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Storage and Flexibility Options for Renewables-Driven Grid Applications

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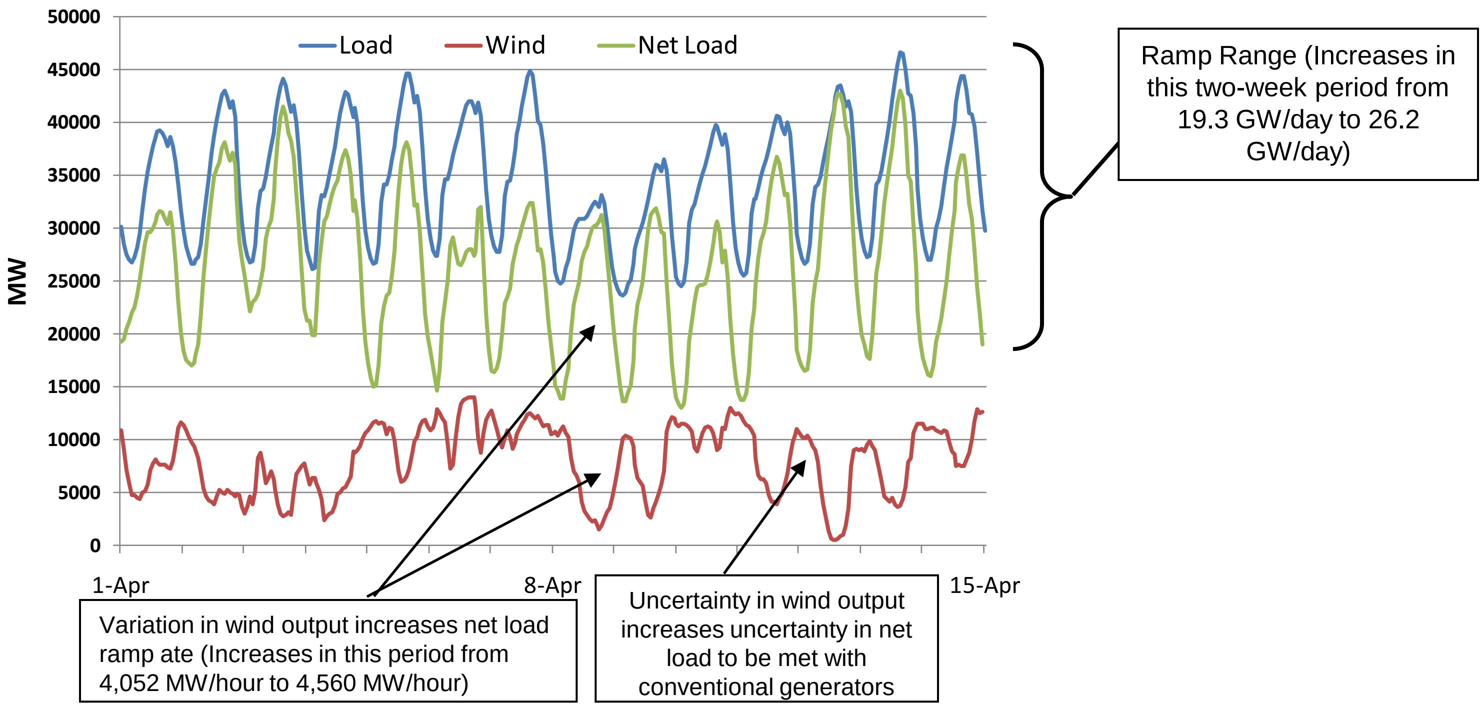
Outline

- Impacts of Renewables on the Grid – Is Storage "Needed"?
- Additional Value Created by Deployment of Renewables
- Flexibility Options – Don't forget the competition!
- Conclusions

Impacts of Renewables on the Grid

- Storage is often perceived as “necessary” for renewables to achieve a large (>10%? >20%?) penetration.
- Renewables are seen as a source of value for storage
- Can renewables be used without storage?
- How do renewables impact the grid?

Impacts of Renewables on the Grid

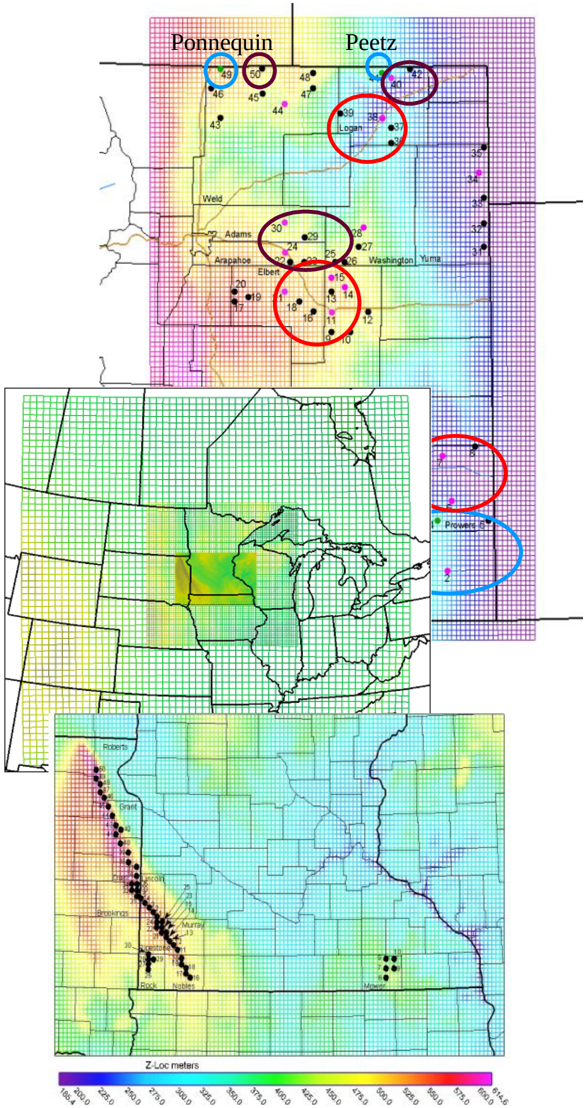


Four major impacts of variable generation (VG) on the grid:

1) Increased need for frequency regulation
2) Increase in hourly ramp rate
3) Increase in uncertainty of net load
4) Increase in ramp range

Is Storage Needed - Costs of Wind Integration

- Simulate system with and without solar and wind
  - Use unit commitment software includes existing generation mix, transmission system
  - Use lots of wind and solar simulations to consider spatial diversity
  - May involve substantial costs
- Evaluate costs of:
  - Additional regulation reserves
  - Additional load following
  - Wind uncertainty



Costs of Wind Integration

Date	Study	Wind Capacity Penetration (%)	Regulation Cost ($/MWh)	Load-Following Cost ($/MWh)	Unit Commitment Cost ($/MWh)	Other ($/MWh)	**Total Oper. Cost Impact ($/MWh)**
2003	Xcel-UWIG	3.5	0	0.41	1.44	Na	**1.85**
2003	WE Energies	29	1.02	0.15	1.75	Na	**2.92**
2004	Xcel-MNDOC	15	0.23	na	4.37	Na	**4.6**
2005	PacifiCorp-2004	11	0	1.48	3.16	Na	**4.64**
2006	Calif. (multi-year)[a]	4	0.45	trace	trace	Na	**0.45**
2006	Xcel-PSCo[b]	15	0.2	na	3.32	1.45	**4.97**
2006	MN-MISO[c]	36	na	na	na	na	**4.41**
2007	Puget Sound Energy	12	na	na	na	na	**6.94**
2007	Arizona Pub. Service	15	0.37	2.65	1.06	na	**4.08**
2007	Avista Utilities[d]	30	1.43	4.4	3	na	**8.84**
2007	Idaho Power	20	na	na	na	na	**7.92**
2007	PacifiCorp-2007	18	na	1.1	4	na	**5.1**
2008	Xcel-PSCo[e]	20	na	na	na	na	**8.56**

[a] Regulation costs represent 3-year average.

[b] The Xcel/PSCO study also examine the cost of gas supply scheduling. Wind increases the uncertainty of gas requirements and may increase costs of gas supply contracts.

[c] Highest over 3-year evaluation period. 30.7% capacity penetration corresponding to 25% energy penetration

[d] Unit commitment includes cost of wind forecast error.

[e] This integration cost reflects a $10/MMBtu natural gas scenario. This cost is much higher than the integration cost calculated for Xcel-PSCo in 2006, in large measure due to the higher natural gas price: had the gas price from the 2006 study been used in the 2008 study, the integration cost would drop from $8.56/MWh to $5.13/MWh.

