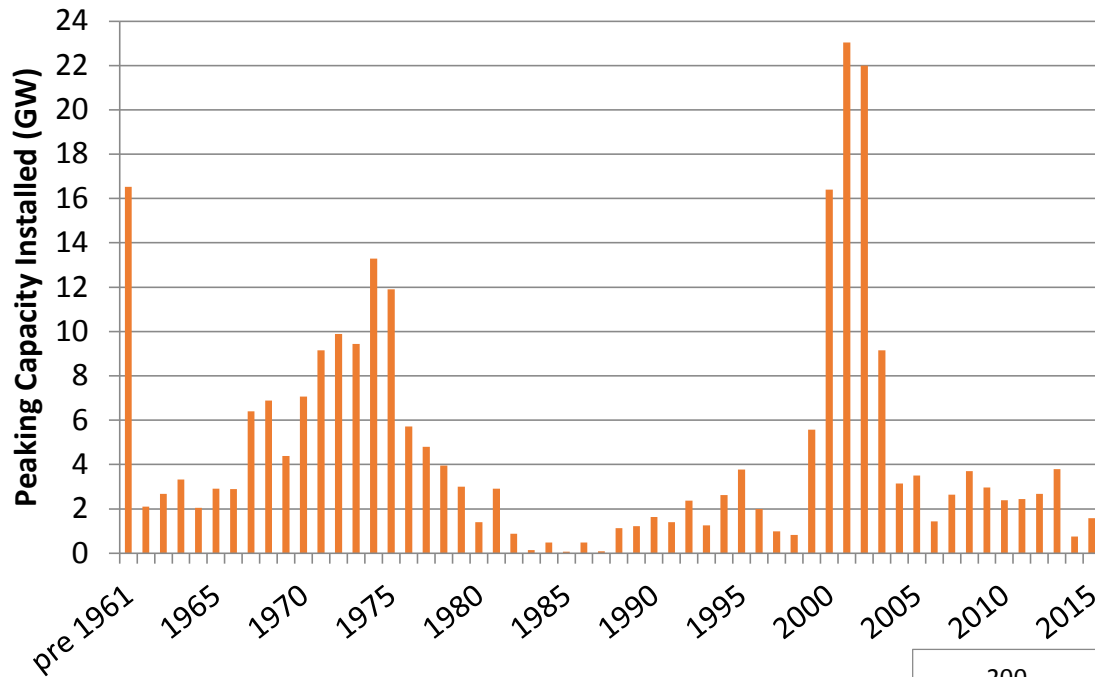
Distribution and Transmission?

- **Nope. Value from single services just isn't big enough. (Maybe in a vertically integrated utility, but good luck in an ISO/RTO market)**

The Next Big Thing?

