The Impacts on Wholesale Energy Markets from the Massive Entry of Storage Stations and Large Consumers such as Data Centers and AI

Renewable & Storage Forum # 7

Organized by the Energy Press

October 23, 2025

Alex Papalexopoulos, Ph.D.

President, CEO & Founder, ECCO International, Inc., USA

CEO & Chairman of the Board, ZOME Energy Networks, Inc., USA

CEO & Chairman of the Board, World Energy Consortium, MALTA

San Francisco, CA

alexp@eccointl.com

ECCO INTERNATIONAL

An Energy Consulting and Software Company

Outline

- Impact of BESS in the energy markets
- Impact of AI Data Centers in the energy markets
- The AI threat to the energy markets and the grid resiliency
- Lessons for Greece
- Conclusions

Context and Market Transformation

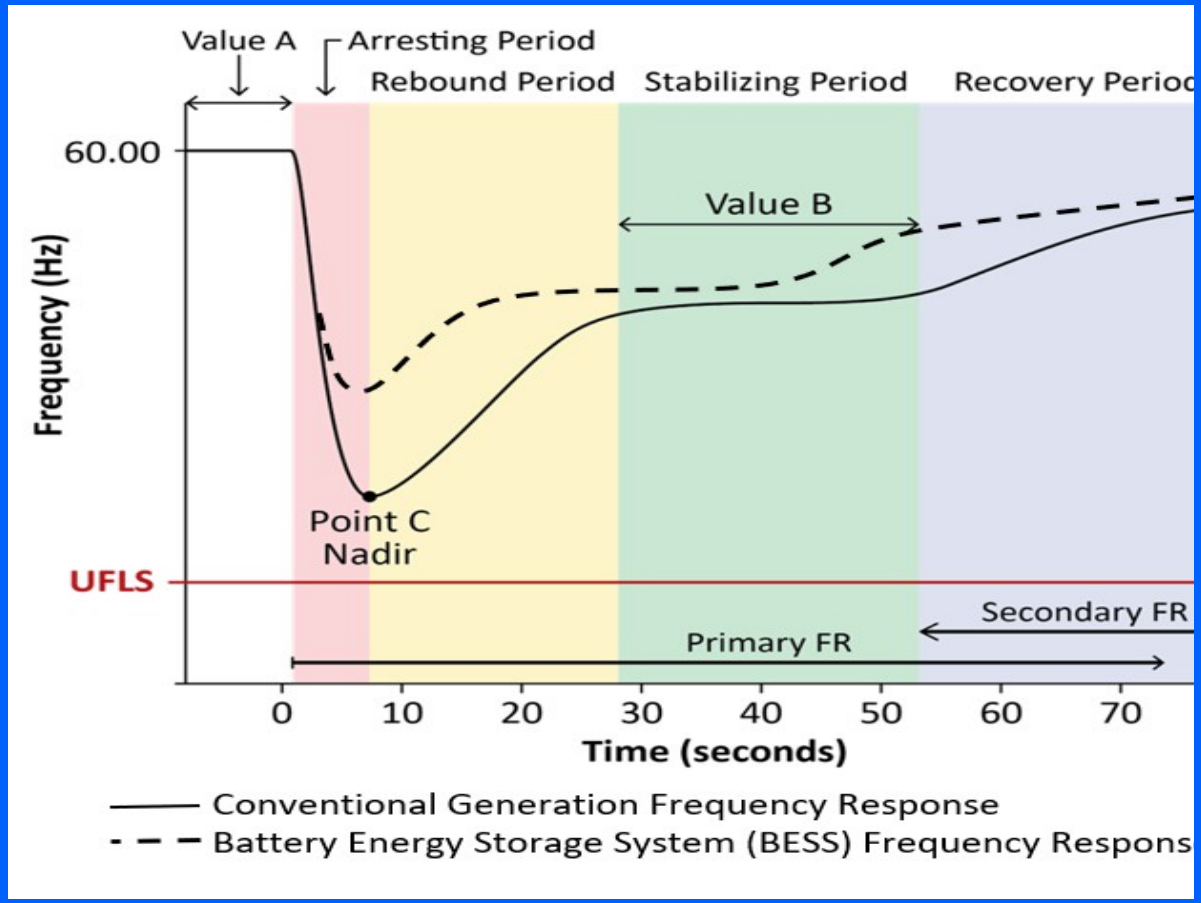
- Global energy markets are experiencing massive penetration of clean assets (PV, Wind, BESS, DR)
- Acceleration of electrification & data-centric growth are reshaping demand curves in all energy markets
- Storage (BESS) and flexible loads becoming core reliability assets strengthening grid resilience
- Wholesale energy markets are facing increasing volatility and stress from new actors