Conclusions of Wind Integration Studies

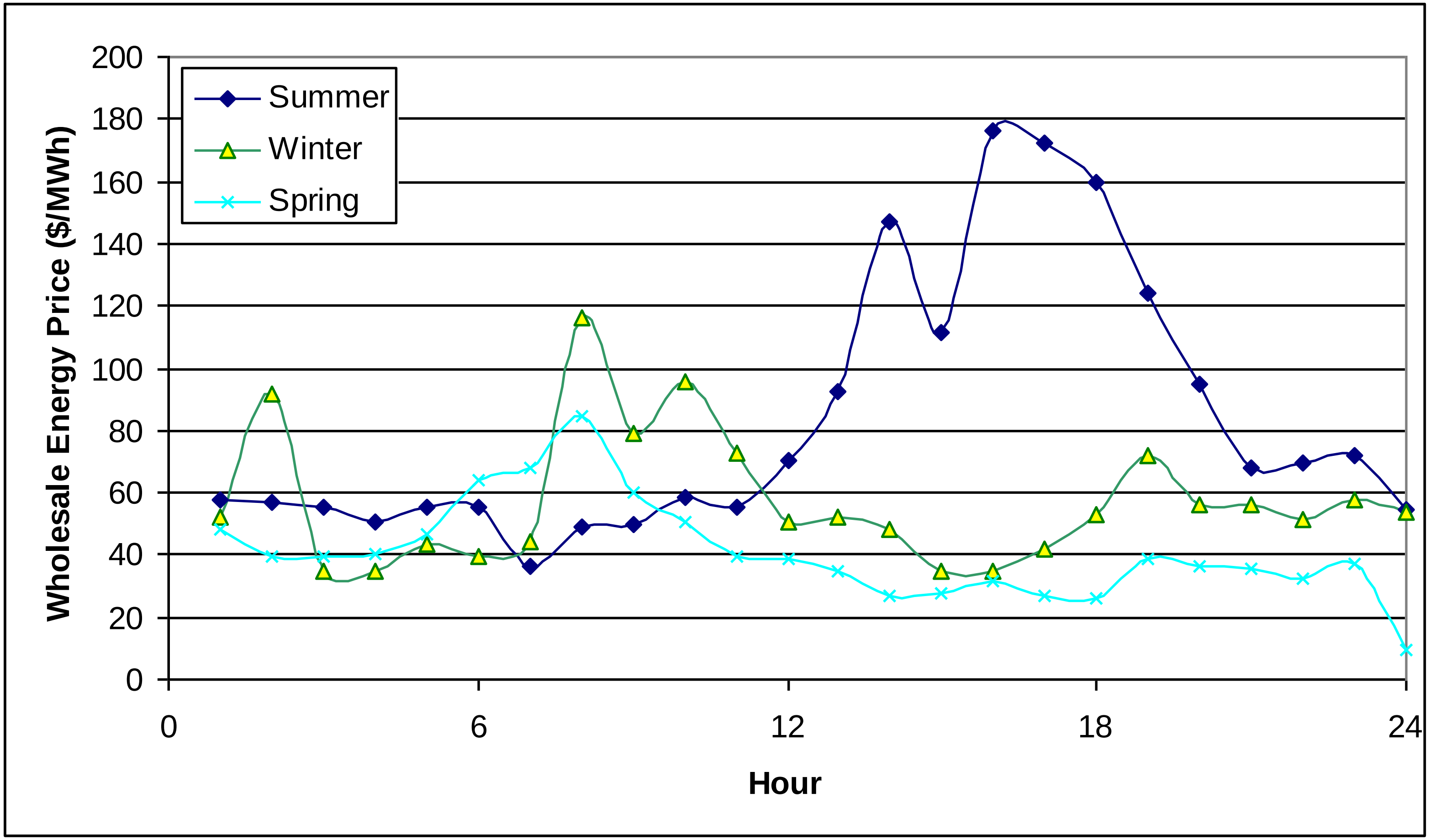
(<30% Penetration)

- Storage is not "needed" to successfully integrate VG at studied penetration levels
- Increased variability can be accommodates by existing grid flexibility
  - Flexibility of existing generator mix
  - Existing storage
  - Increased balancing area cooperation (balancing wind generation and load over larger areas to "share" the increased variability.
  - Spatial diversity smooth's aggregated wind output reducing short-term fluctuations to hour time scale

So What are the Opportunities?

- Renewables increase the already existing value (and size) of markets for storage
  - Arbitrage/load leveling/unit cycling
  - Operating Reserves
  - Transmission Alternatives
- How do storage economics compete with the alternatives?

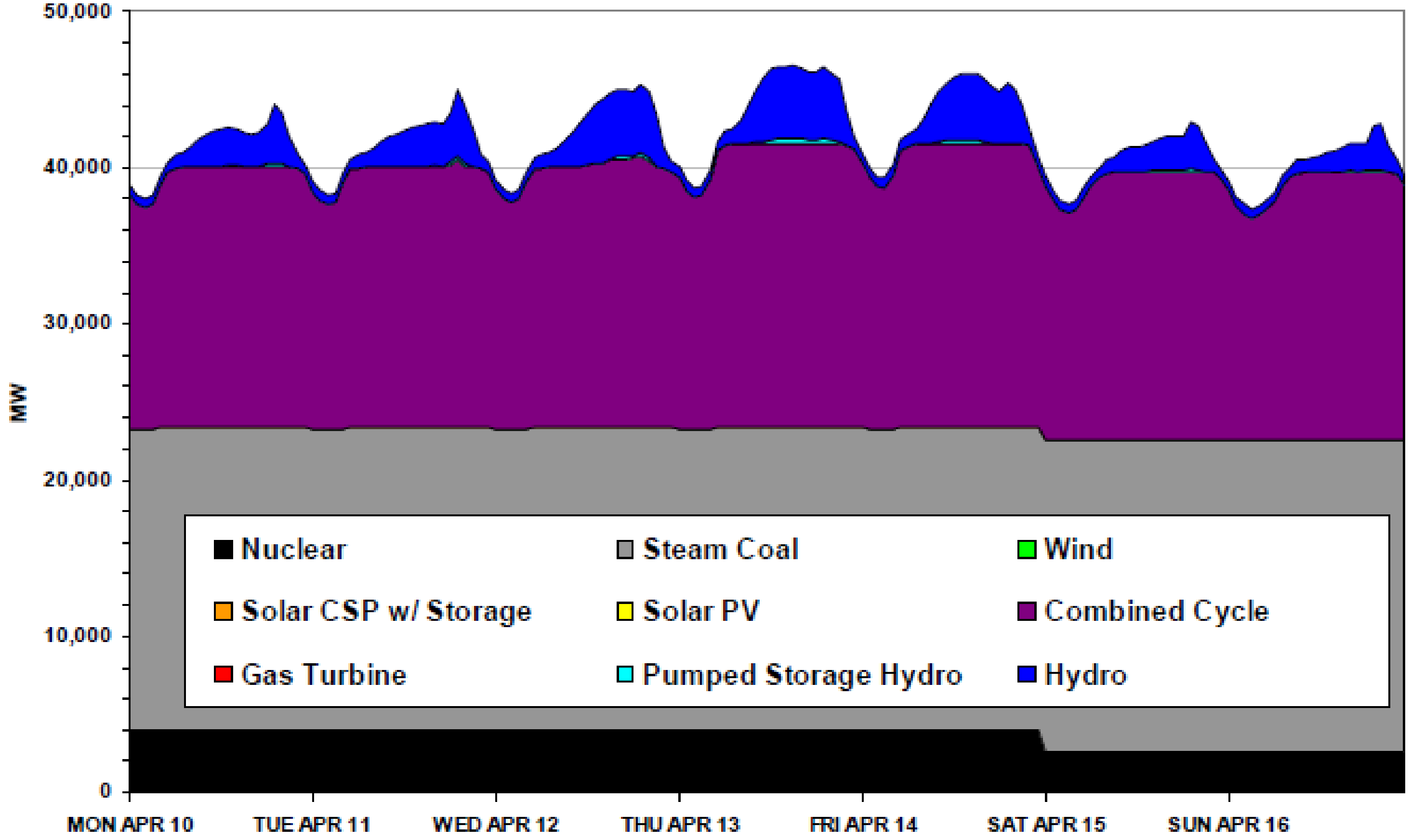
Load Leveling & Arbitrage



Increased Opportunities from VG?