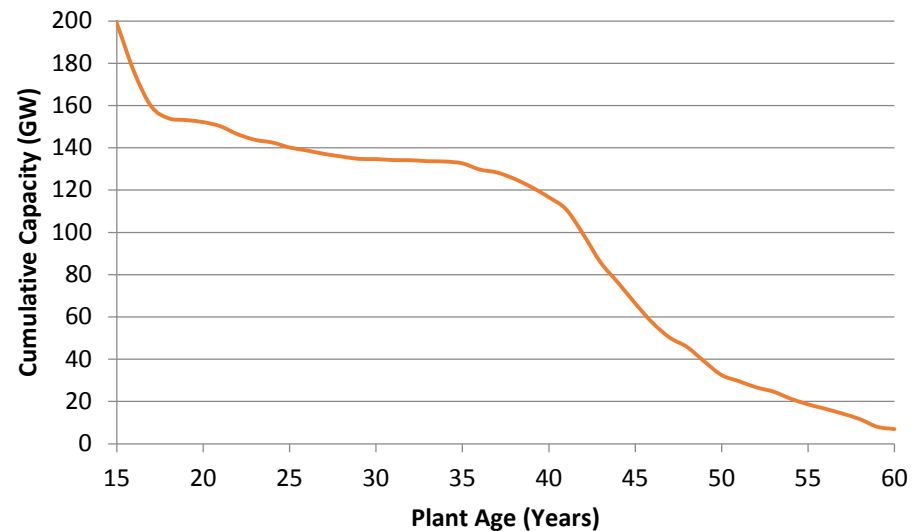


U.S. Peaking Capacity



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

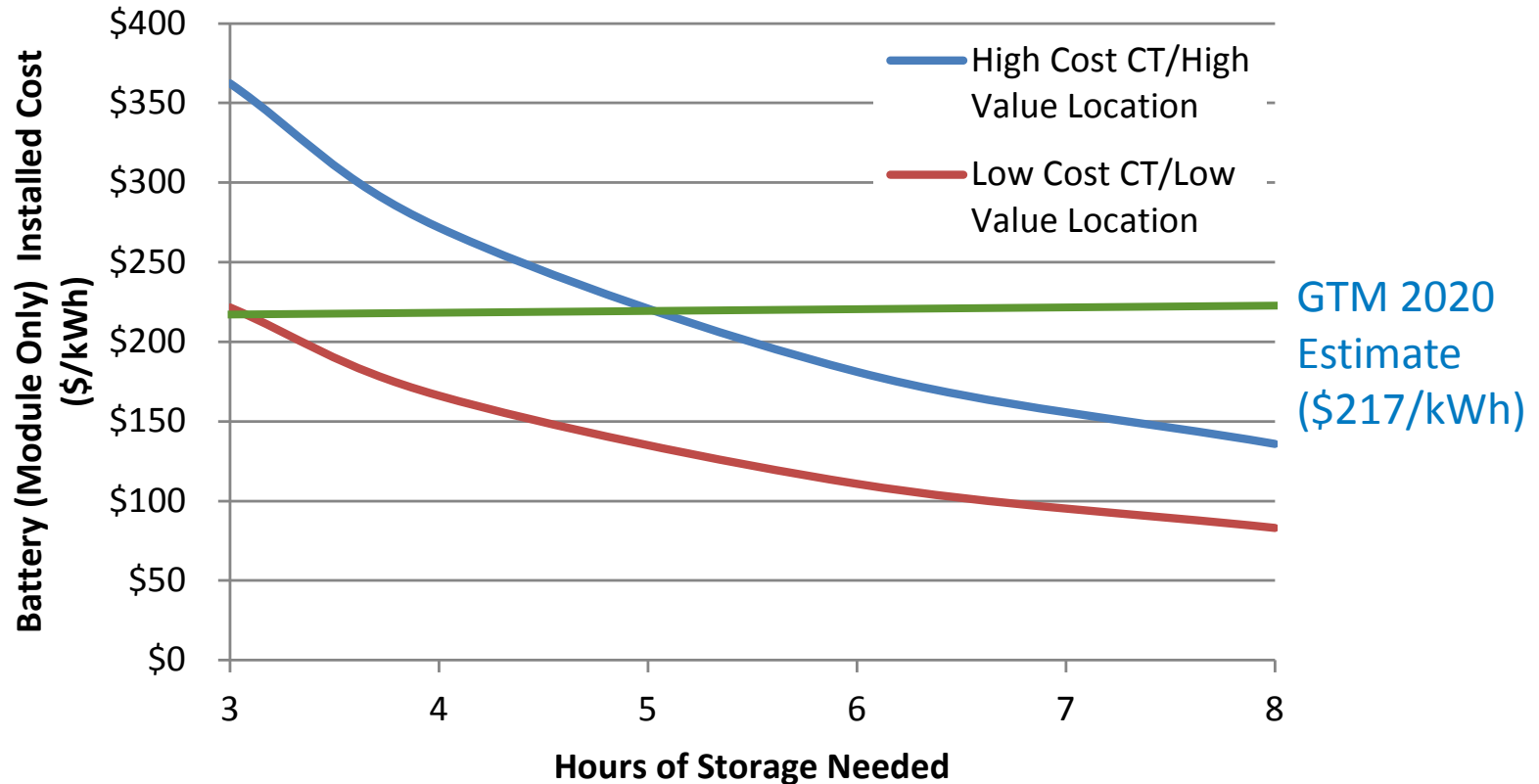
Significant peaking capacity now over 40 years old. Over the next 20 years, we would expect about 152 GW of peaking capacity to retire



