The Role of Energy Storage in Future Grids

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Royal Irish Academy Breakfast Briefing
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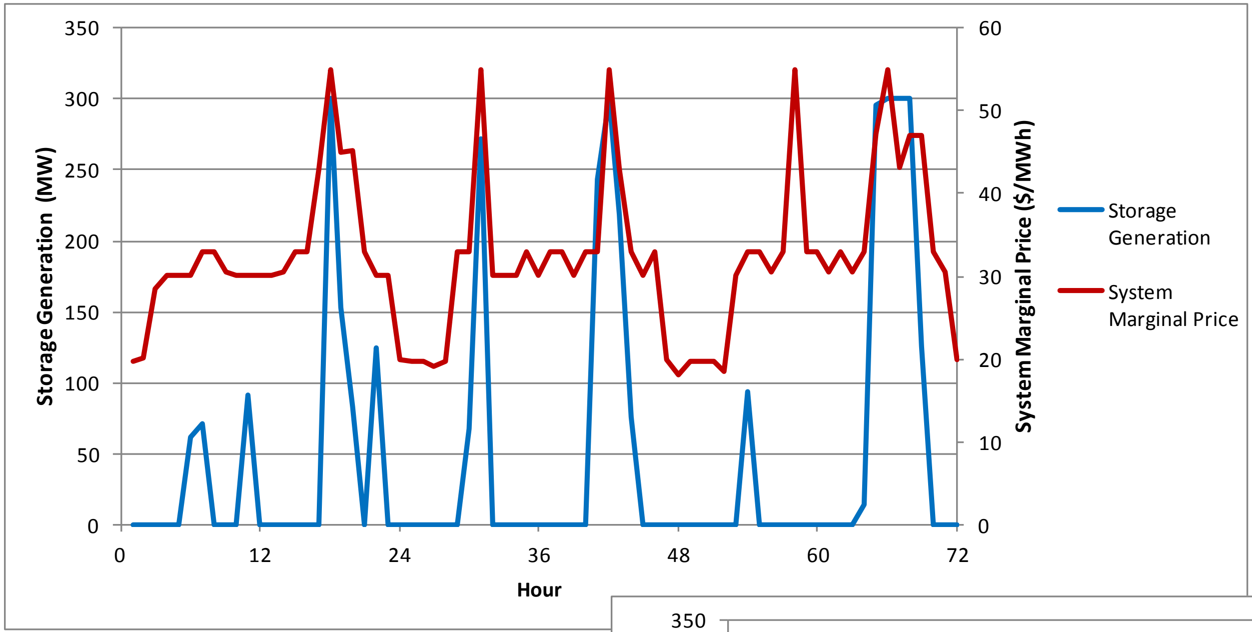
The Endless Debate – Do We Need Storage?

- Not a very well-formed question
- A better question: At what point do the costs and benefits of storage make it a cost-effective technology to help us integrate renewable energy?
- Valuation studies examine the costs and benefits of energy storage to alternative technologies

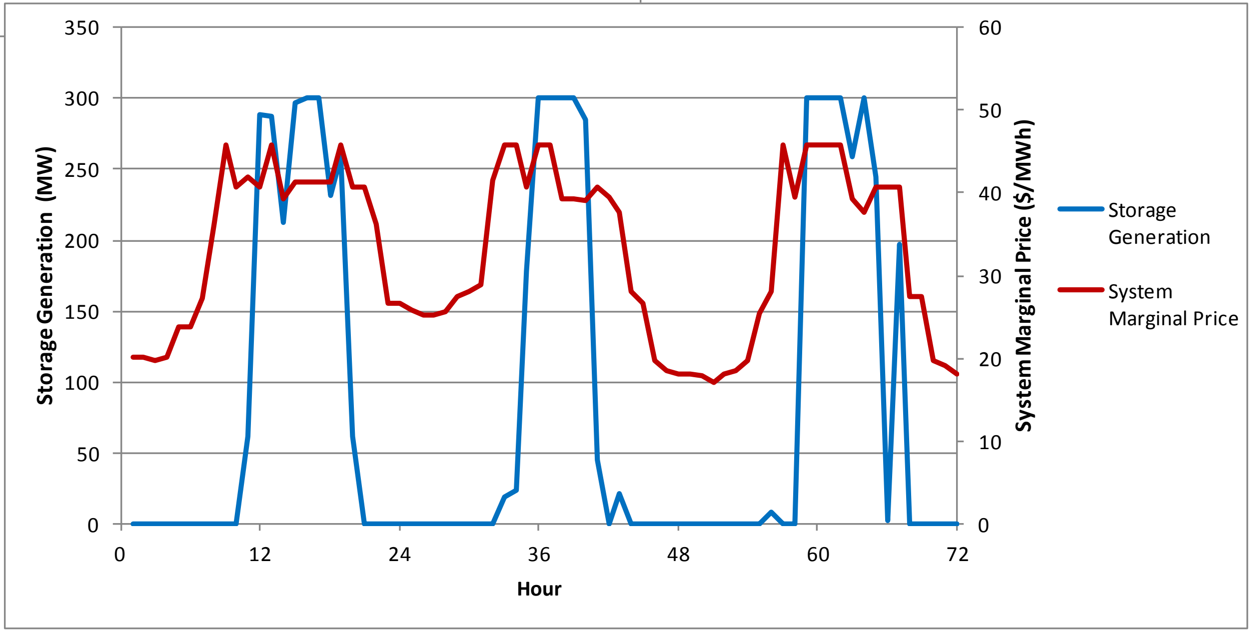
Applications of Utility-Scale Energy Storage

Application	Valued in Restructured Markets?
Load Leveling/ Arbitrage	Yes
Firm Capacity	Via scarcity pricing or combined scarcity plus capacity markets. Suffers from missing money problem.
Regulation Reserves	Yes, with potentially increased compensation for fast response through FERC 755 initiated market reforms
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.

Example Analysis – Storage Dispatch (Energy)