Contrasting Market Forces

- **Positive:** Energy storage enhances reliability and frequency stability
- In the US most of the frequency related Ancillary Services are awarded to BESS assets; they have completely crowded out gas power plants
- **Negative:** AI/data centers have tightened capacity margins creating huge market and operational problems for Grid Operators
- Divergent effects on reliability vs. price signals challenge market equilibrium

Frequency Response Comparison Example

- Frequency response improved where BESS concentration is high
- BESS mitigate under-frequency events and prevent cascading outages
- Reliability indicators trending positive (frequency response, mis-operations)
- No operator-initiated load shed in 2024

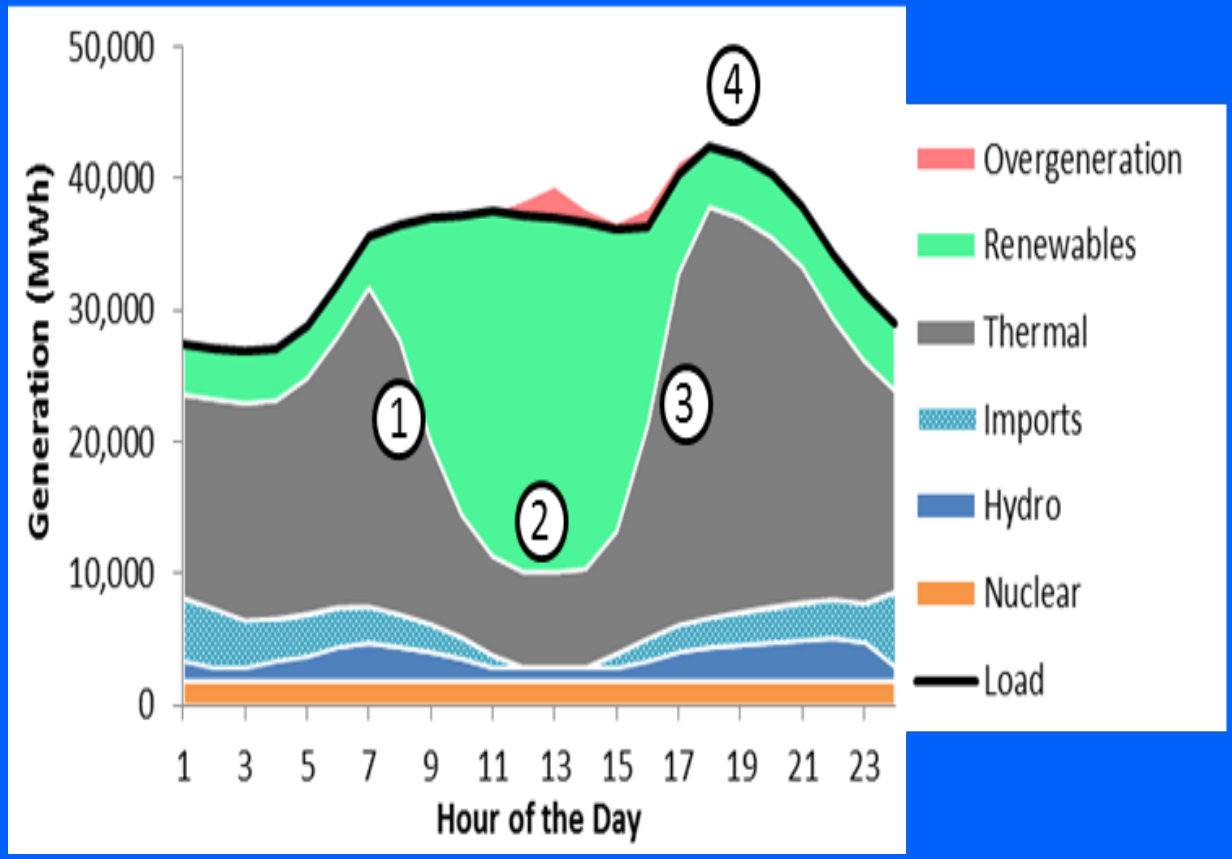


Long-Duration Storage (LDES) Wholesale Market Impacts

- ITC for long-duration storage (A-CAES) is preserved: stores compressed air in purpose-built underground caverns, heated by waste heat and released through turbines
- LDES = 8+ hr discharge, firm capacity, domestic job creation
- Hydrostor's Willow Rock (CA): 500 MW, 8 hr (4,000 MWH of storage) → power for 500,000 people
- Based on our analysis it can provide black-start, **capacity, ramping reserves, other reserves** and peak load support
- Strategic value: enhances resilience, supports long-term adequacy and is critical for decarbonization and grid reliability including rising **data-center and AI demand**