How to Compare Costs

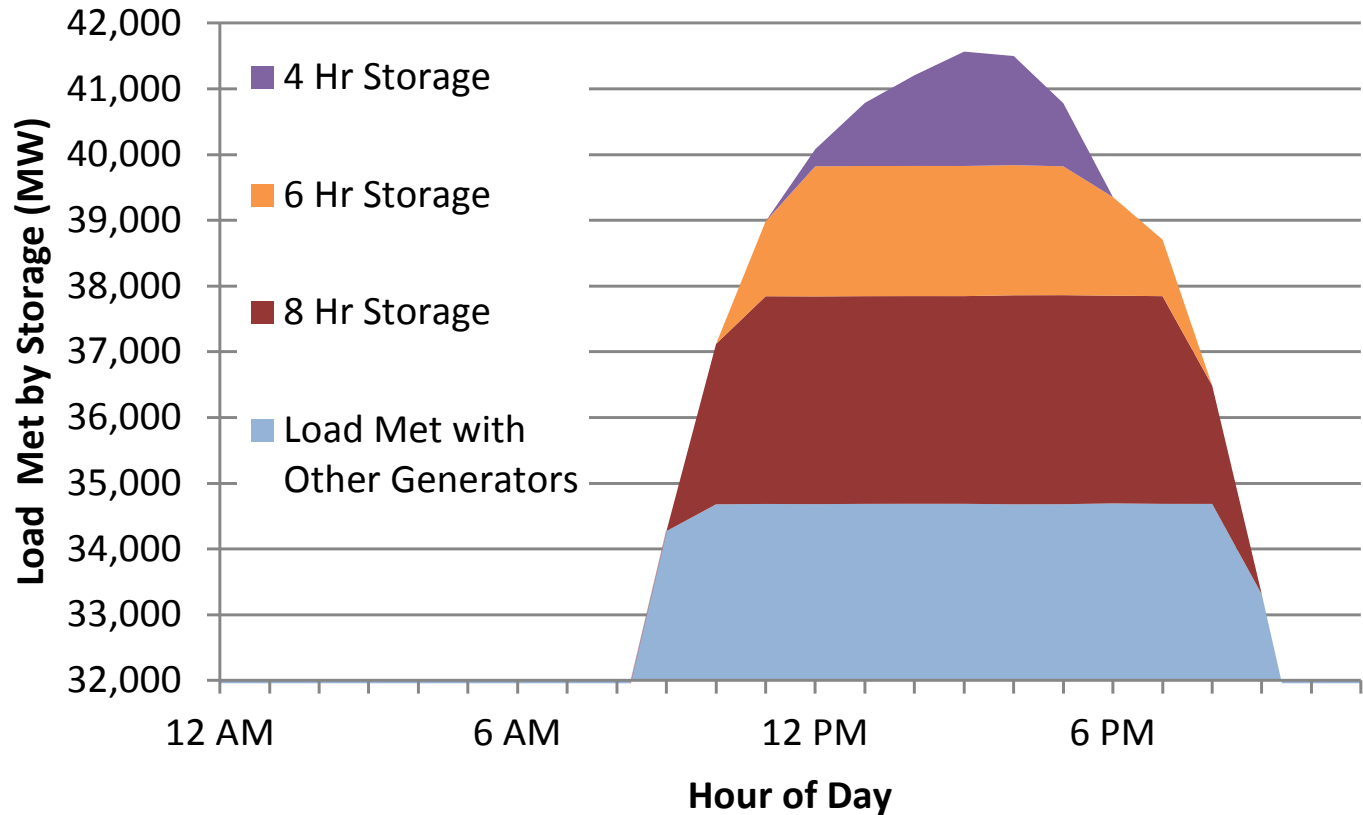
- **Difficult for storage compete purely on capital cost**
- **CT: \$700/kW (frame) - \$1200/kW (aeroderivative)**
- **Translates to \$75 to \$200/kWh for battery module if we assume \$400/kW BOS**
 - Assumes 4 hour duration
 - And before accounting for limited lifetime
- **But storage provides other values that can be captured in an energy market**

So How Cheap Does Storage Have to Be?