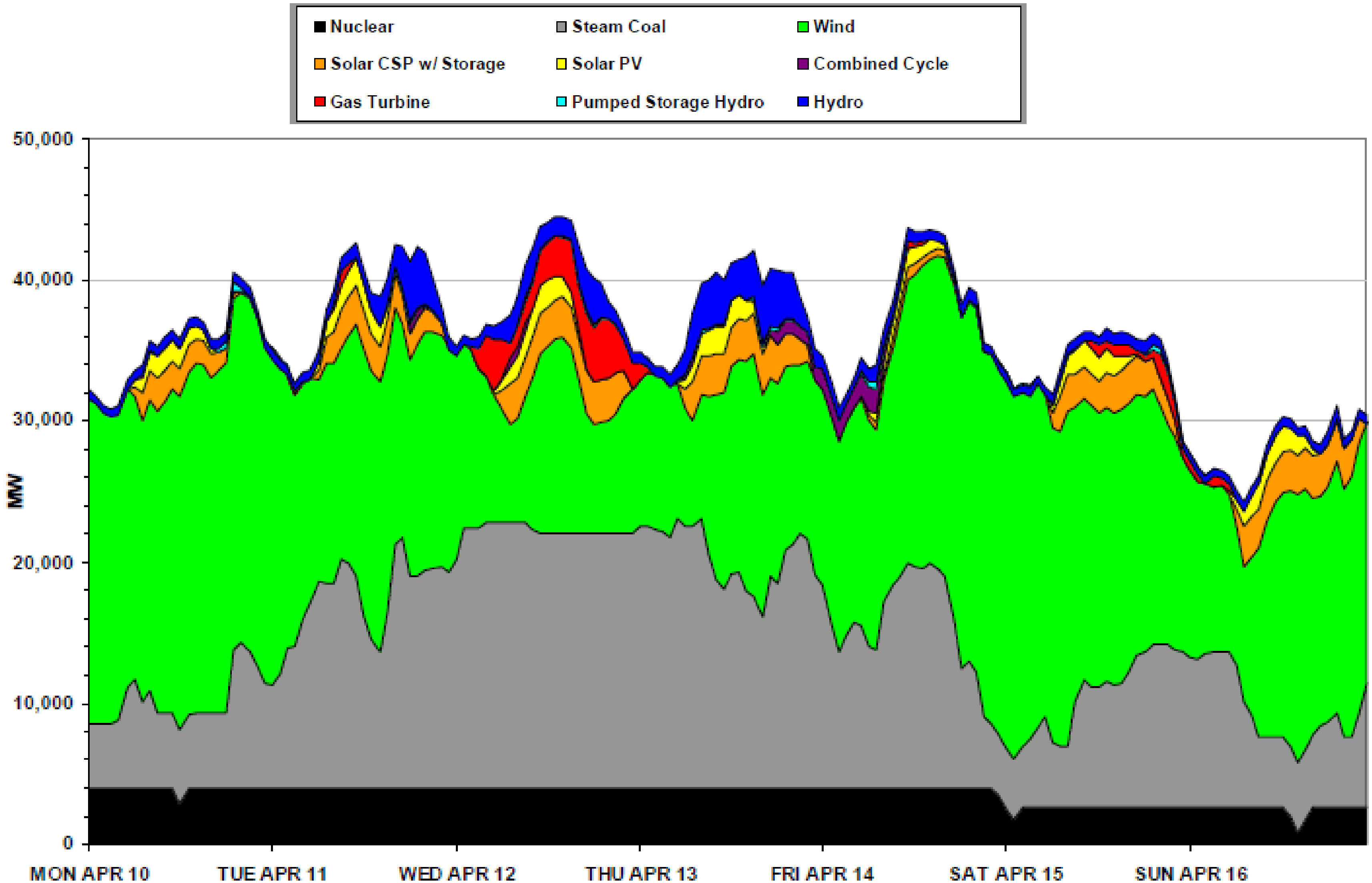
- Increased VG increases on-peak/off-peak spread and may increase opportunities for arbitrage
  - Limited coincidence of VG supply and normal demand
  - Minimum load constraints on thermal generators
  - Thermal generators kept online for operating reserves
  - Depends on many factors including transmission availability (more on this later…)

Minimal On/Off-Peak Spreads in Spring



WECC Dispatch – No new renewables

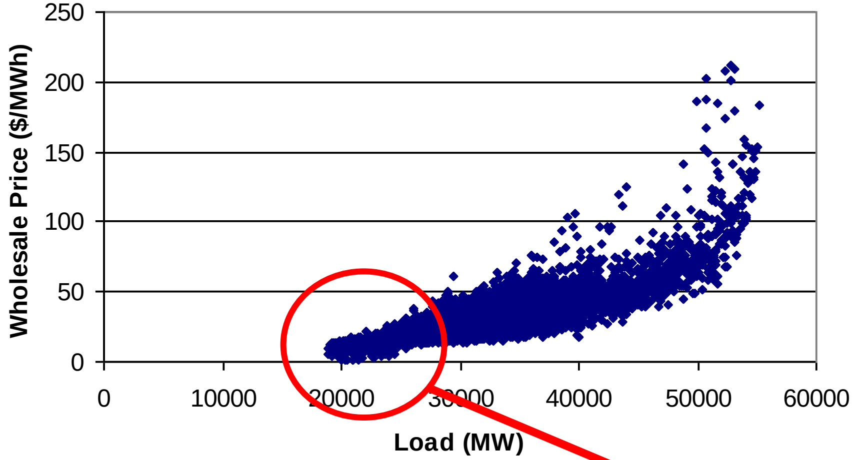
Wind Increases On/Off Peak Spreads



WECC Dispatch – 30% Wind

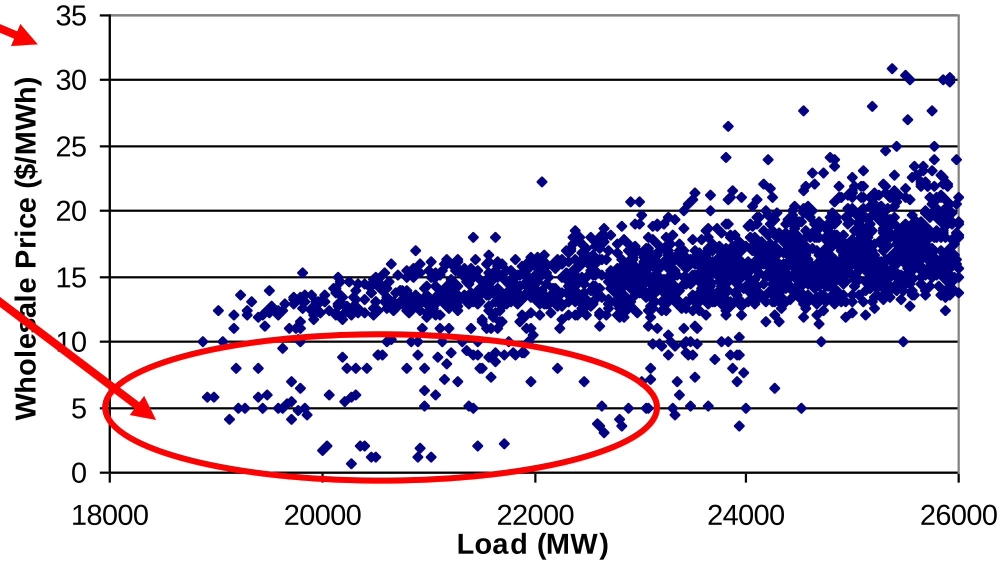
Current System Flexibility

Limited by Baseload Capacity



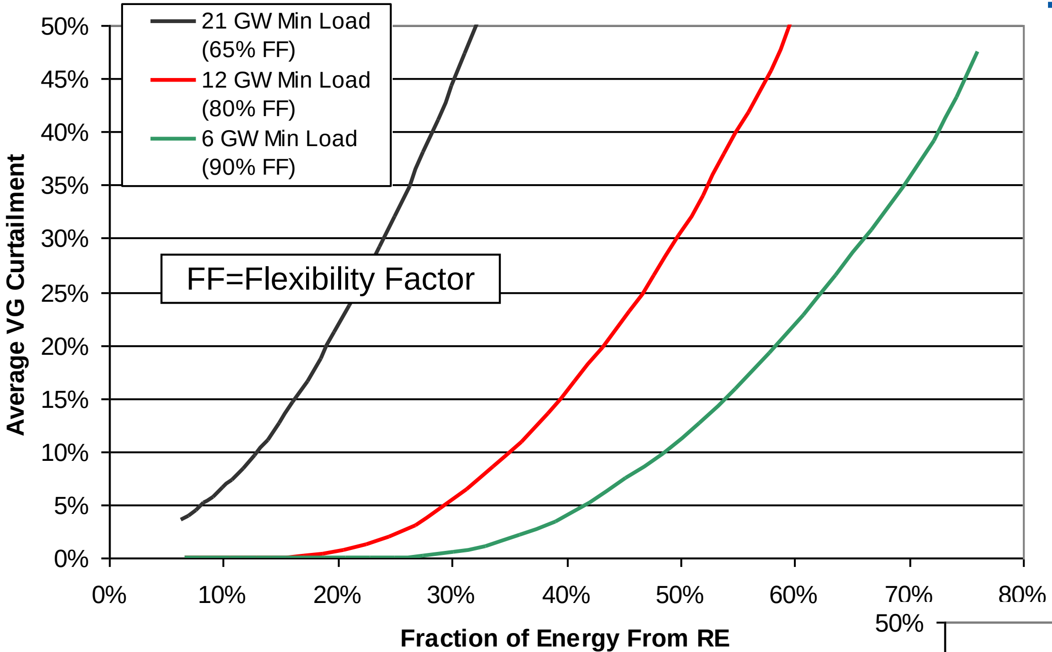
Price/Load Relationship in PJM

Below Cost Bids

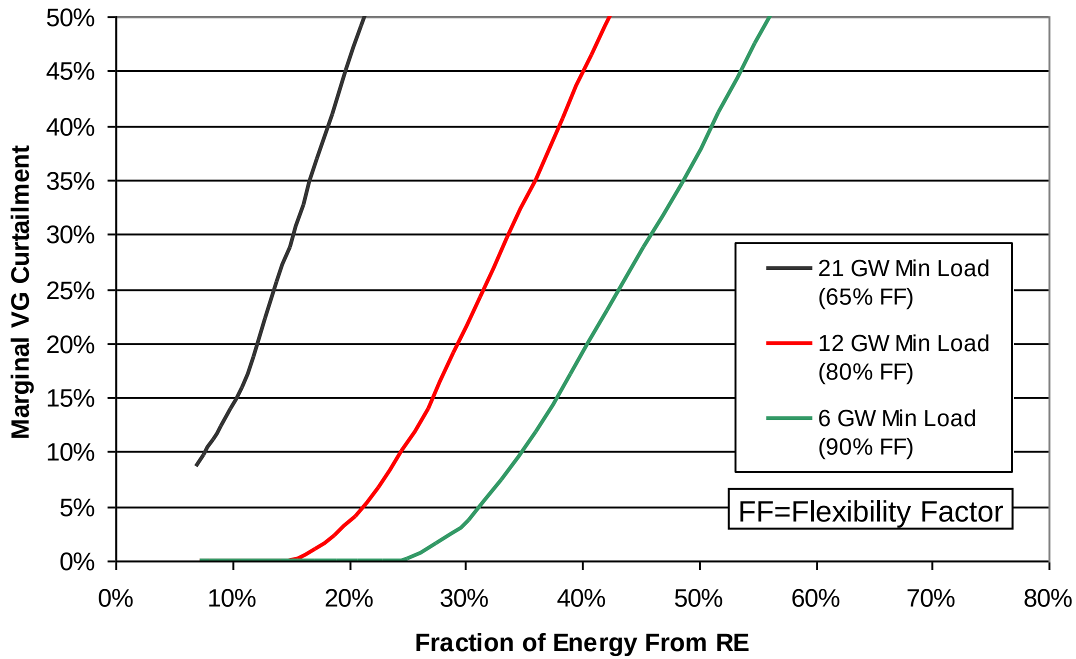


Plant operators would rather sell energy at a loss than incur a costly shutdown. Wind may be curtailed under these conditions

