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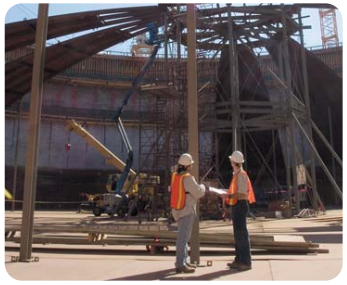



Valuation Drivers for Large Scale Energy Storage Projects: Creation and Destruction of Value

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U.S. Power Market Drivers Support Storage

- Renewable portfolio standards and pending greenhouse gas rules are driving increases in renewable resources.
  - Evolving carbon legislation will favor renewables, nuclear and natural gas to displace coal and less efficient gas.
- Wind and solar resources
  - **Long Term Issue:** Intermittent nature of renewable resources will require “firming” by storage or natural gas-fired generation.
  - **Short Term Issue:** Transmission integration of wind and solar resources requires assets to manage intermittency.
  - **Geographic Issue:** Generally located far from load centers.
    - Massive, long-lead time power transmission requirements are likely to constrain the planned increase in renewable resources.
- Storage is an ideal resource to integrate evolving power generation projects and shifts in generation portfolios.

Storage Advantages

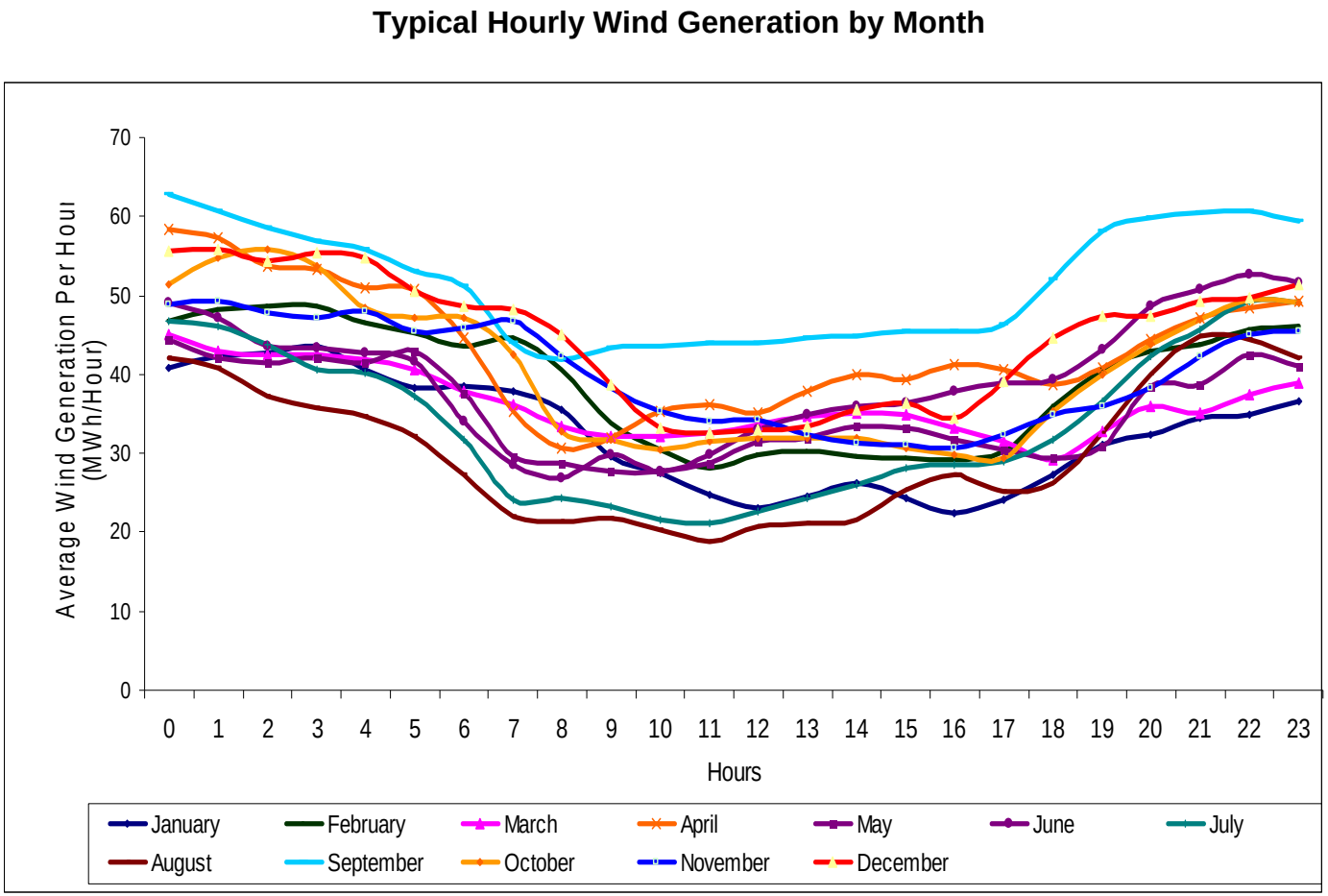
- Use of low cost and/or excess off-peak energy during storing (pumping or compression mode) which helps in optimizing the dispatch of other generating assets.
- Provides profit opportunity from on-peak vs. off-peak energy price arbitrage.
- Can be an effective tool for complementing intermittent renewable energy resources
  - Short term grid integration issues
  - “Firming” wind energy to provide dispatchability.
  - “Shaping” wind energy to reduce the need for new transmission
- Storage has the potential of mitigating all or some of the constraints facing HVDC transmission due to low minimum operating levels, rapid schedule changes and short circuit ratings, depending on the particular situation.