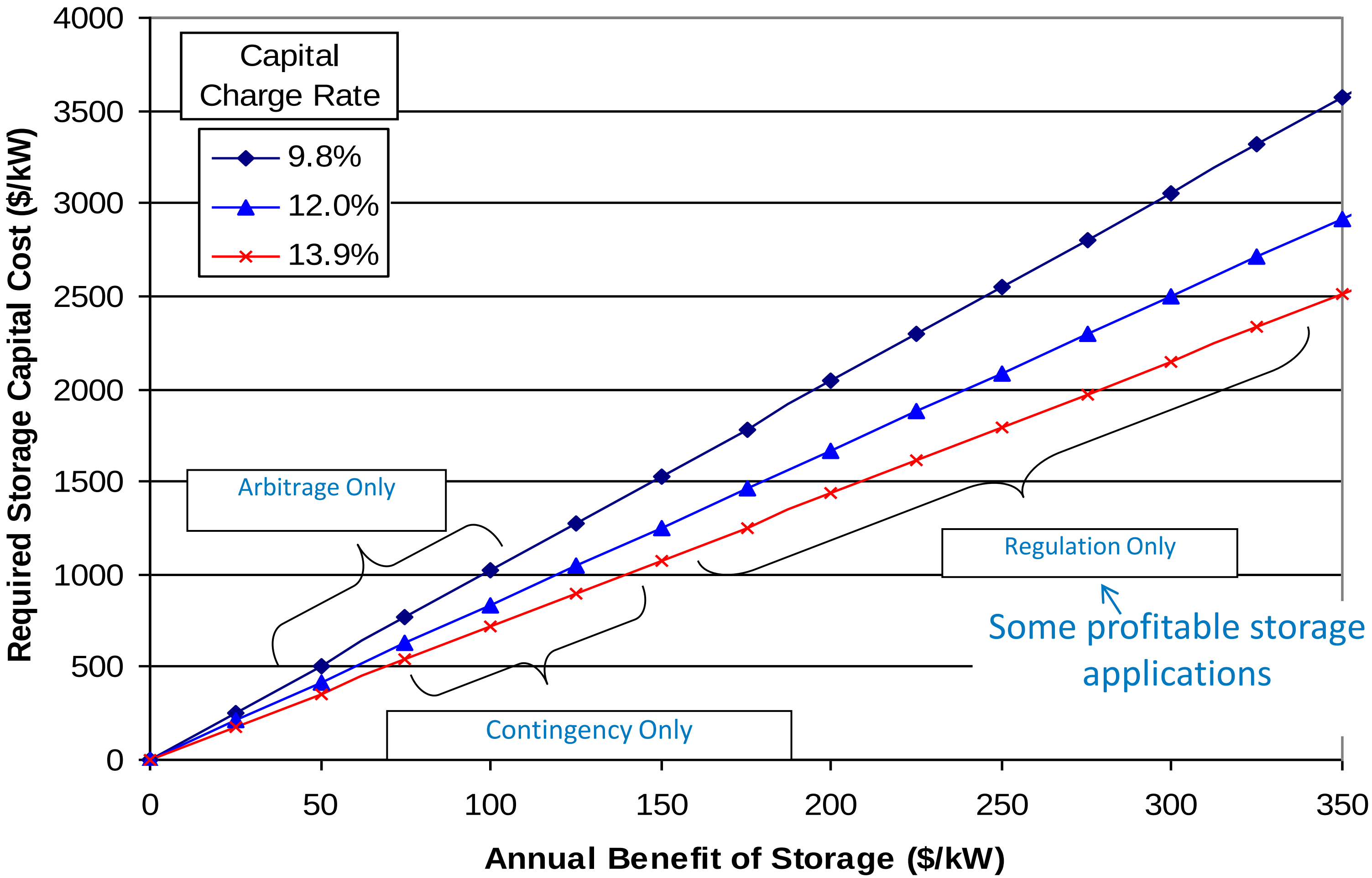


February 3-5



July 19-21

Historical Value of Energy Storage in U.S. Markets



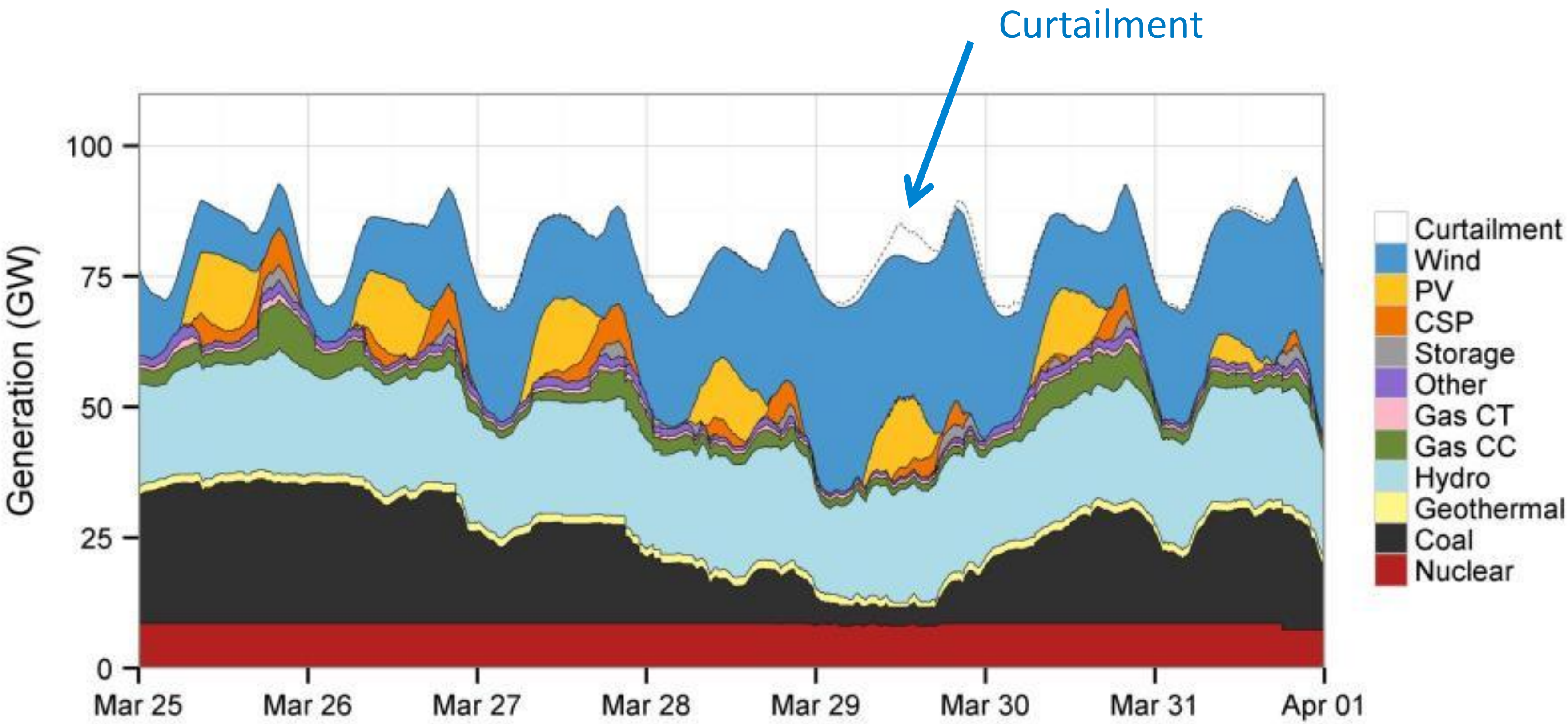
Reserves Market Saturation

- Total market for regulating reserves in all U.S. 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

The Future?