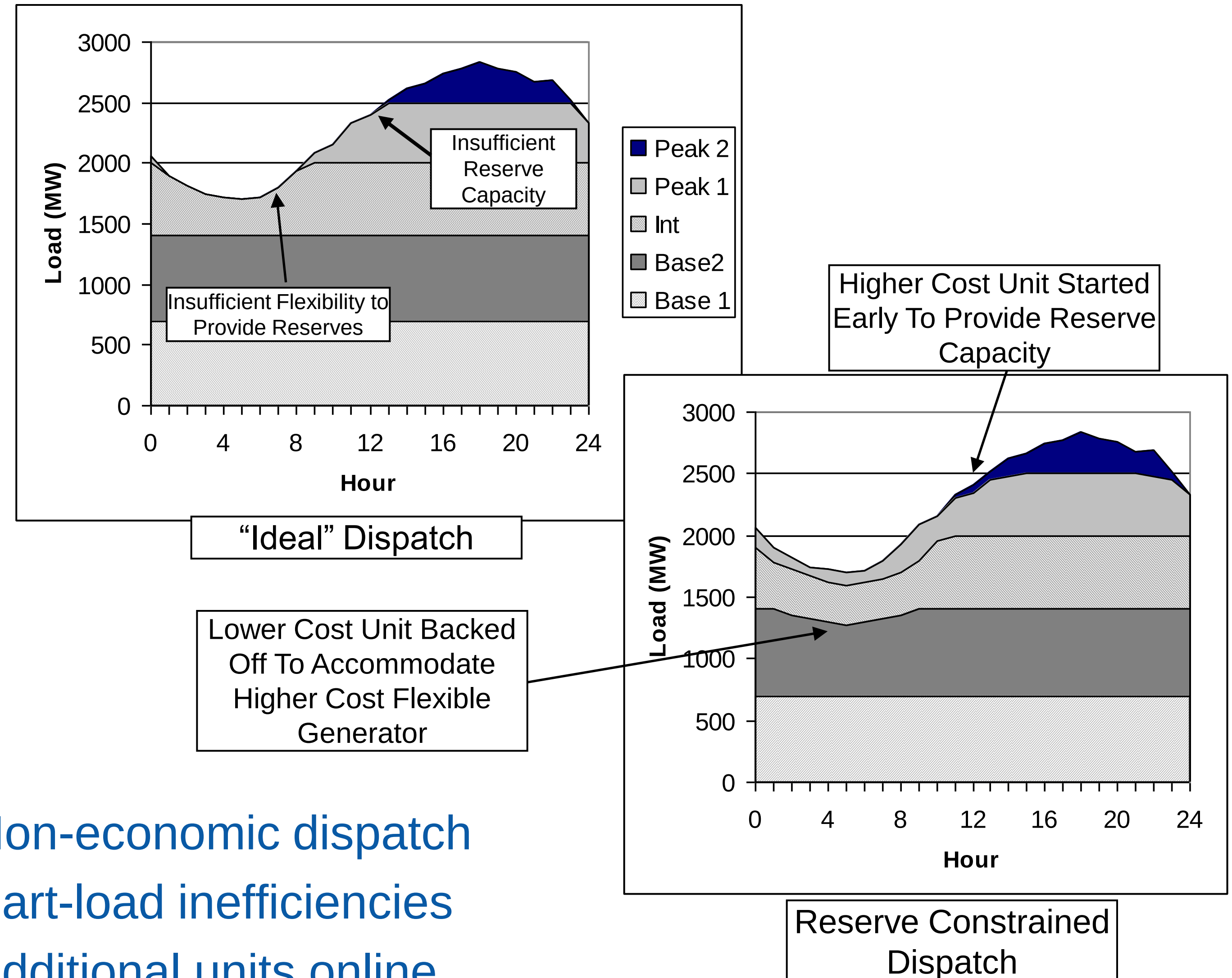
VG Curtailment/Zero to Negative LMPS



Fraction of wind generation occuring at zero LMP – average (top chart) and marginal (bottom chart) – as a function of VG penetration for different system flexibilities in ERCOT



Operating Reserve Requirements

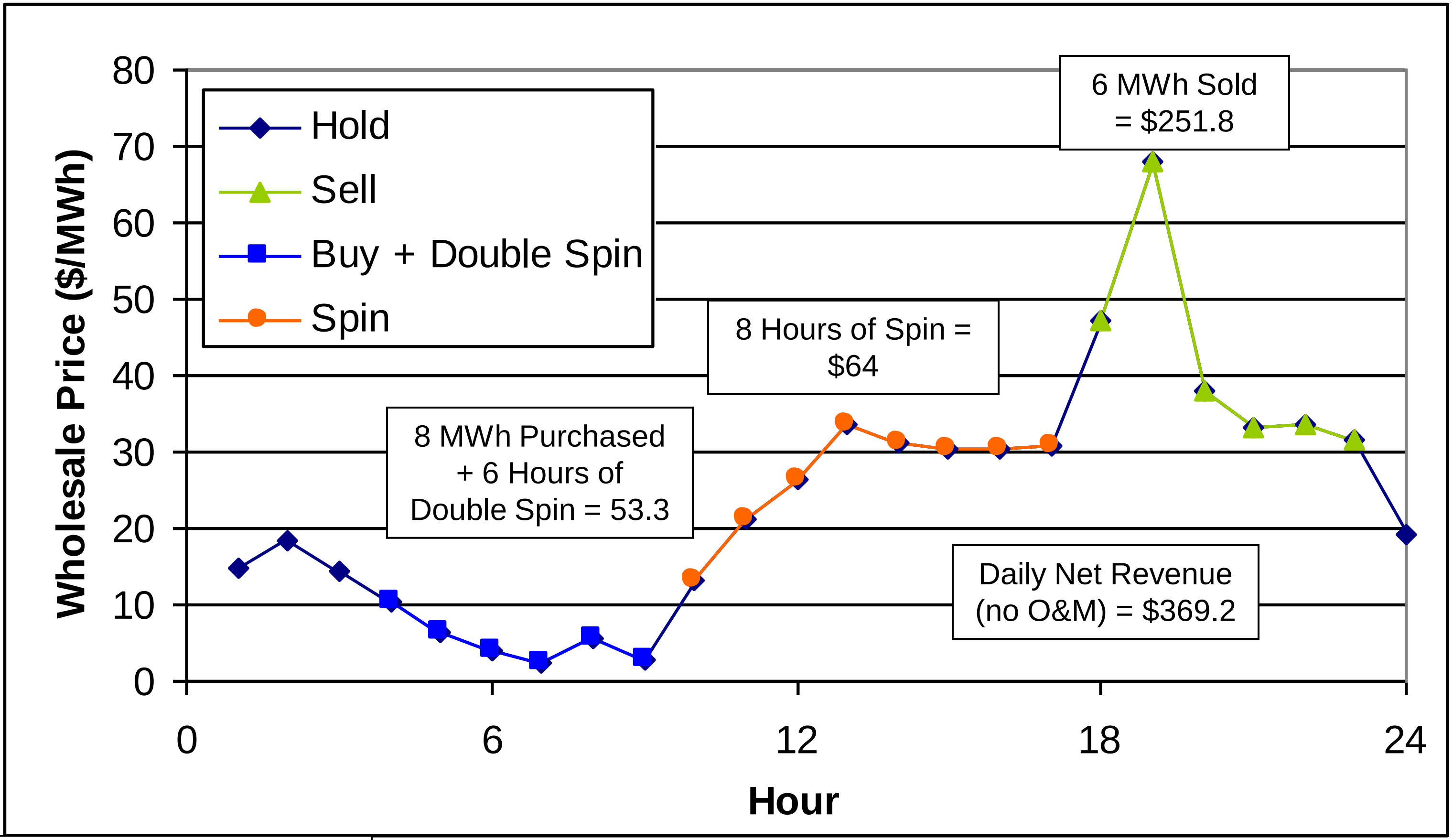


- Non-economic dispatch
- Part-load inefficiencies
- Additional units online

Operating Reserves

- Studies have found a modest increase in operating reserves due to RE deployment
- Western Wind and Solar Integration Study (30% wind) found contingency reserve shortfalls during 89 hours of the year
- These impacts add to opportunities for storage to sell both energy and ancillary services