Value of Storage Derives From Multiple Attributes

- Energy Price Variation
  - Spread between on-peak and off-peak prices
  - Volatility of that spread
  - Seasonal price variation
- Capacity Value
- Dispatchable Demand Resource
- Ancillary Services
  - Regulation reserves (up and down)
  - Spinning reserves
  - VAR support, black start, etc.
- Renewable Energy Integration
  - Improved management of HVDC lines
  - Growing interest in using storage technologies to manage real-time integration issues

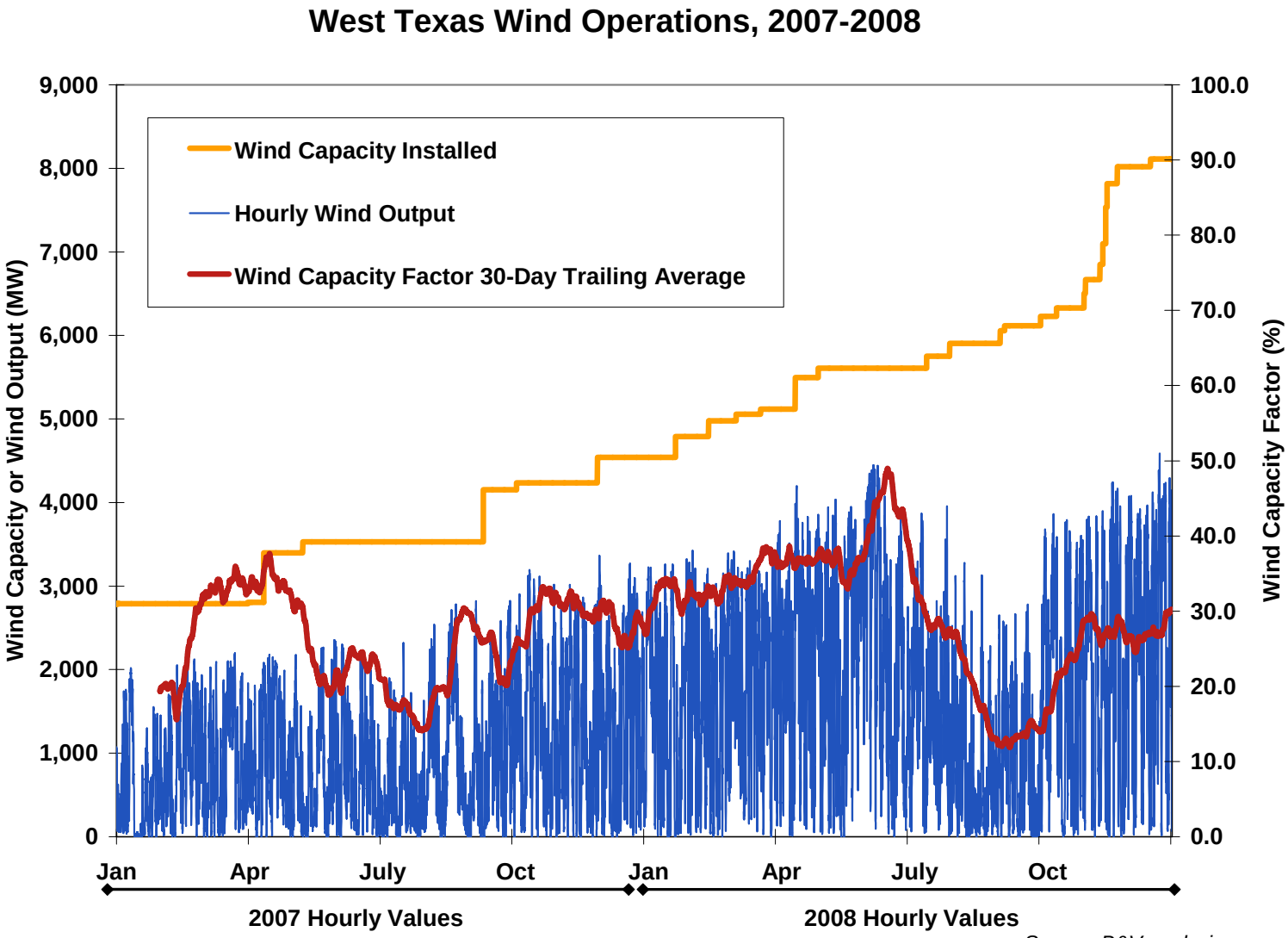
Advantages of Storage: Complements Wind Energy

- Wind is typically counter cyclic to electricity demand as wind generation tends to be higher in off-peak hours.
- Storage can "time shift" the off-peak energy into on-peak energy, which lowers system costs and improves efficiency.