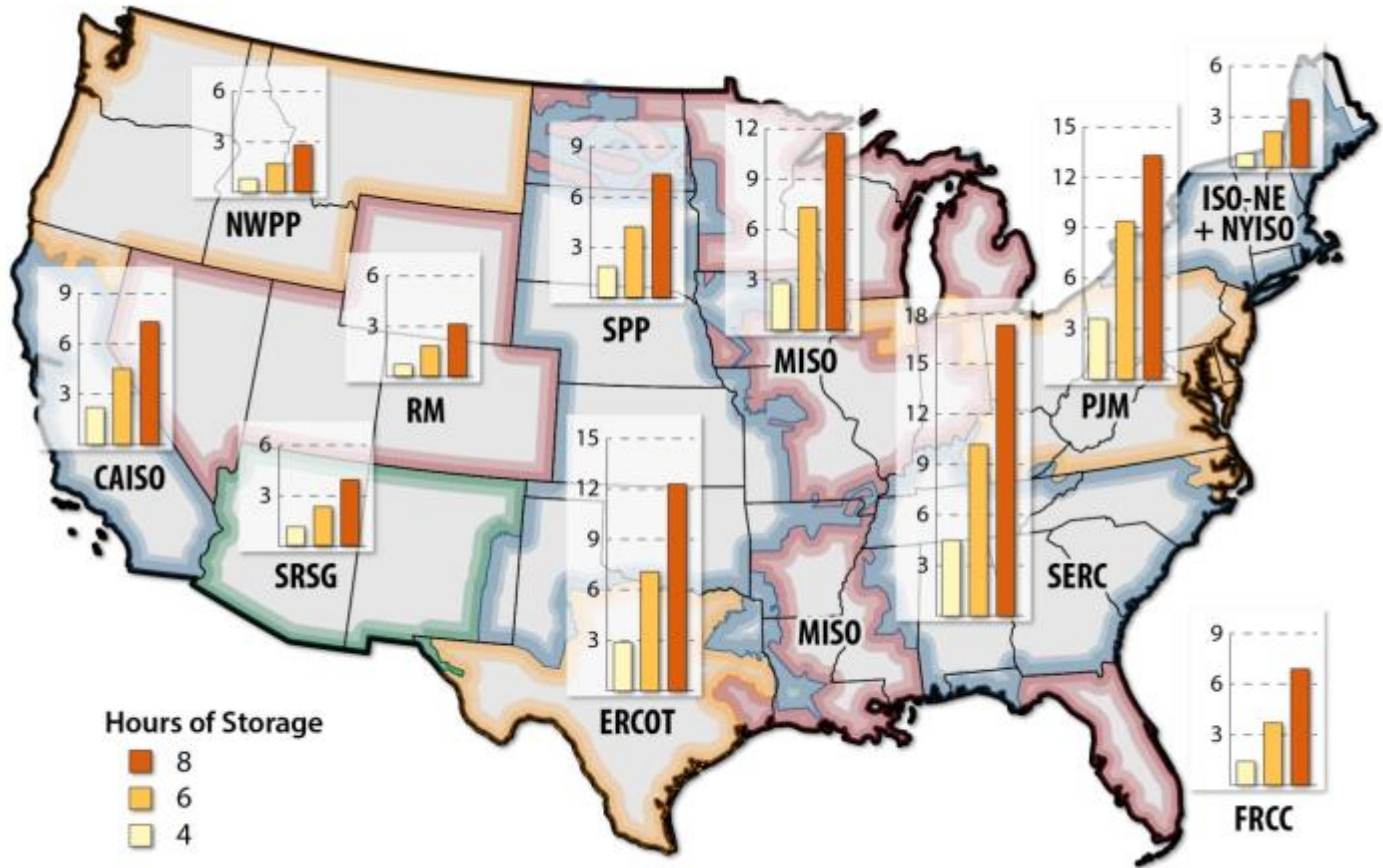
We are nearing a tipping point for 4-hour storage providing capacity services – but how big is this market?