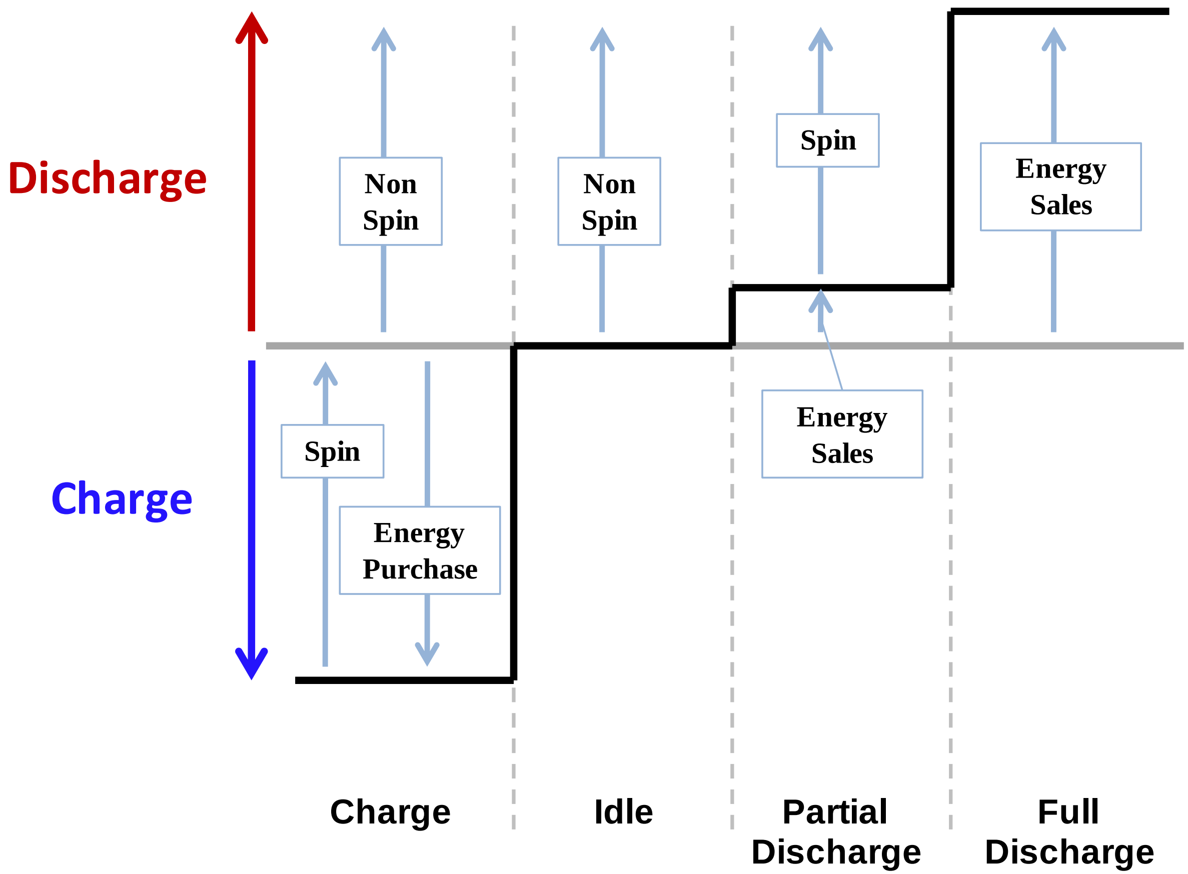
Co-Optimization Energy Storage Benefits



1 MW, 6 MWh Device, 75% efficiency

Revenues have increased 76% by combining services (battery-like device)

Co-Optimization of Energy and Ancillary Services



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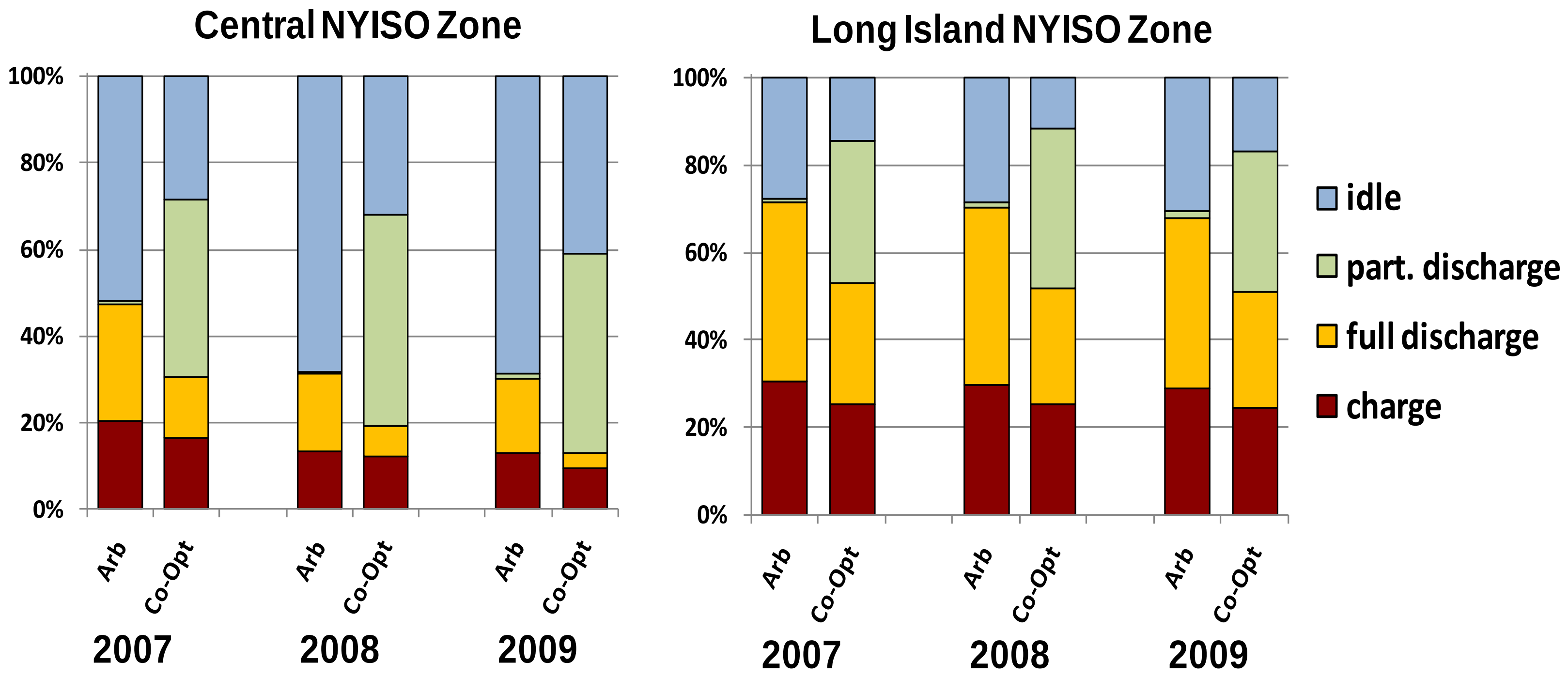
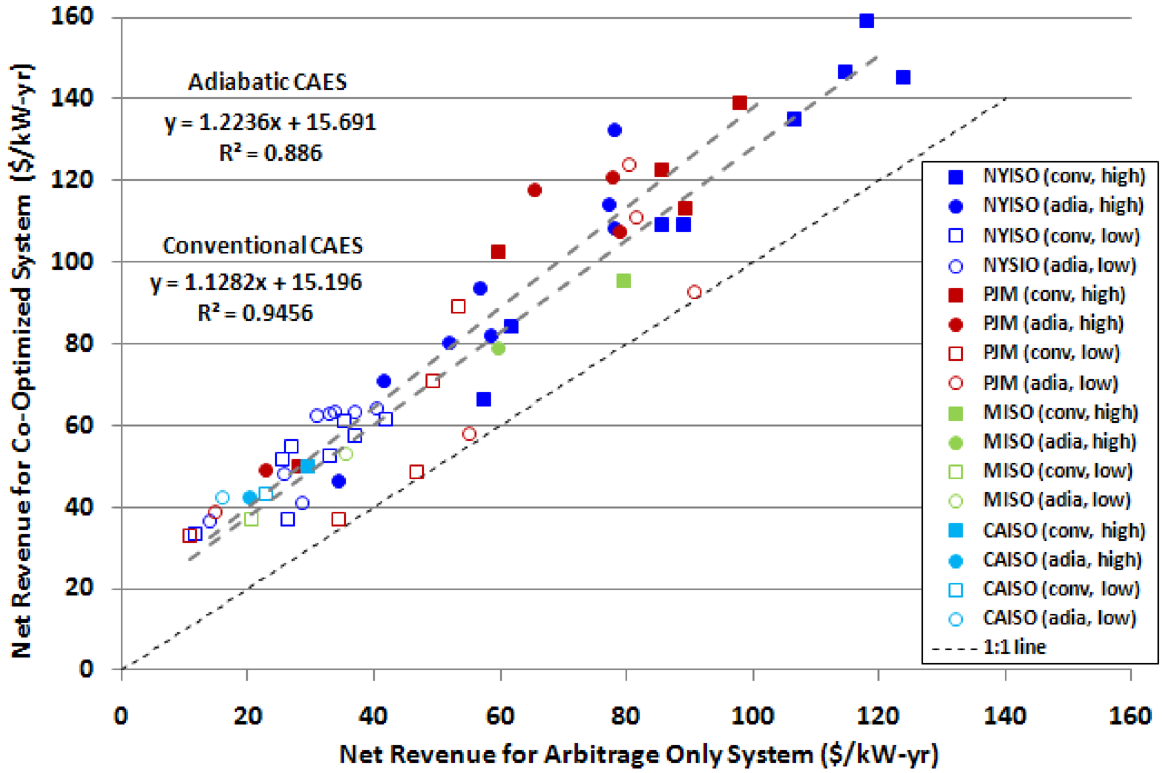
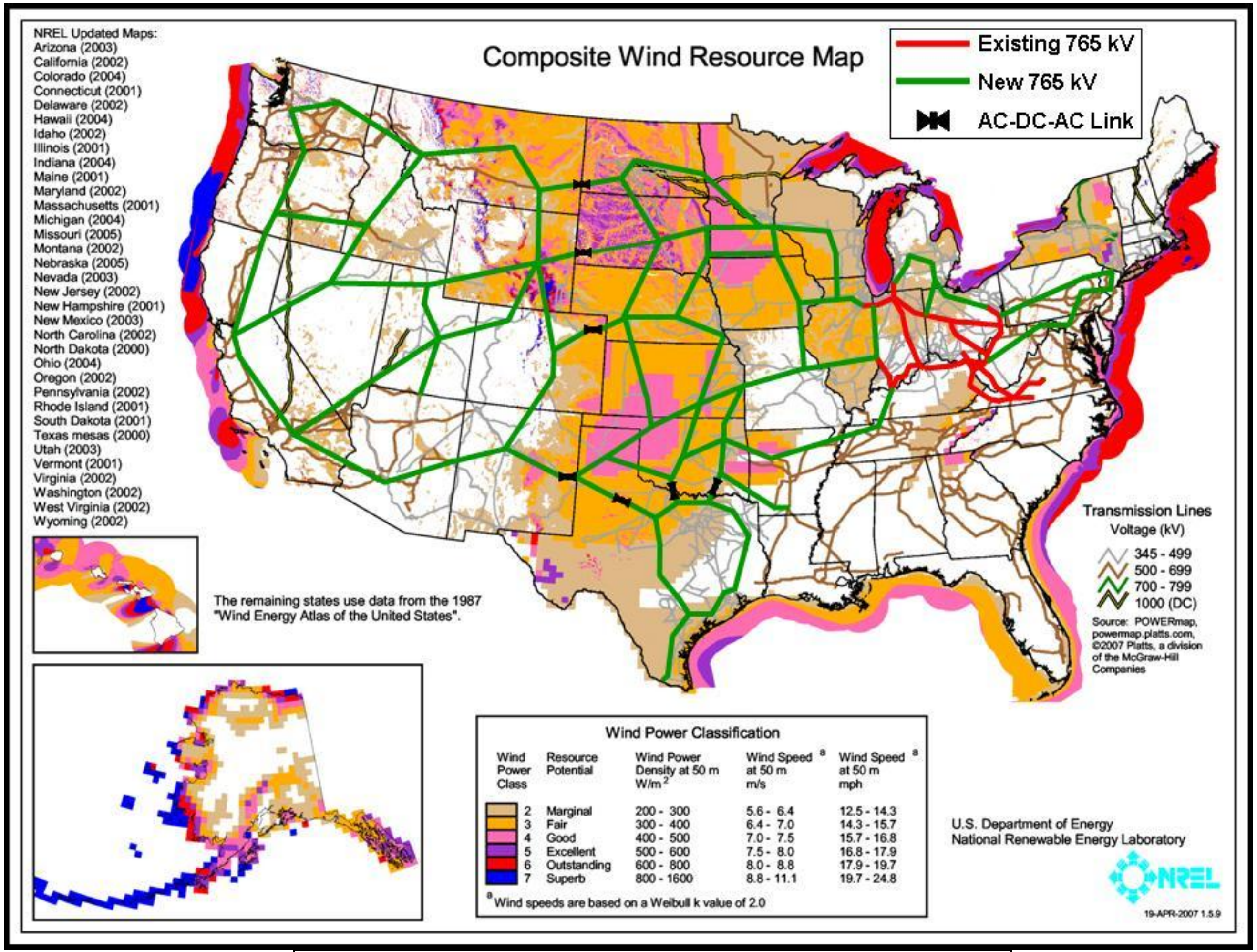