Ramifications of Increased Wind Resource Buildout

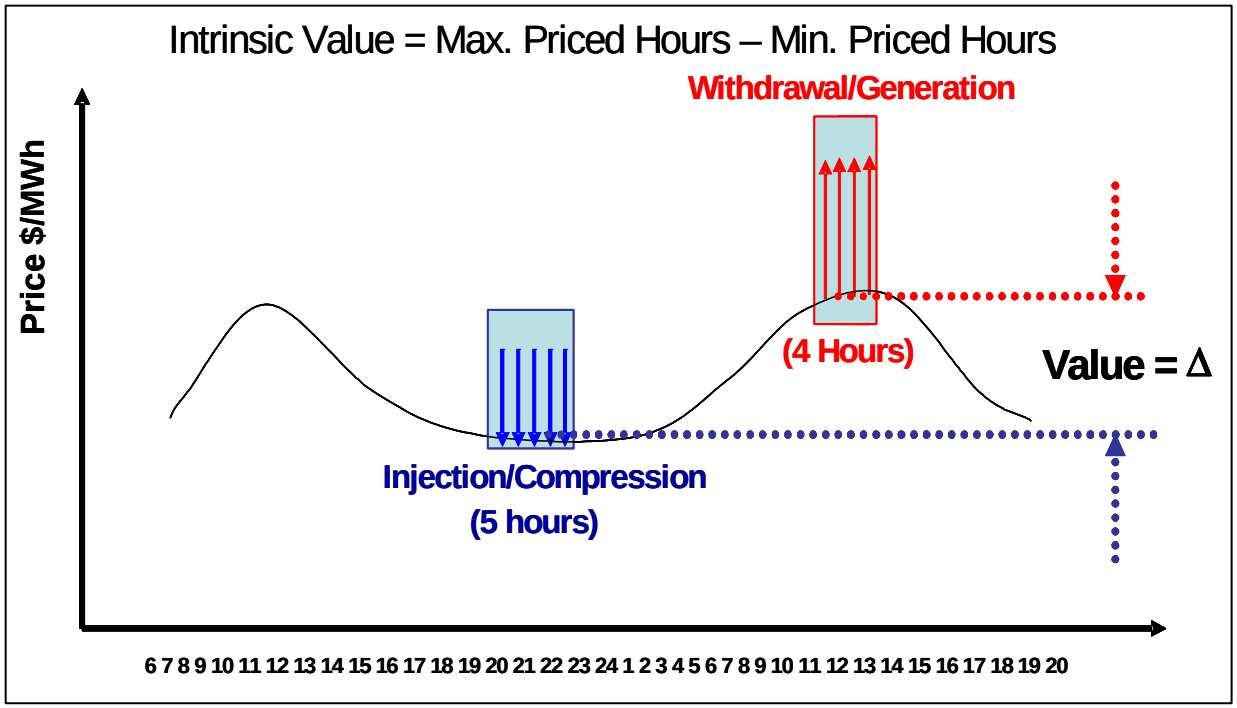
- Wind resources output and revenues can be crushed by transmission.
- Can be solved with new transmission lines or storage, or both.