But How Big is the Market?



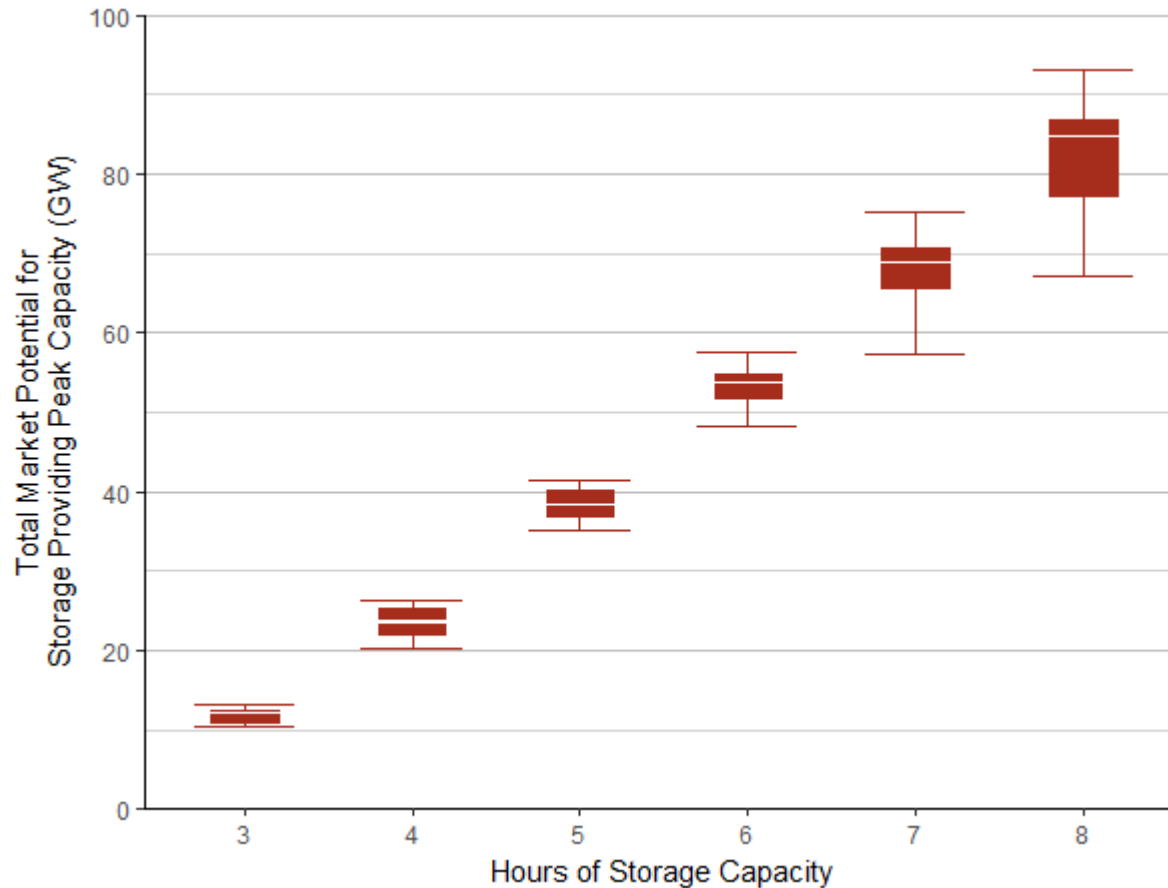
CAISO and MISO allows 4-hour storage to provide resource adequacy. But only a limited market size due to “widening” of net demand peak.

Market Potential?