Co-Optimization of Energy and Ancillary Services



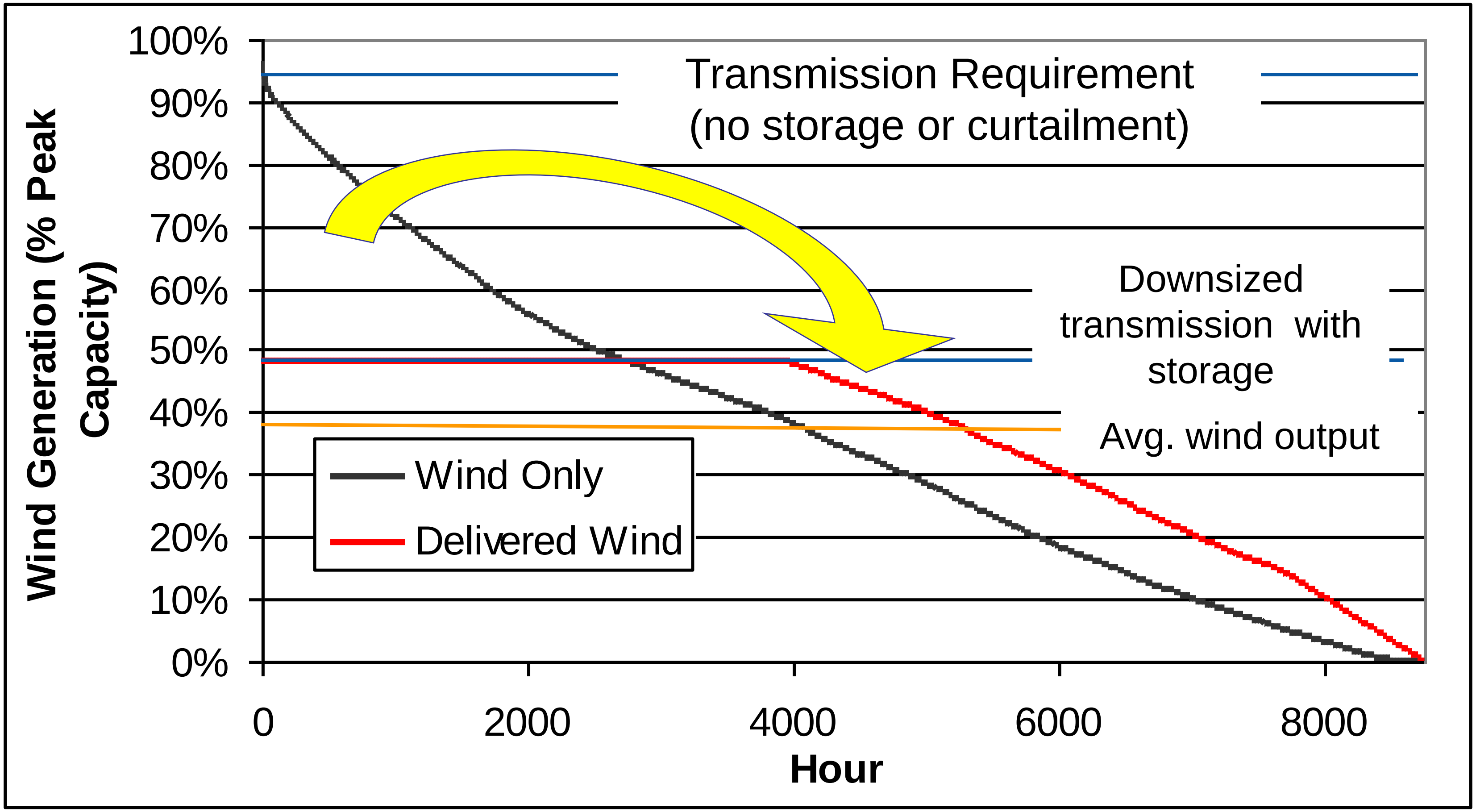
Operating reserves add ~$25/kw-year for a CAES device