- Decreasing costs of storage
- Increasing value due to renewables deployment

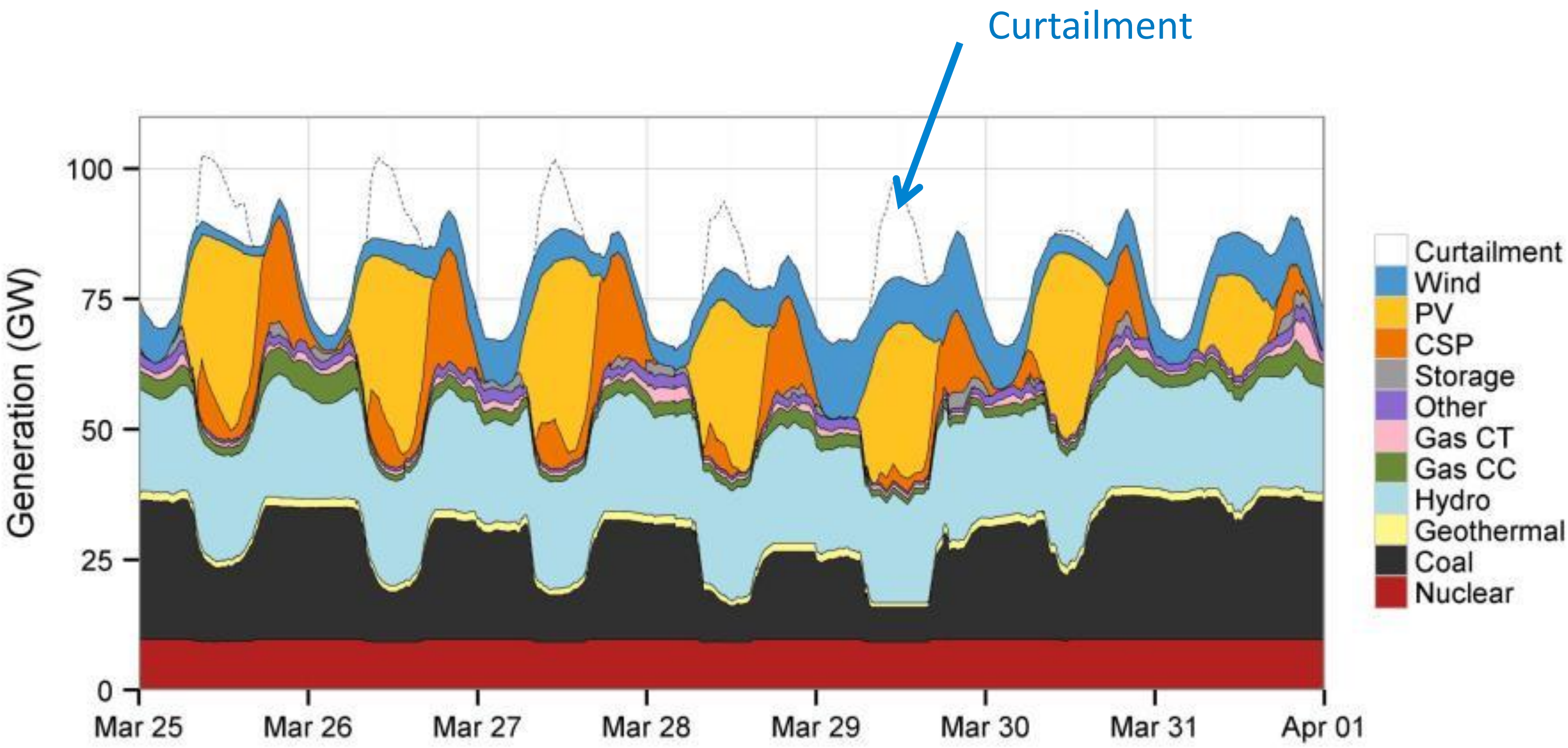
WWSIS II High Wind Case (8% solar, 25% wind)



http://www.nrel.gov/electricity/transmission/western_wind.html

Lew et al. 2013

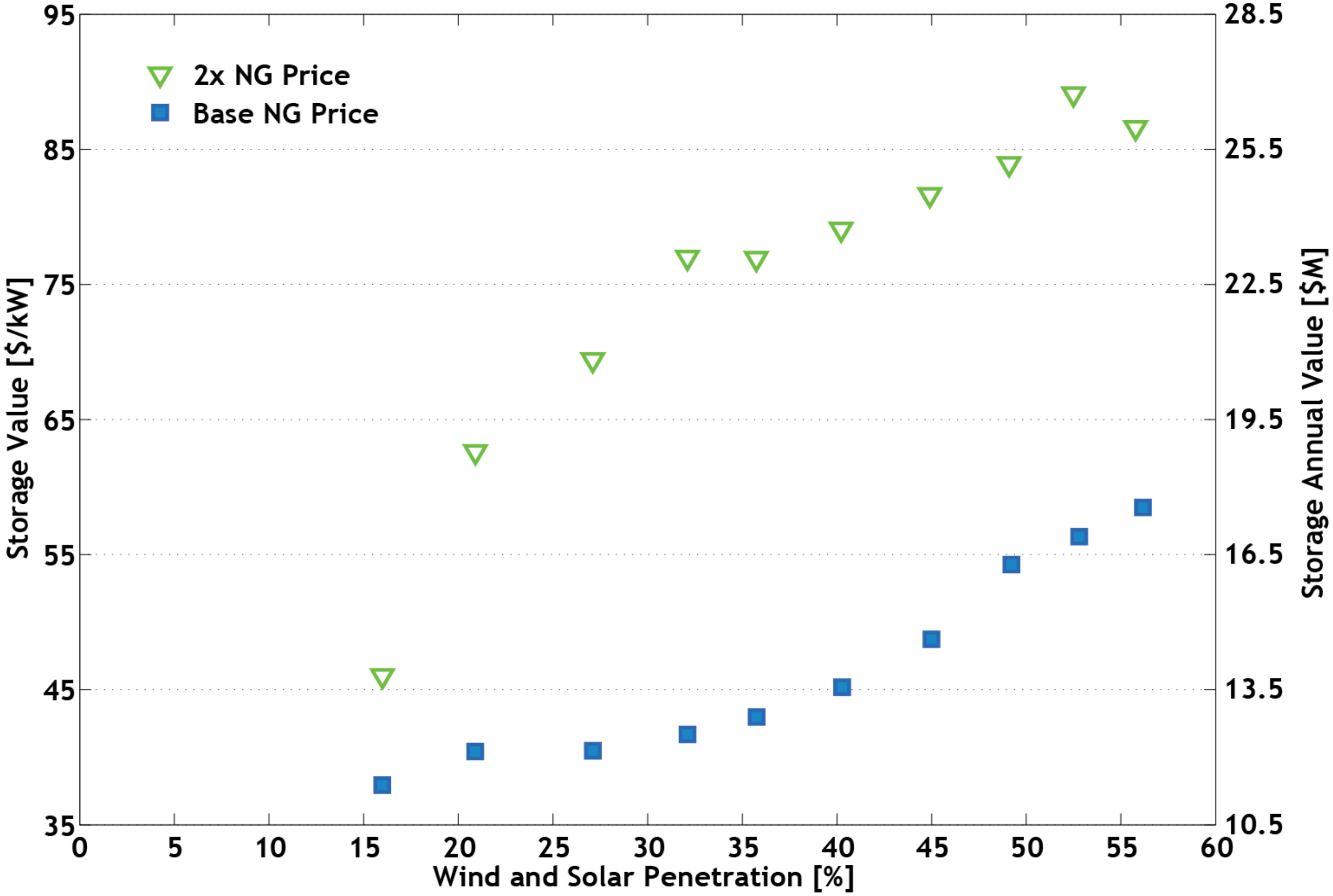
WWSIS II High Wind Solar (25% solar, 8% wind)