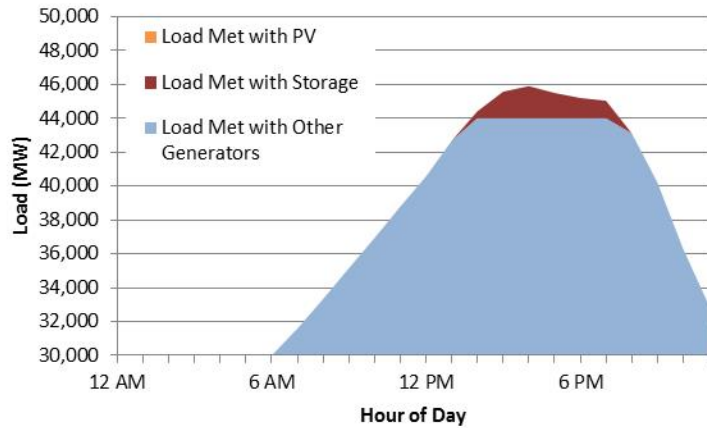
Total market potential for energy storage as a peaking capacity in the U.S.

Total U.S. Market Potential for Storage as Peaking Capacity

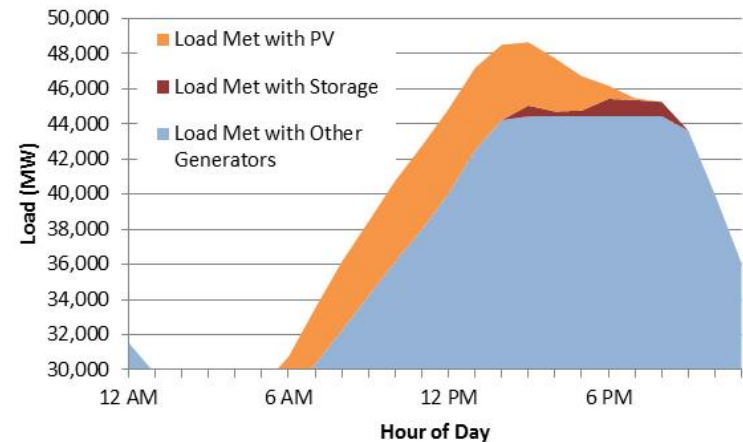


Total market potential for energy storage as a peaking capacity in the U.S.

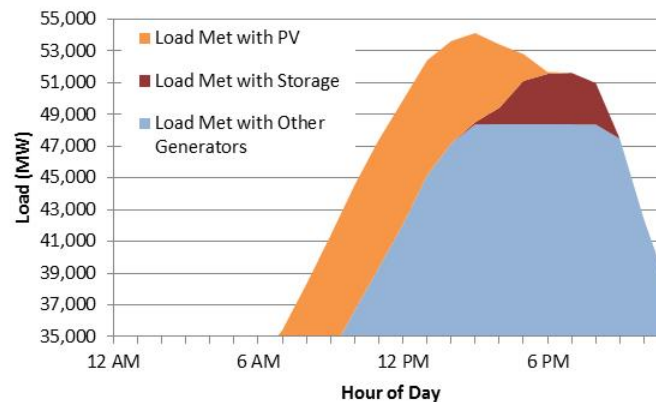
How Do Renewables Affect This?