Source: B&V analysis of ERCOT data

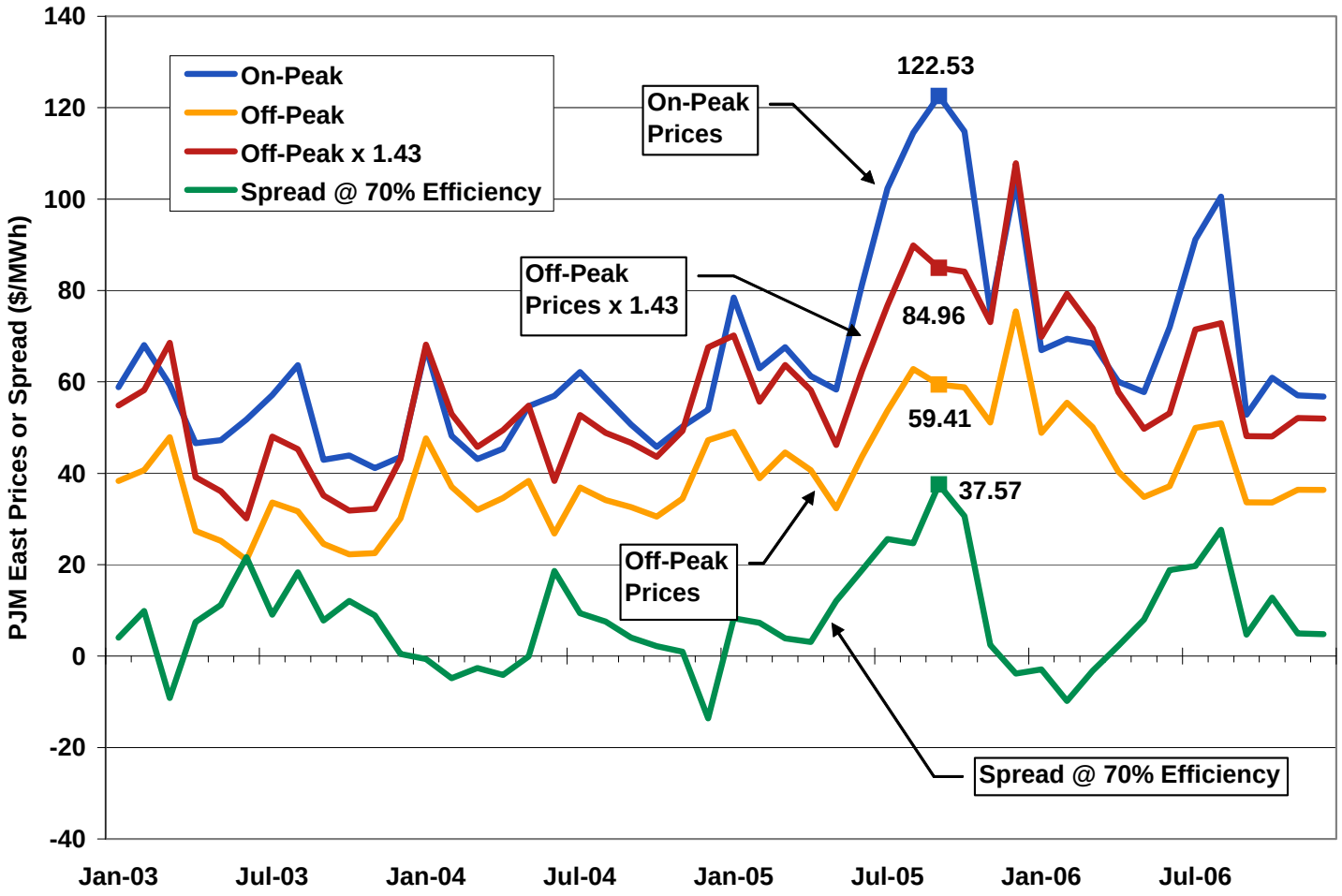
Value From Energy Revenue

- Energy value created when spread exceeds round trip efficiency
  - Storing during off-peak periods and generating during on-peak periods
    - PS "Round trip" efficiency typically around 70%
    - 1 MWh off-peak = 0.70 MWh on-peak, or 1.43 MWh off-peak = 1 MWh on-Peak
- Value can vary seasonally
  - Spread likely to vary seasonally due to market conditions
  - PS needs to be concerned about seasonal reservoir in-flow, and reservoir levels may be managed for non-power reasons (e.g., irrigation, fish management).



Energy Revenue Spread

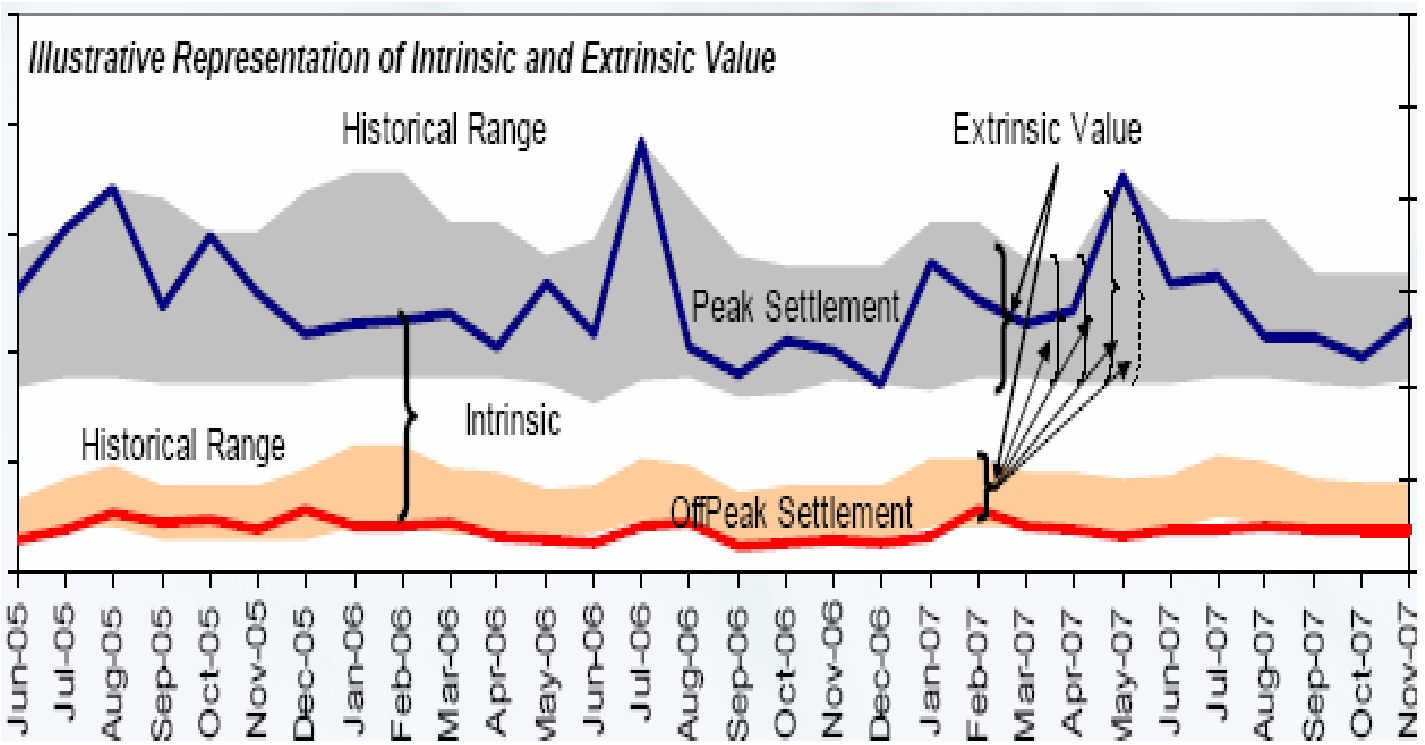
- Based on monthly averages this storage unit is often “in the money.”
- This alone is not likely to be enough margin to justify a new project.