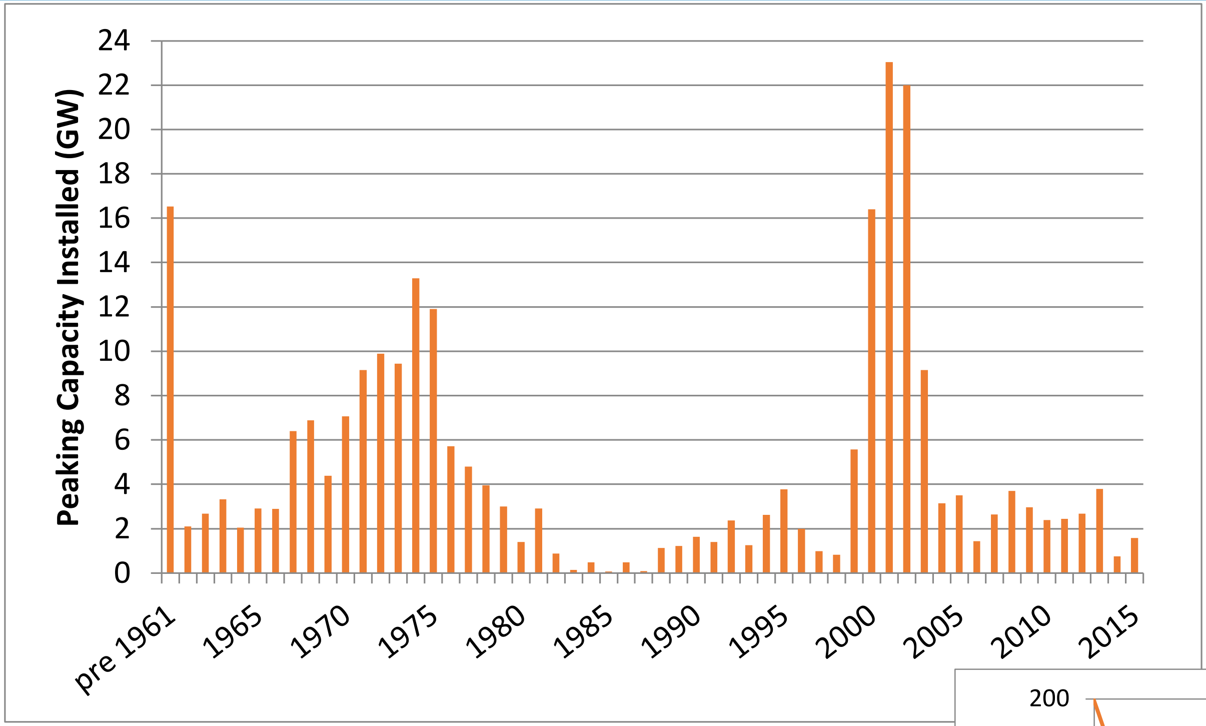
Solar is 60% PV and 40% Concentrating Solar Power with 6 hours thermal storage

Lew et al. 2013

Value as a Function of RE Penetration

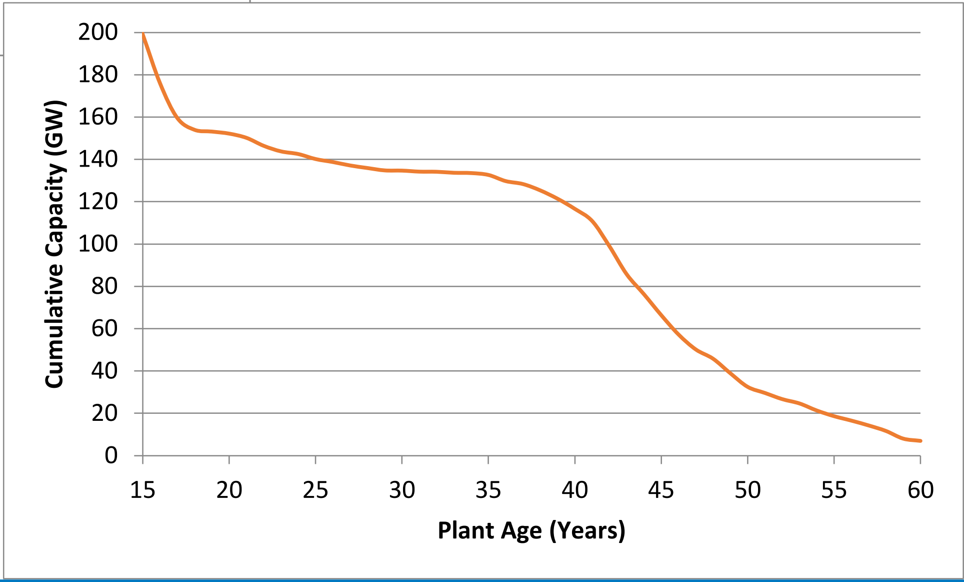


Peaking Capacity Retirements



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

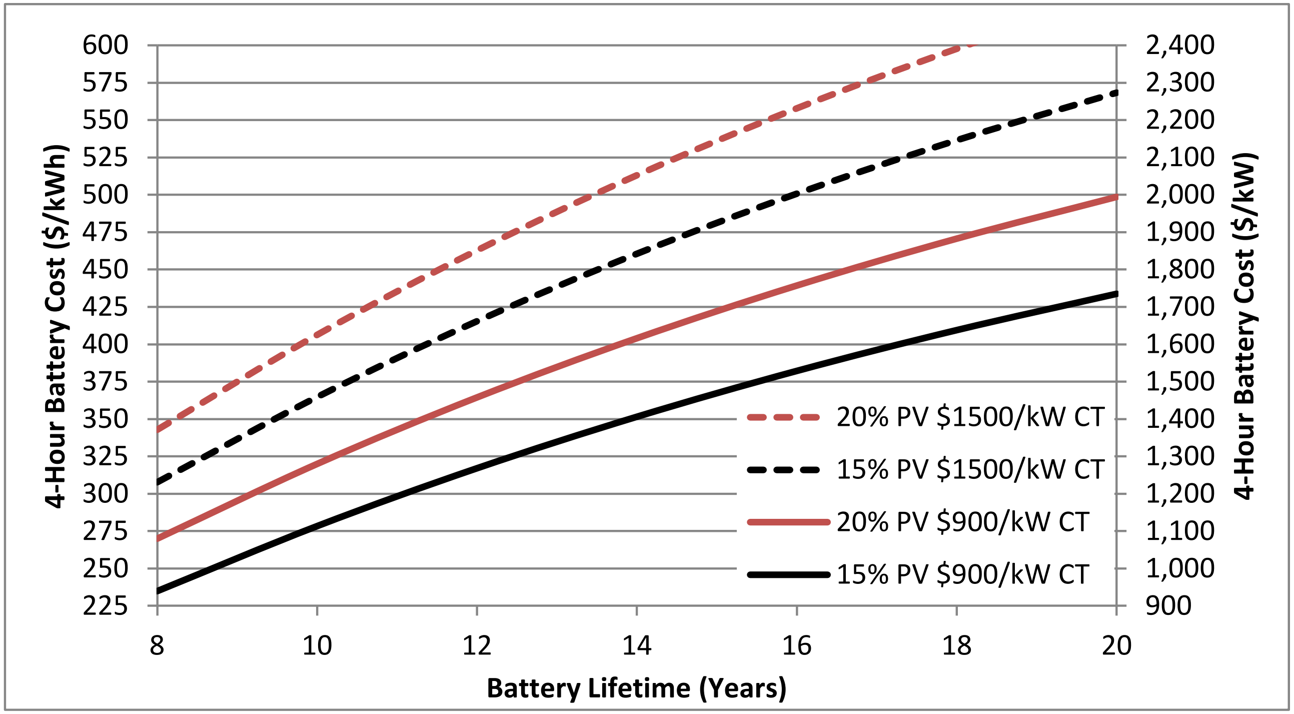
Significant peaking capacity now over 40 years old. Over the next 20 years, we would expect about 152 GW of peaking capacity to retire