Storage as a Transmission Deferral/Alternative

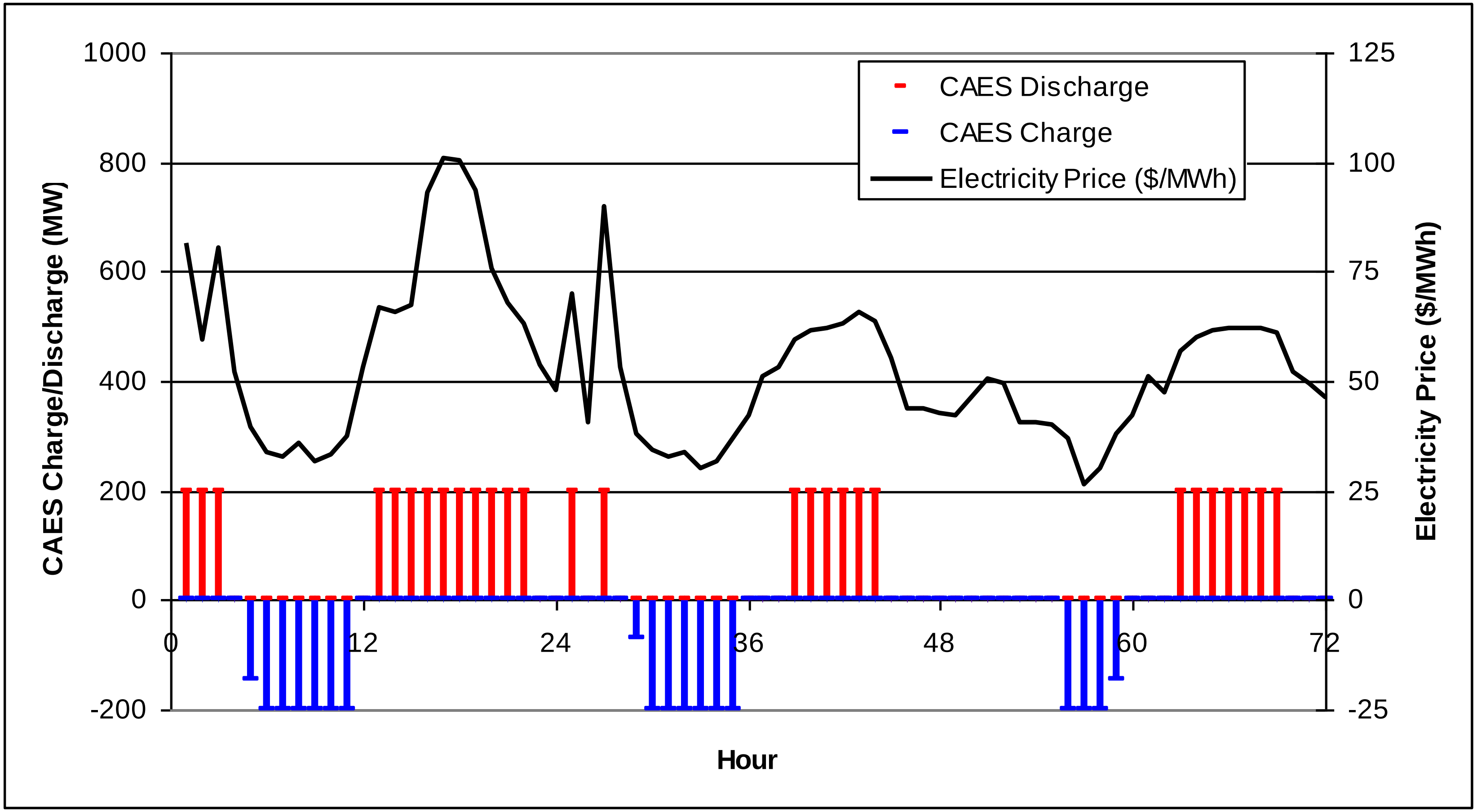


Source: AEP's Interstate Transmission Visions for Wind Integration

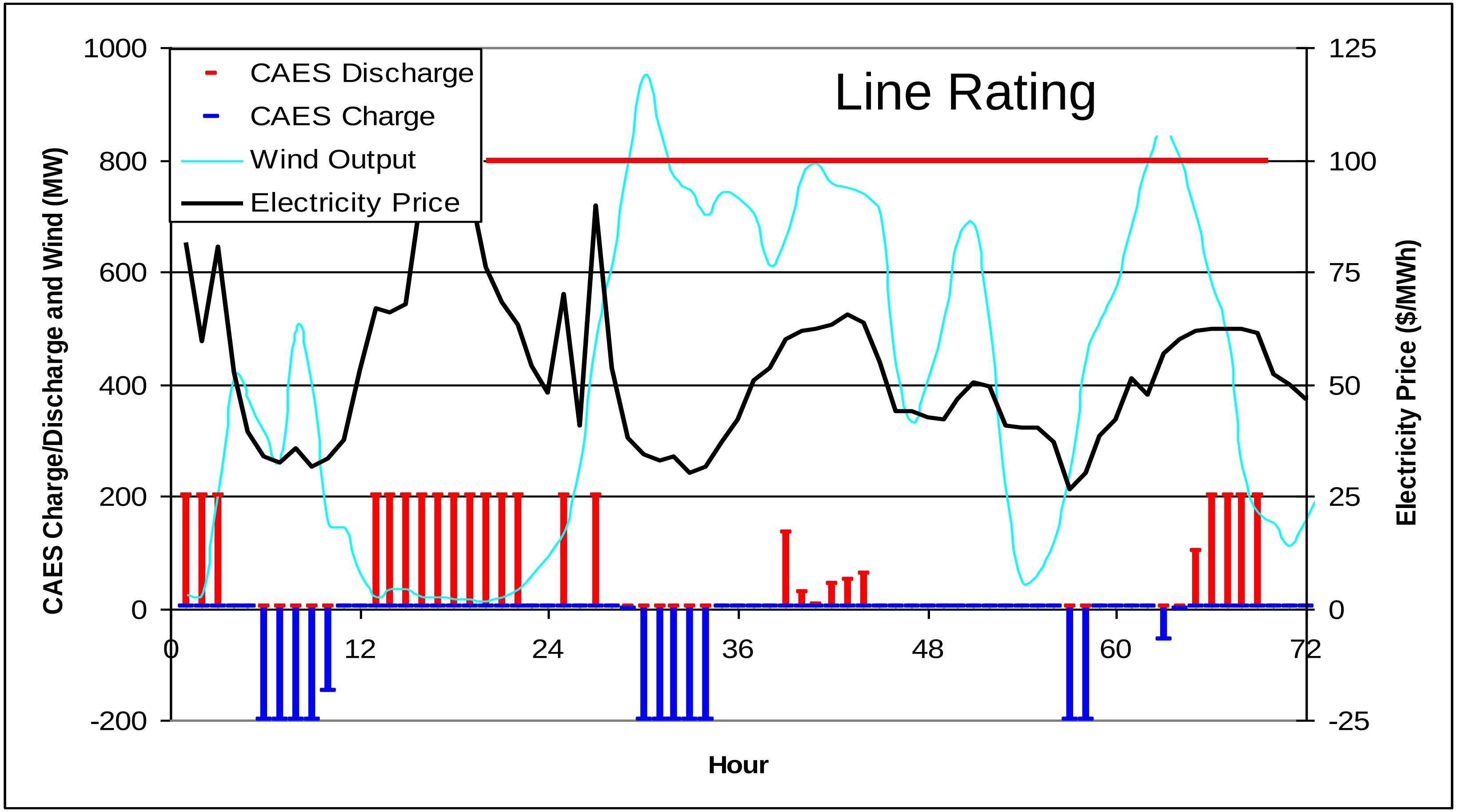
Storage As Transmission Alternative



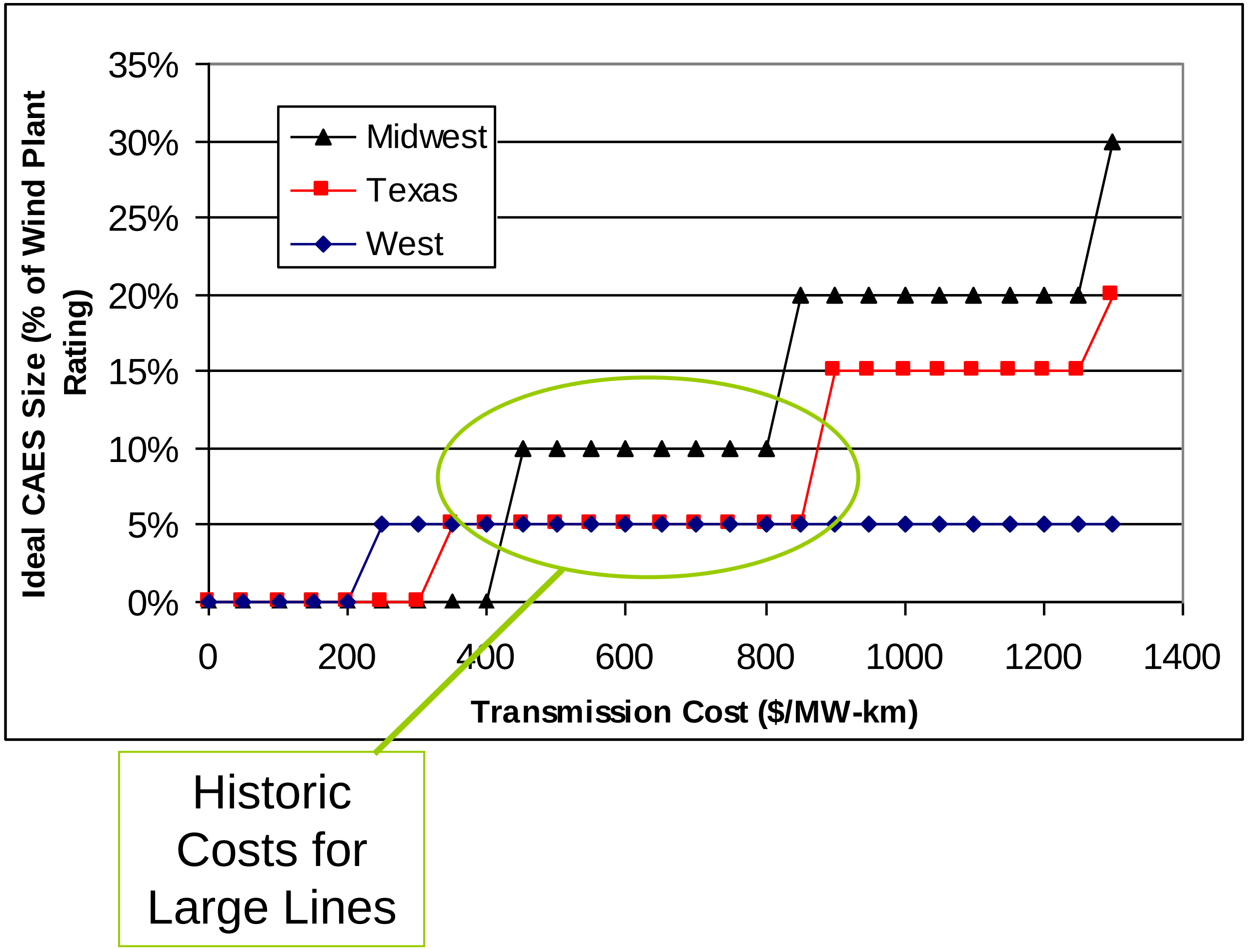
Independent CAES



Co-Located CAES

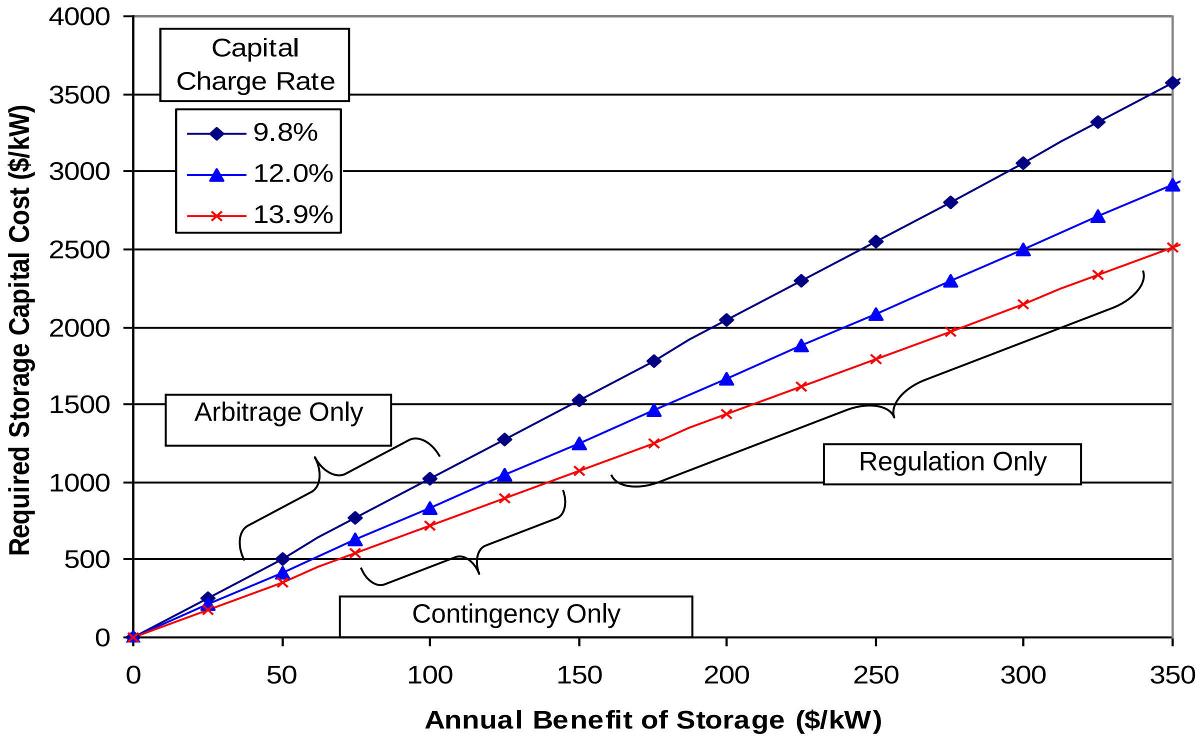


Optimum Mix of CAES and Wind



CAES can present a cost-effective alternative to transmission - *sometimes*

Value of Energy Storage in U.S. Markets

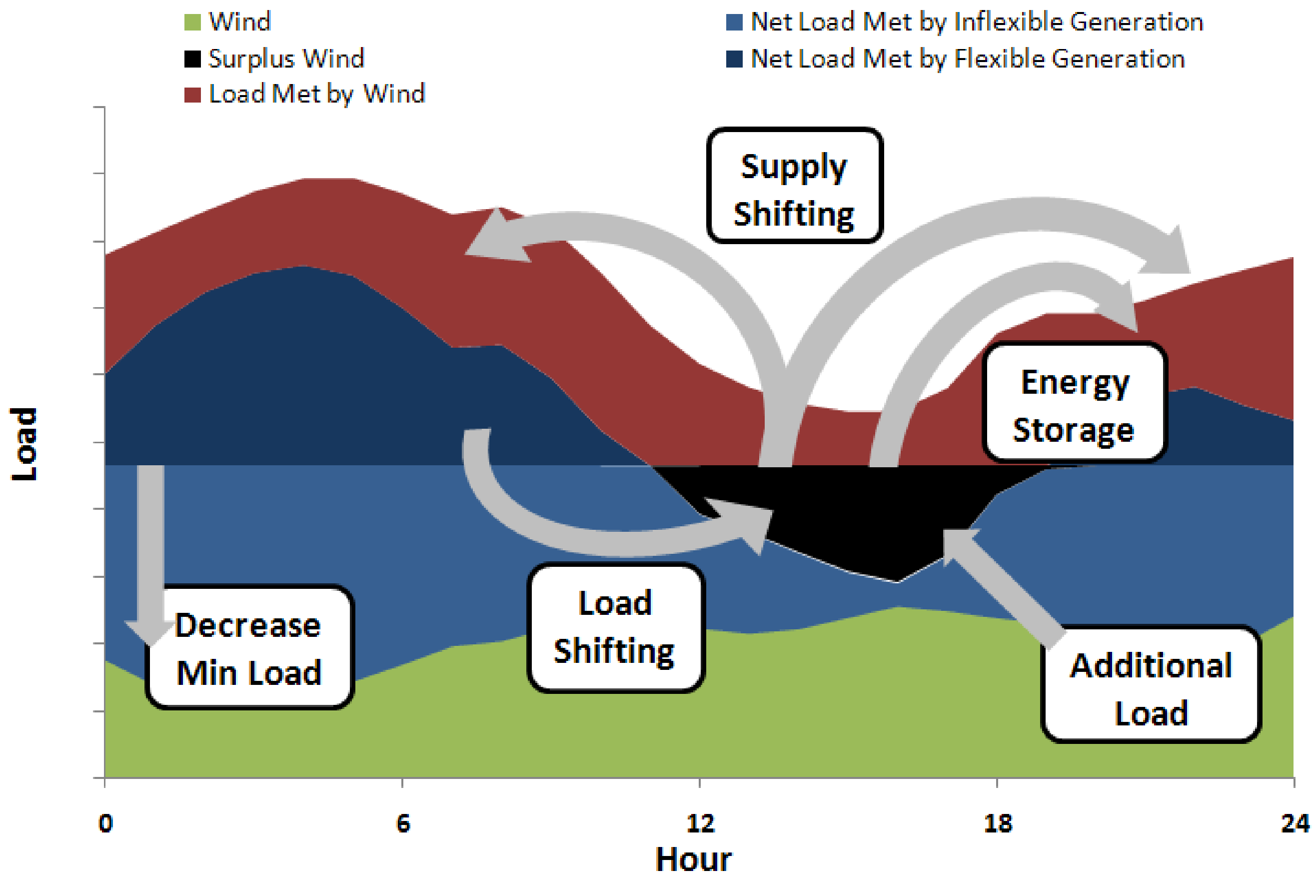


Arbitrage alone is generally insufficient to support most storage technologies, which are generally >$1,000/kW

Renewable deployment will increase opportunities for economic storage deployment..and also the competition

The Competition..

While storage provides an "obvious" answer to the problem of supply-demand coincidence, there are a number of options



The Competition..

- Demand response is a largely untapped market in most of the U.S.
- ERCOT already gets 50% of its spinning reserves from its “Load Acting as a Resource” program
- Lots of people want to get a piece of the high value but relative small frequency regulation market

Conclusions

- The role of storage is an economic issue – does the capturable benefits of storage exceed its costs?
- Storage is undervalued in existing markets and it is still difficult to assess the true value and opportunities for energy storage in the current and future grid
- Renewables may not “need” storage, but they can increase opportunities for storage (but also the competition)