A Complete Analysis Considers Extrinsic Value

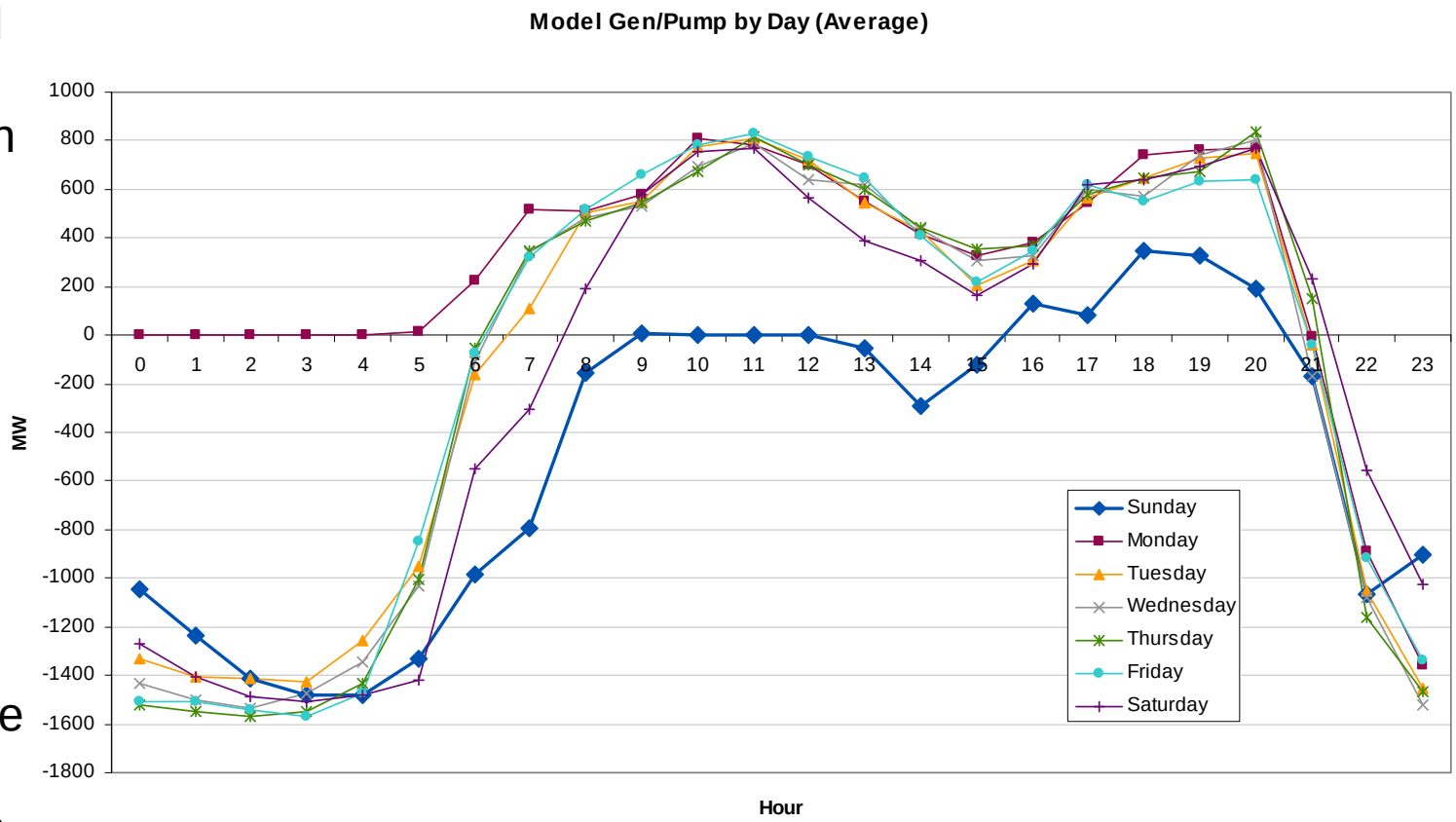
- Intrinsic value is the spread between the cost of power to store and the sale price of the generated power.
- Extrinsic value is derived from the volatility in both the spot and forward markets.