How to Compare Costs

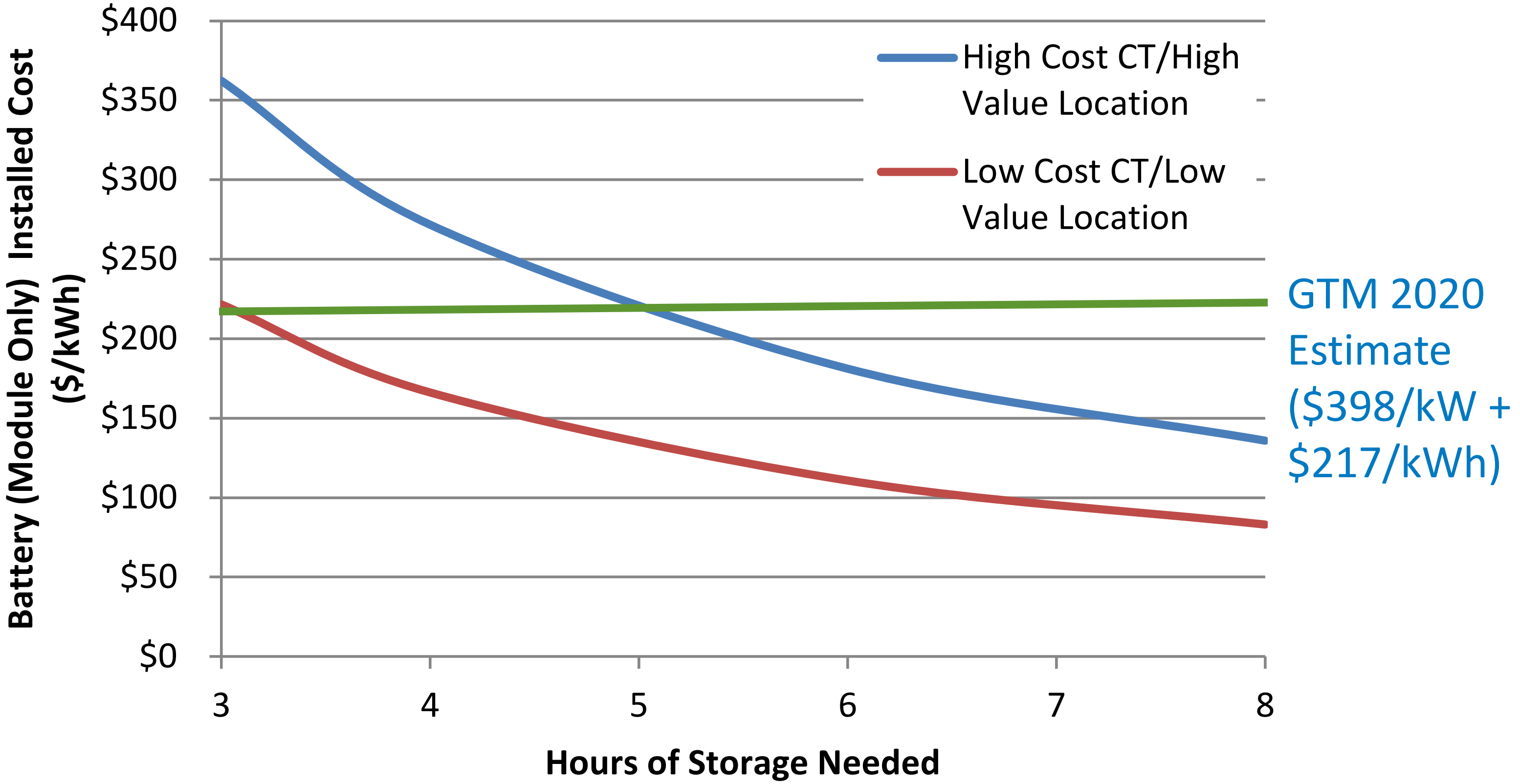
- Difficult for storage compete purely on capital cost
- CT: \$700/kW (frame) - \$1200/kW (aeroderivative)
- Translates to \$75 to \$200/kWh for battery module if we assume \$400/kW BOS
  - That's before accounting for limited lifetime
- But storage provides other values

Example: Comparison of Storage to CT



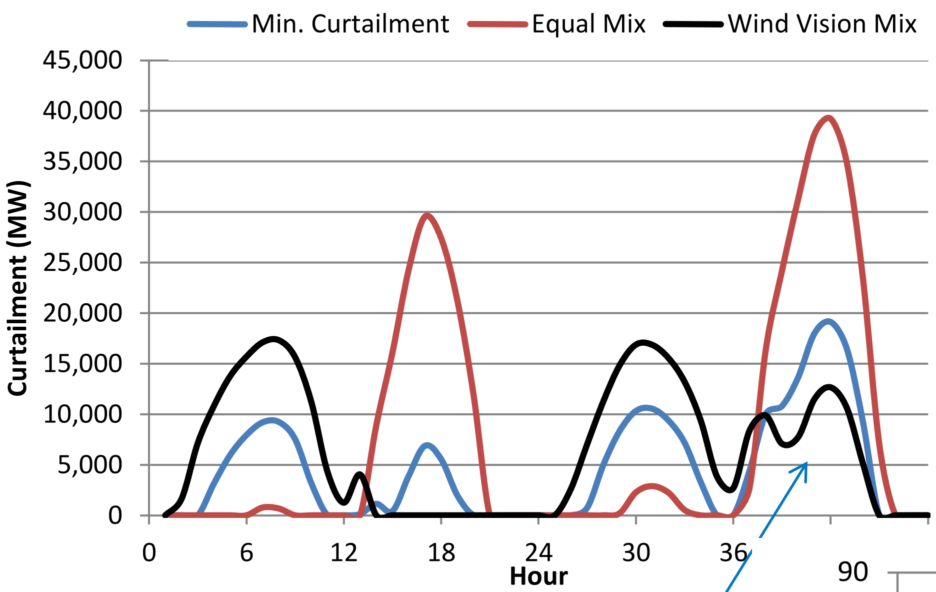
How much would a battery have to cost to have an equivalent life-cycle cost to an advanced combustion turbine?

So How Cheap Does Storage Have to Be?



We are nearing a tipping point for 4-hour storage providing capacity services – but can 4 hour batteries provide integration services? Is this just another niche market?

Curtailment Patterns

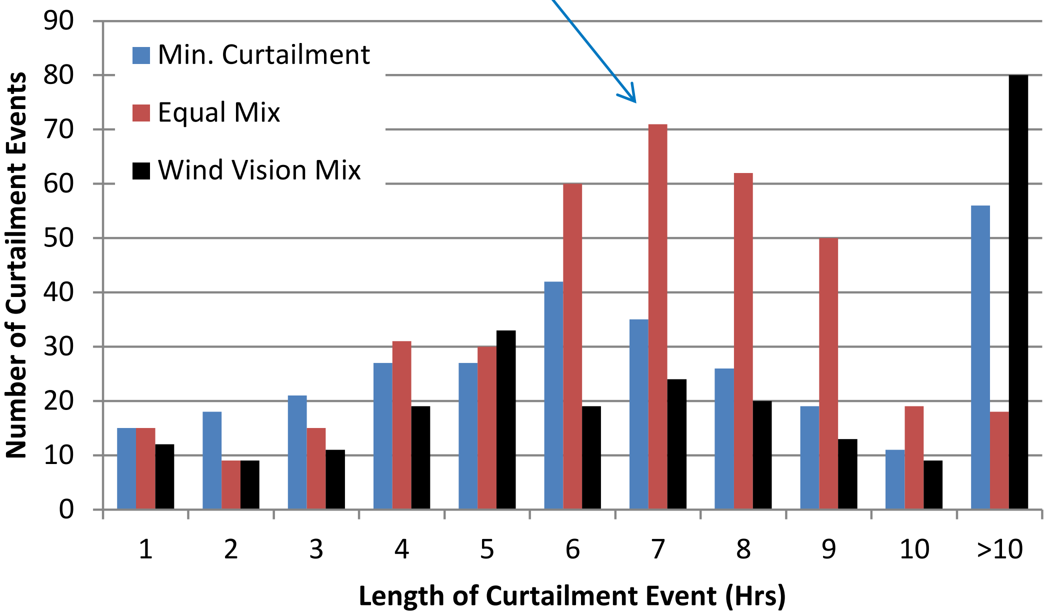


Simulated Curtailment During Jan 18-19 with no Storage

19 hours of curtailment

More solar = shorter duration events

More wind = more long duration events



32% of events occurring over at least 10 hours in the Wind Vision mix. The longest curtailment event in the Wind Vision scenario lasts about 90 hours.