Zero PV



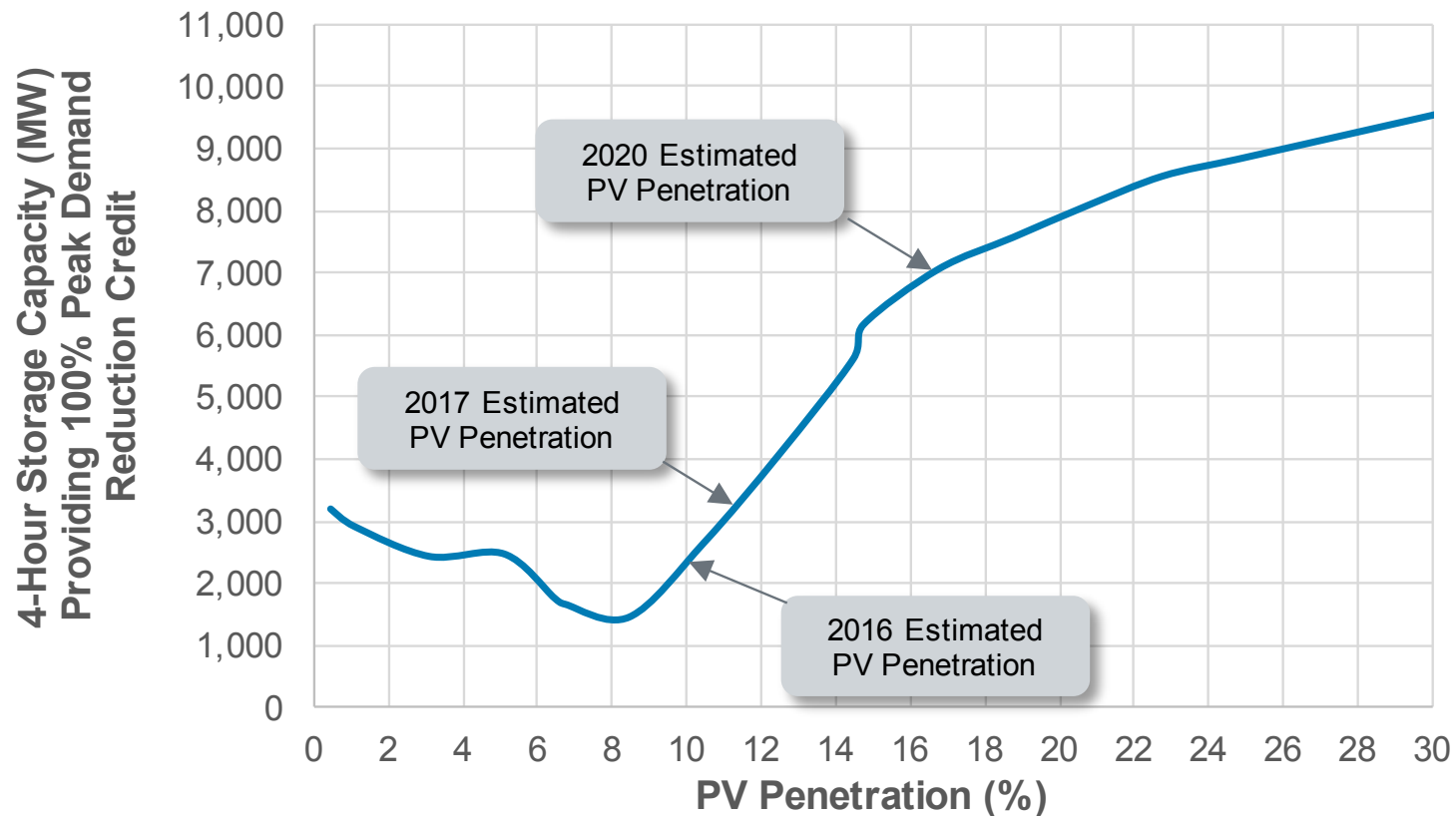
5% PV



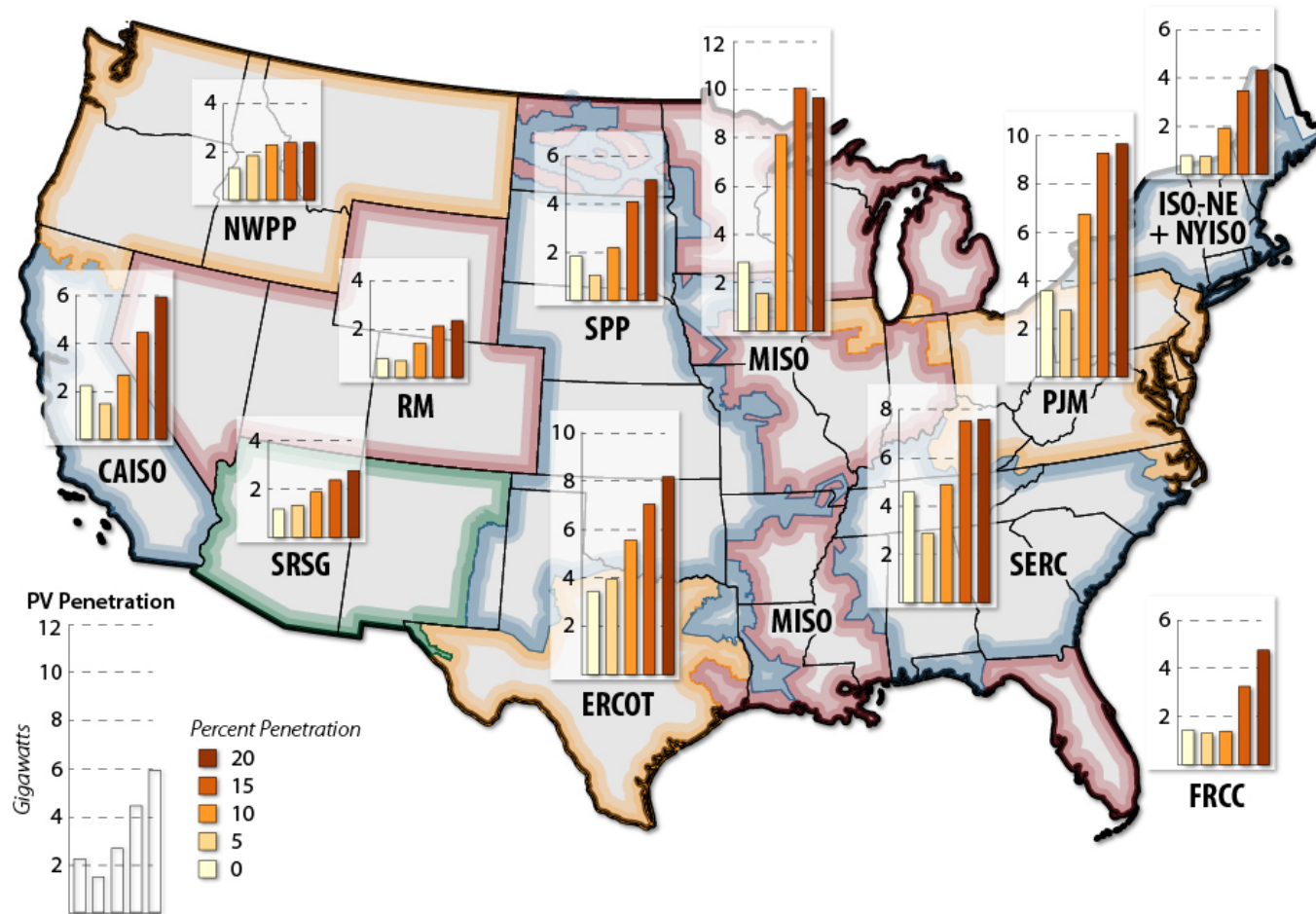
10% PV

- With increased PV penetration, the capacity credit of PV decreases while the capacity credit of storage increases

Impact of PV in California on Potential



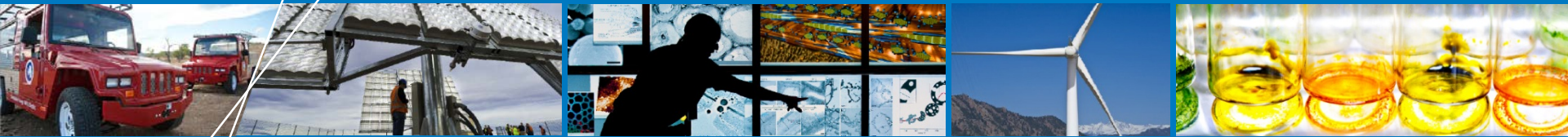
Increase in 4-hour storage technical potential



Preliminary, non-bankable results

Conclusions / Opinions

- 1. When properly scheduled, long-duration (several hours of capacity) batteries provide an alternative to combustion turbines for meeting peak capacity requirements.**
- 2. We are at or close to a tipping point for storage as peaker alternative**
- 3. This market is 10s of GWs for 4-hour storage and could be >100 GW for 8 hour storage after considering growth in PV**
- 4. MANY CAVEATS**
 - Current markets long on capacity, still need to address missing money in energy-only markets etc



Contact

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