Importance of Extrinsic Analysis



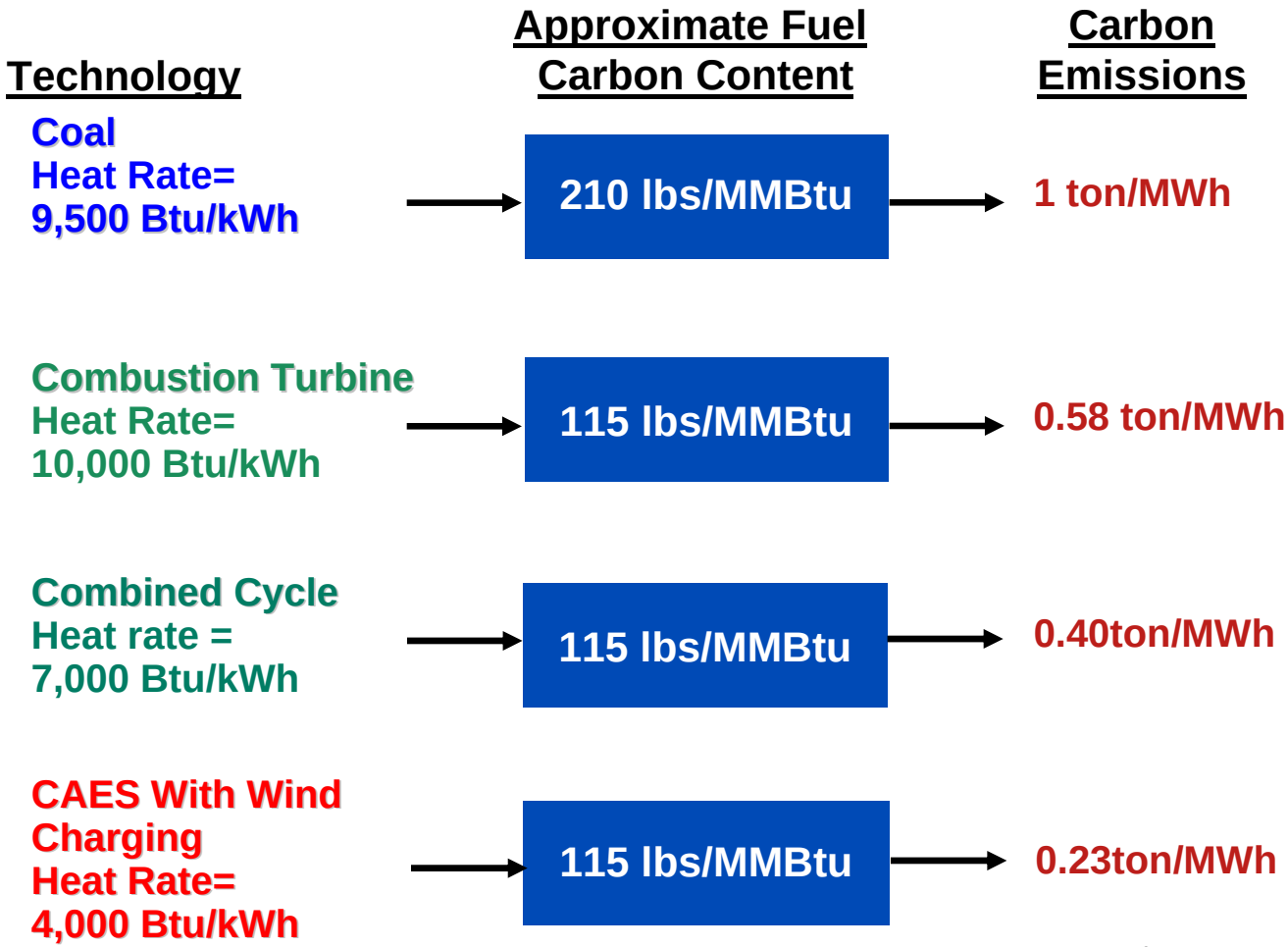
Daily Operations Are More Complicated

- Market depth, transmission limitations and native load obligations can all complicate operations.
- PS often focused on daily and weekly operations.
- For CAES, cavern size can change the time horizon from weekly to monthly or seasonal.



Advantage of Storage: Reduction in CO2 Emissions

- Storage charged with “grid energy” will increase carbon emissions
- CAES units can potentially reduce CO_2 emissions by 60 percent when compared to conventional CT units.