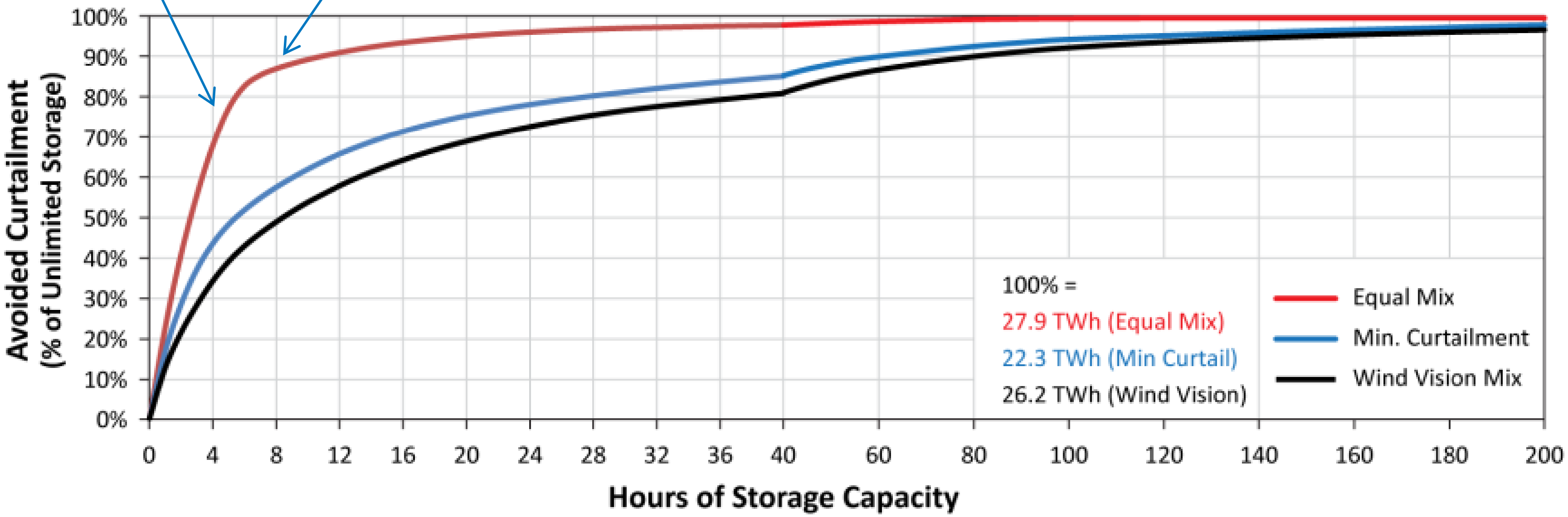
So does that mean we need long duration storage?

Determining Energy Storage Requirements

4 Hours avoids 35%-65% of curtailment

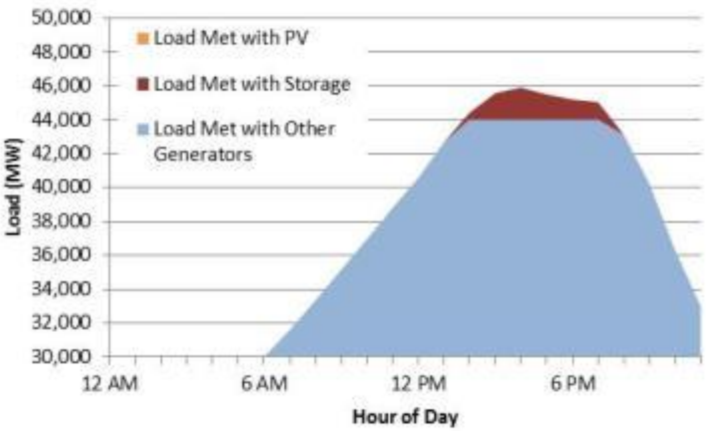
8 Hours avoids 50%-90% of curtailment

Is eliminating 100% of wind a realistic goal?