- And to emphasize….

Proper Valuation of Energy Storage

- Many studies start and stop with a basic arbitrage value using load lambdas or system-wide production cost
  - This will virtually guarantee that no storage technology in existence will be cost effective
- Capture multiple value streams
  - Capacity
  - Load leveling/arbitrage
  - Reducing cycling
  - Ancillary services
- Distribution storage benefits
  - Avoided infrastructure and losses
  - Local congestion

Dedicated Renewable Storage?

- Dedicated renewable storage is generally a non-optimal use
- Could have scenarios where one storage device is charging while another is discharging simultaneously in the same system
- "Renewable specific" applications are already typically captured in grid operations

RE Specific Application	"Whole Grid" Application
Transmission Curtailment	Transmission Deferral
Time Shifting	Load Leveling/Arbitrage
Forecast Hedging	Forecast Error
Frequency Support	Frequency Regulation
Fluctuation Suppression	Transient Stability

Questions?

Storage Caveats

- Efficiency
  - Not uniformly defined (should be AC-AC, but sometimes stated in terms of DC-DC, which doesn't capture conversion)
  - May not include parasitics
  - CAES (which uses natural gas) and thermal storage cannot be easily compared to pure electricity storage devices such as pumped hydro
- Cost
  - Many technologies have not been deployed as large scale, so costs are largely unknown
  - Commodity prices affect estimates from different years
  - Difficult to compare devices that offer different services (power vs. energy)