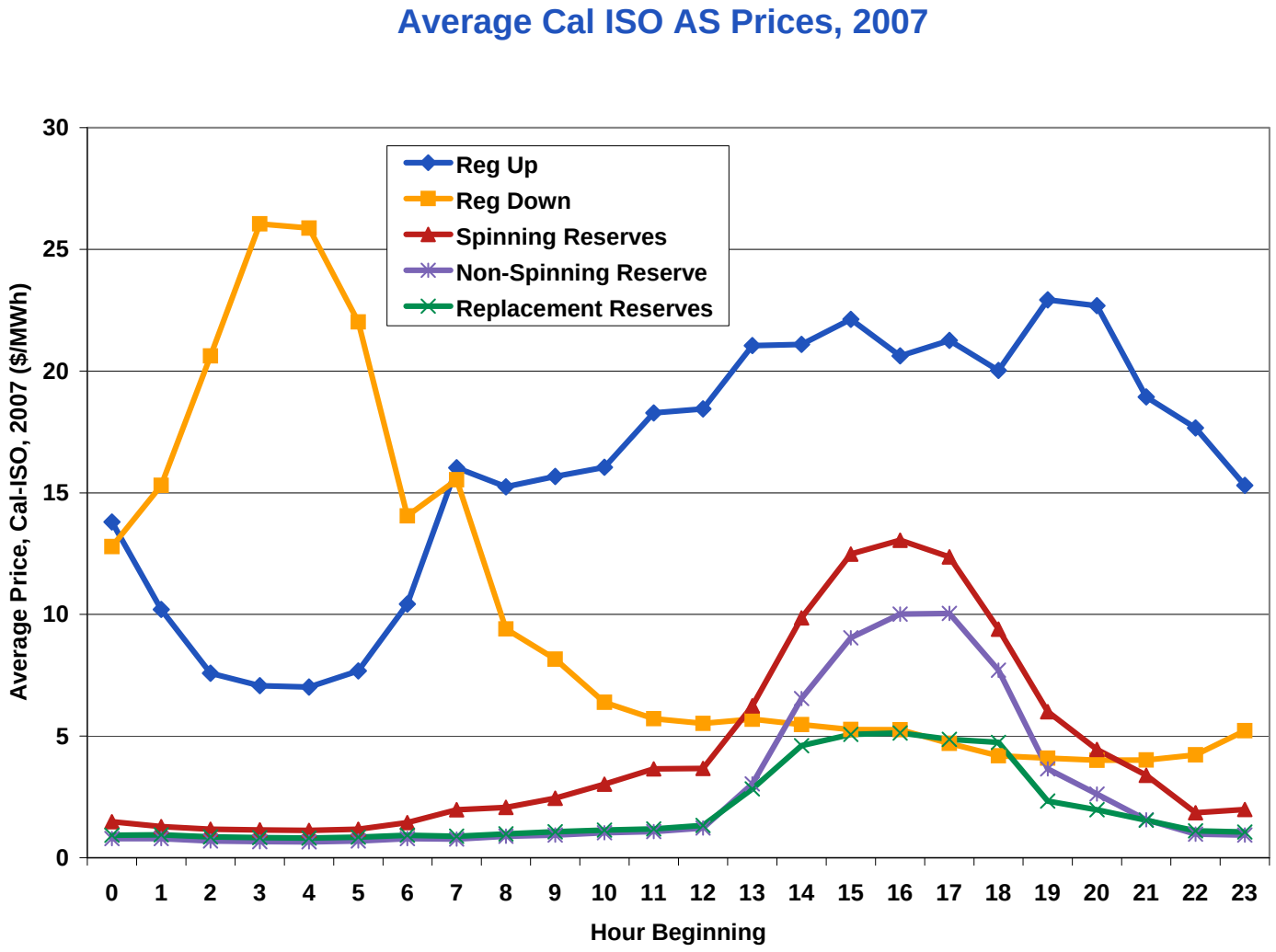


Value From Ancillary Services Revenue

- Ancillary Services (AS) are needed to provide the short term balancing between load and generation
- Quicker response = greater value
  - Regulation: "Real time" service that moves generation via AGC. Can be divided into "reg. up" and "reg. down."
  - Spinning Reserves: Typically need to respond in 10 minutes.
  - Non-spinning Reserves: Off-line but can be generating in 10 minutes.
  - Replacement Reserves: Off-line but can be generating in 60 minutes.
  - Voltage support and black start capability.
- Value is derived from storage technology's flexibility
  - Quick Starting
  - High ramp rate
- Each RTO/ISO sets its own standards for AS product definition, accreditation standards and pricing
  - The continued evolution of AS rules make the storage owner liable to administrative risks

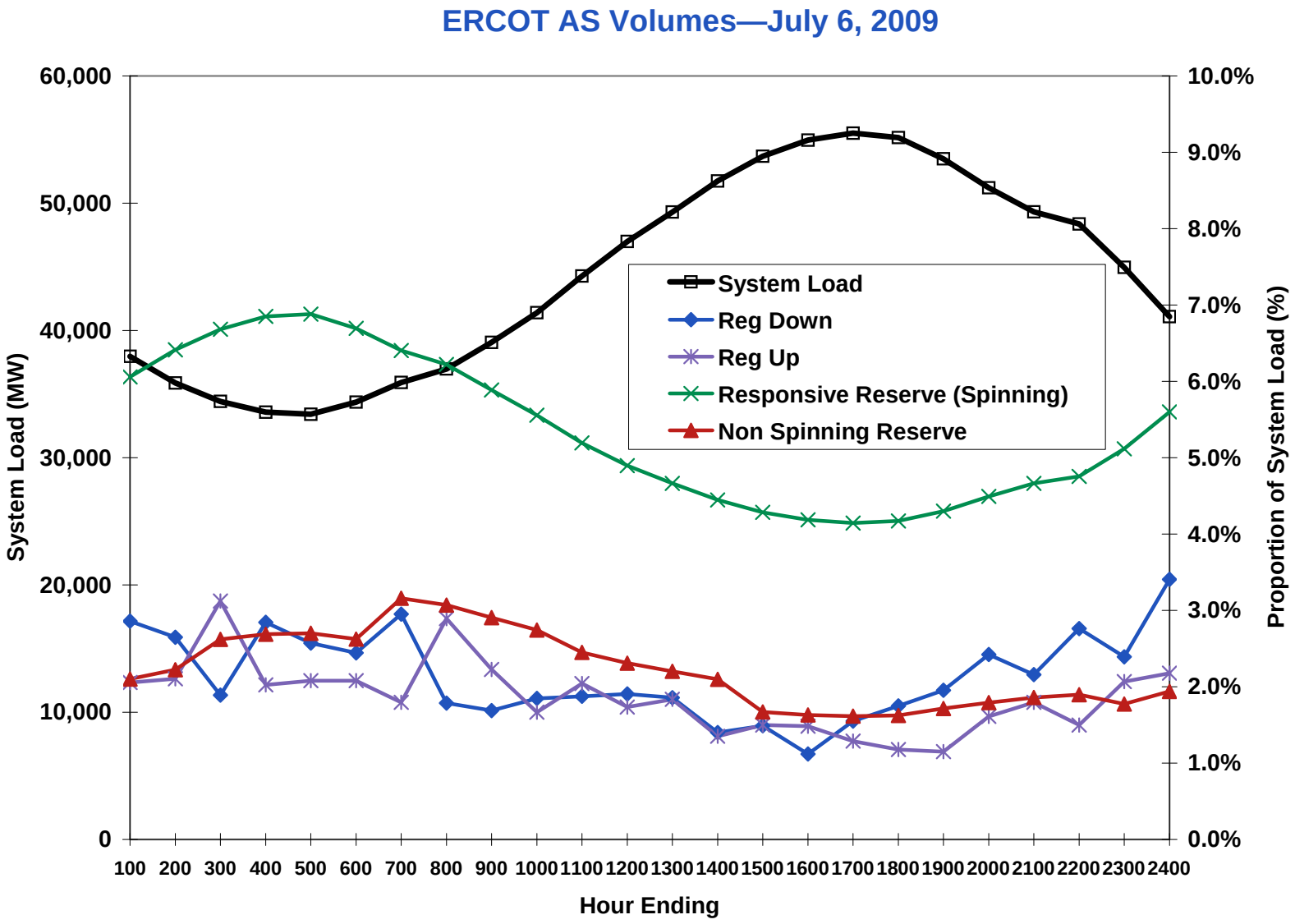
Ancillary Services Price Relationships

- AS is commoditized only in organized ISO-style markets.
- AS values typically follow diurnal patterns tied to the opportunity costs associated with marginal providers.
- AS market is typically thin.