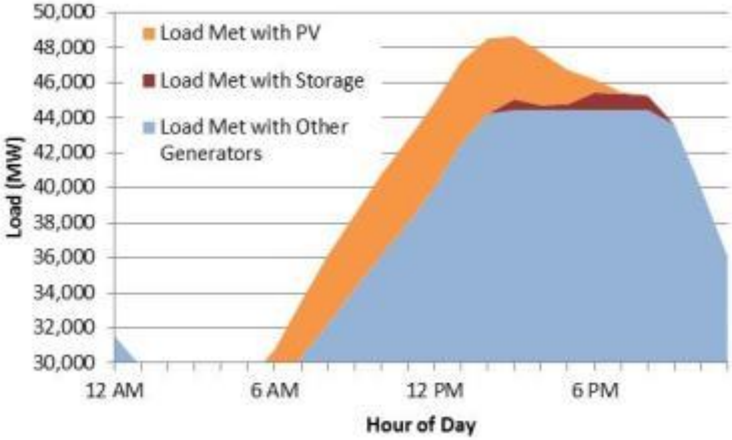


8.5 GW of Storage Power Capacity

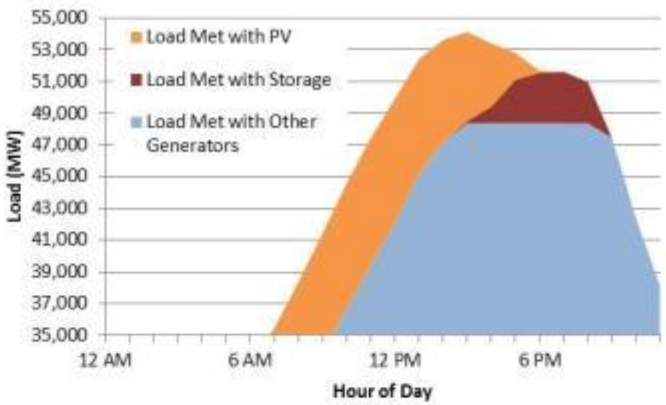
PV Increases Capacity Credit of Storage



Zero PV



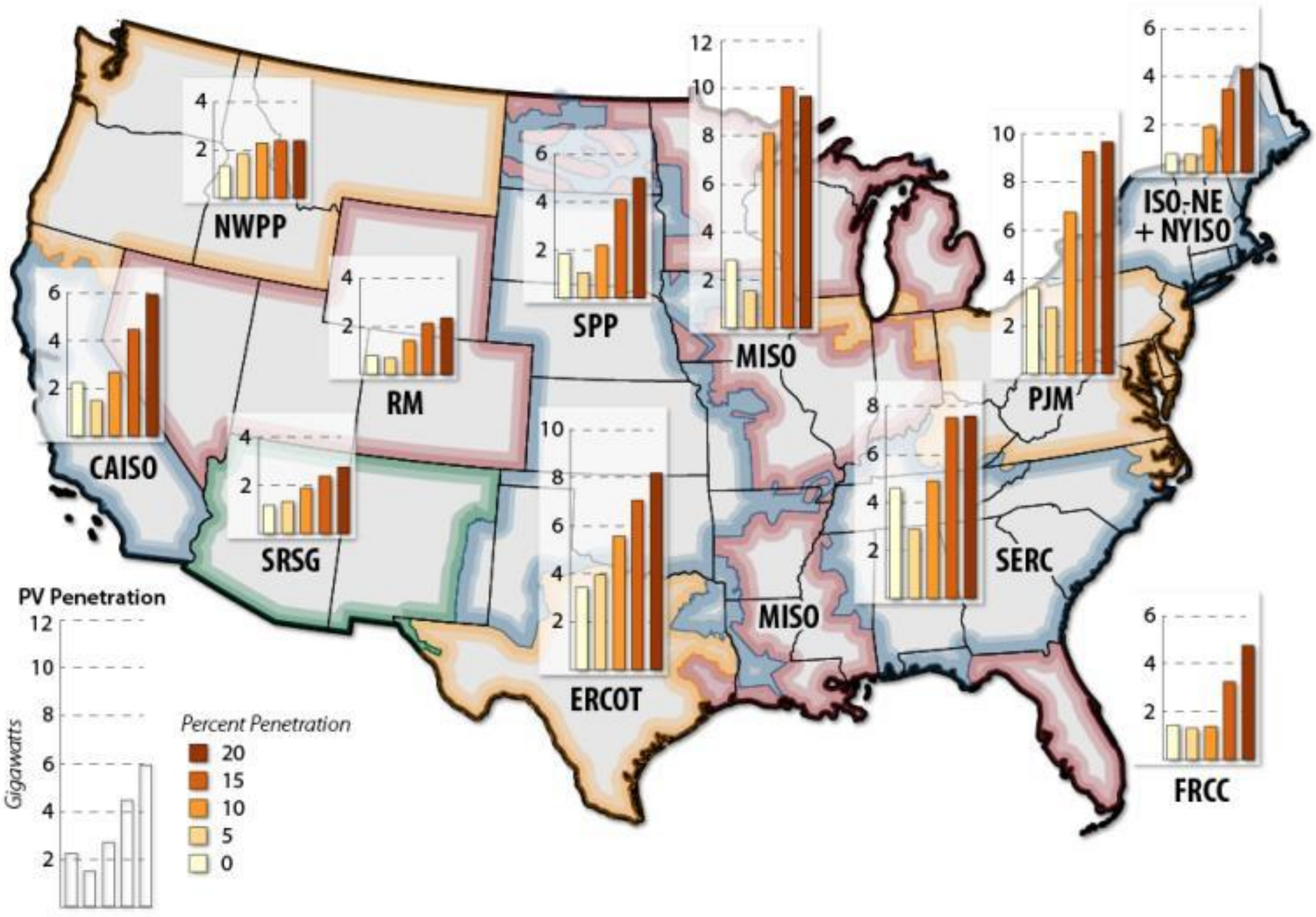
5% PV



10% PV

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

Increase in 4-hour storage technical potential



Non-bankable results

Conclusions / Opinions

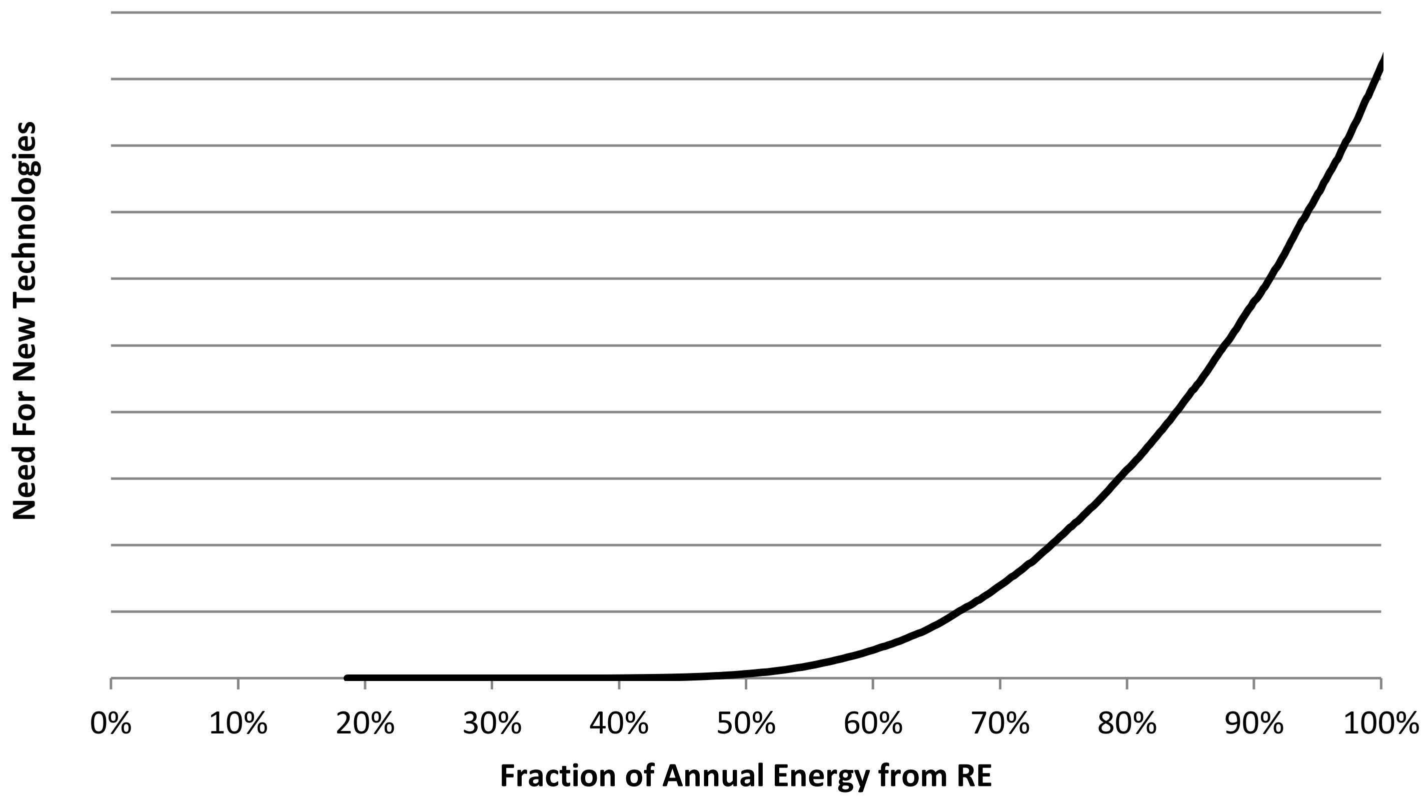
1. The value of storage for energy arbitrage is relatively low and is unlikely pay for any existing storage technology/device.

2. Ancillary services (regulating reserves) appears to be cost effective for a few storage devices, with limited market

3. When properly scheduled, long-duration (several hours of capacity) batteries provide an alternative to combustion turbines for meeting peak capacity requirements.