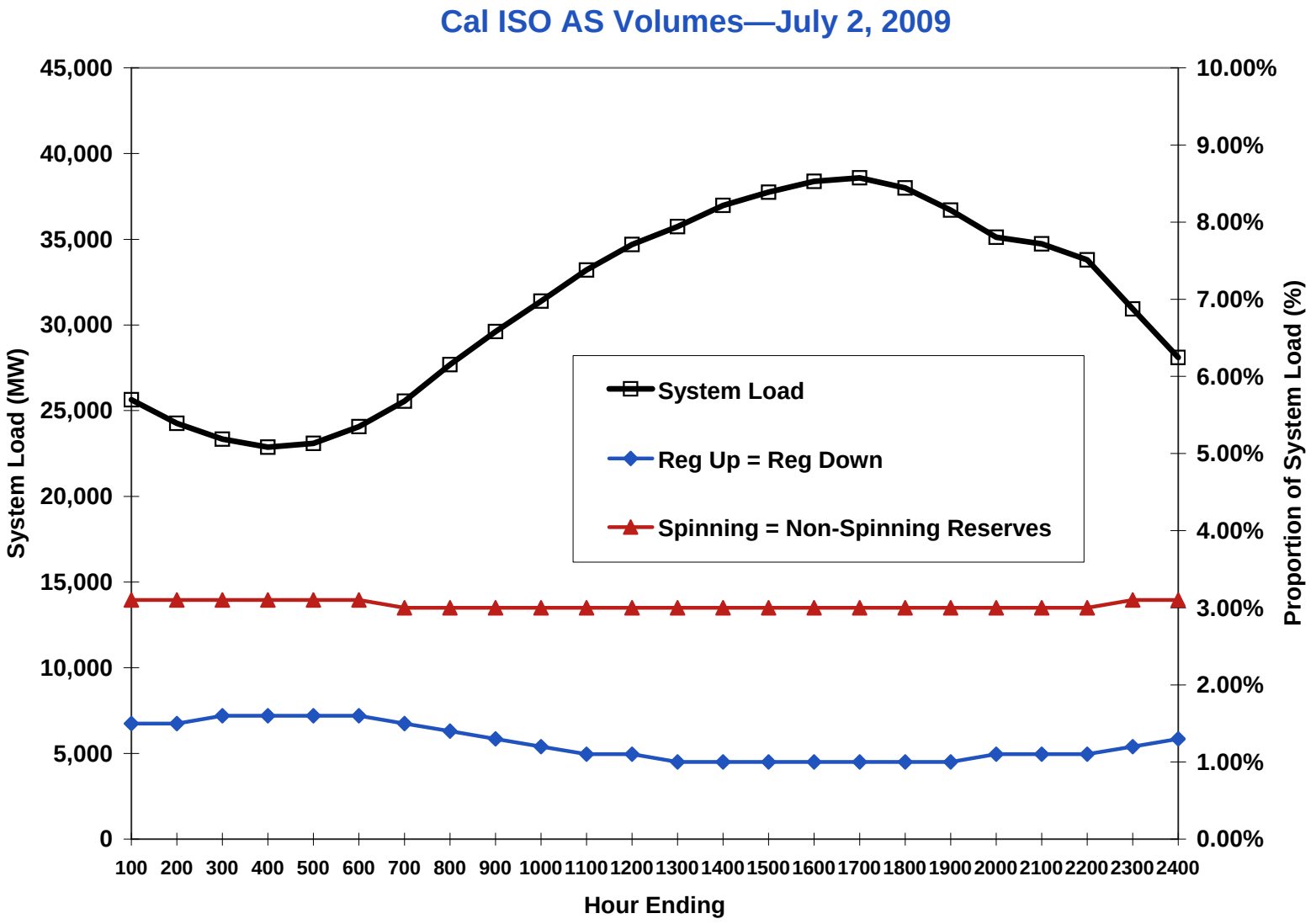
Ancillary Services Volume Relationships

- AS quantities are set to meet reliability requirements and are typically only a few percent of total system demand.
- In ERCOT, around 15-17% is typical.



Ancillary Services Volume Relationships

- Even thinner markets in California, about 9-10% of demand.



Energy and AS Revenue Forecasting

- GOAL: Optimize the operation of storage asset relative to an hourly price forecast of energy and AS prices.
- The energy analysis alone is a complex option valuation, looking at the trade-offs between storing, generating, ramp rates, maximum pool size and any non-power limitations.
- When AS is included, need to understand additional market rules and "opportunity costs" between the energy and AS decisions.
  - Additional problem is that AS markets are relatively small, so the storage asset's operation may impact the AS prices.
- Can quantify merchant risk exposure with pro forma stress cases.
  - Lower on-peak, off-peak spreads.
  - High or low gas price cases.
- Wind integration makes this more complicated.
- Explicit treatment of price volatility to identify option value.

Summary on Storage Valuation Drivers

- Factors that CREATE storage asset value
  - Higher on-peak, off-peak spreads
  - Operational flexibility to serve AS markets
  - Potential to integrate with and increase the value of wind generation
- Factors that DESTROY storage asset value
  - Competition from other market solutions, such as gas-fired CTs, or changing grid management protocols
  - Lower on-peak, off-peak spreads due to factors like low gas prices, capacity over-supply, changes in trading behavior
  - Thin AS markets can be easily over-supplied

Thank You!

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