4. Storage may finally be approaching a tipping point for cost-competitiveness. Renewables (particularly PV) will help accelerate this
5. MANY CAVEATS
    - Challenge of value capture – avoided starts, price suppression etc

A Closing Thought



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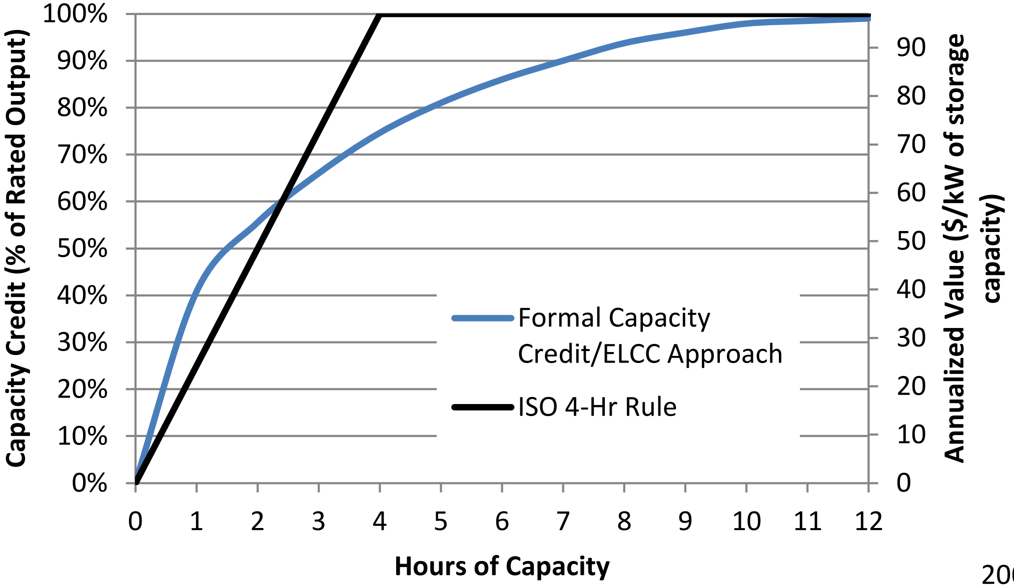
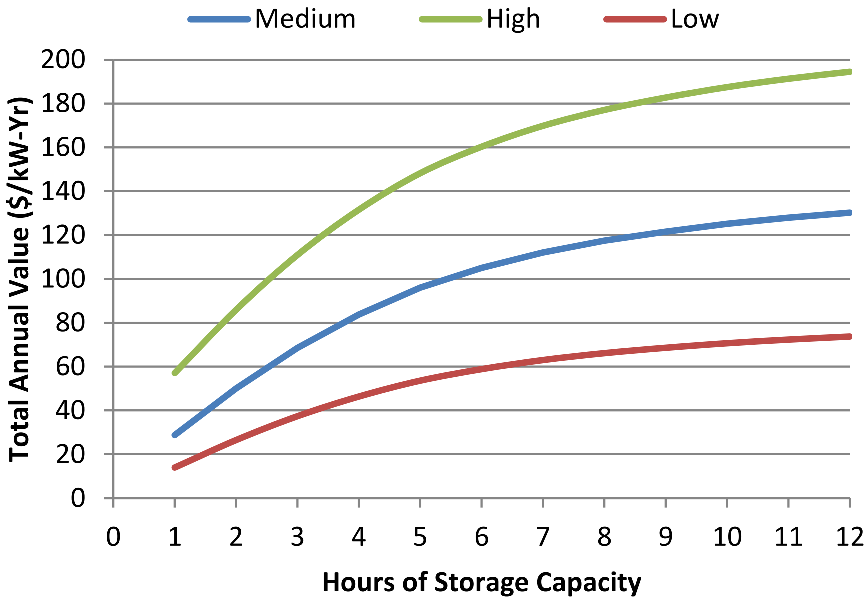
What does this mean for value of storage as a function of duration?



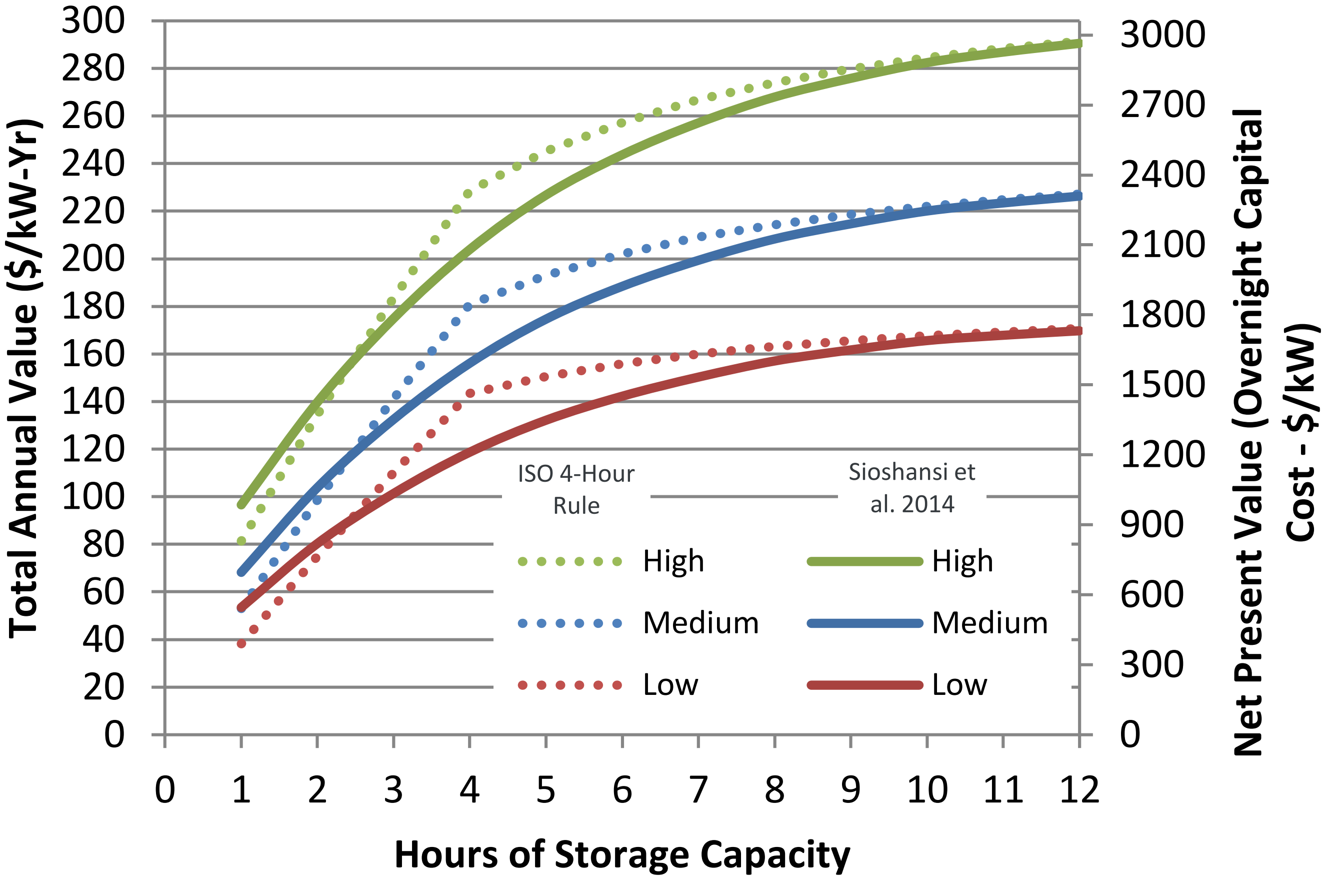
Capacity Value



Energy Value

Name	VG Pen	Wind/Solar Ratio	NG Price ($/MMBTU)	CO2 Cost ($/ton)
Low Value	35%	2.2:1	4	0
Medium	45%	4:1	5	22
High Value	55%	1:1	6	40

Total Value



Energy value of energy storage under different cases