Price Stabilization from BESS

- Mitigates scarcity events, flattens peak/off-peak differentials
- Reduces energy price volatility; dampens DA–RT spread
- Shifts revenue sources toward ancillary services & fast reserves
- Risk: Overbuild may depress returns and secondary market signals



Reliability/Resilience and Market Gains from BESS

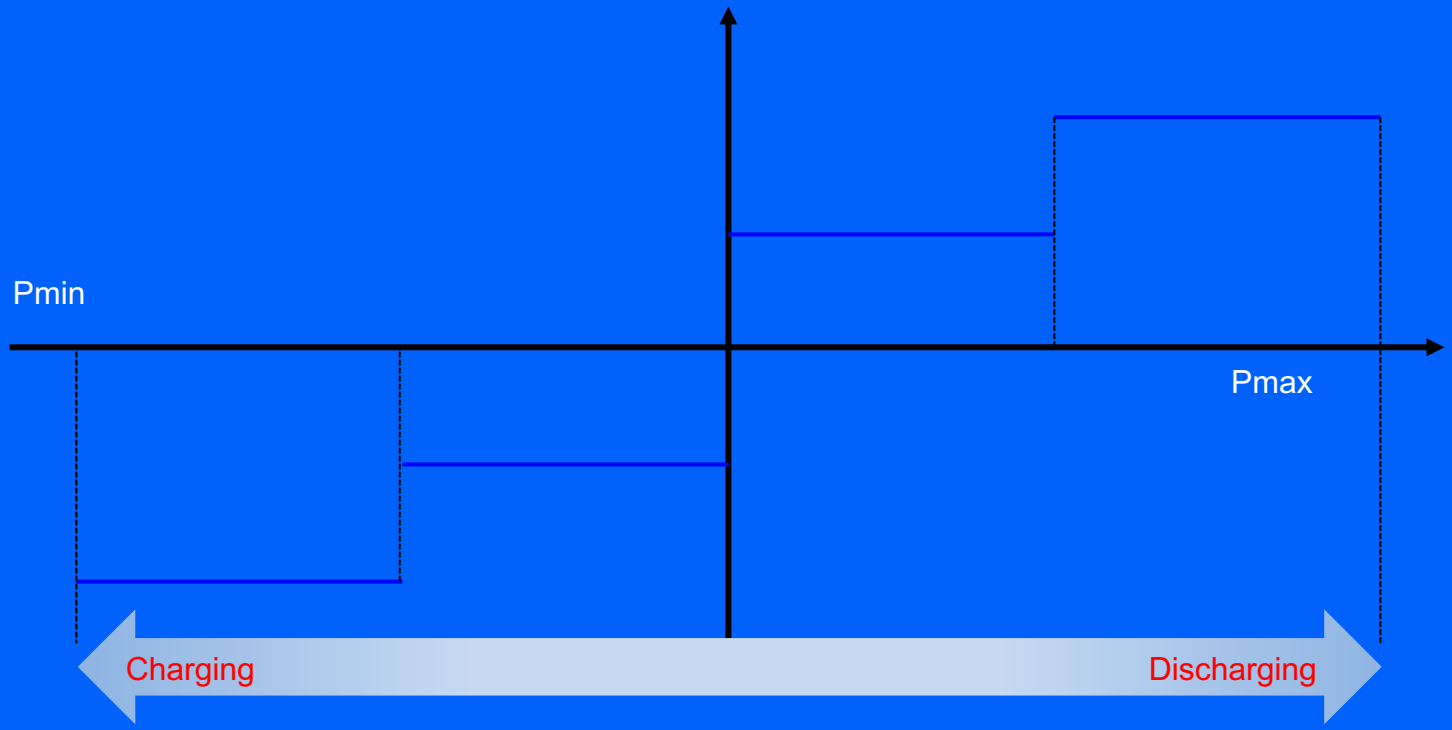
- BESS assets provide inertia-like response, other ancillary services, long term capacity and fast balancing
- Improve recovery time post-events (faster Interconnection Reliability Operating Limit (IROL) restoration)
- Reduce need for operator-initiated load shedding
- BESS can support IROL management by rapidly injecting or absorbing power
- Conversely, rapid load swings from AI data centers can increase IROL risk by stressing transmission corridors
- Key takeaway: storage is now a resilience cornerstone and a key market player

Hybrid Plant System Economic Value Analysis

- The value boost of adding BESS to a RES plant ranges from $3–$22/MWh depending on the year and the region in the US, with an average value of $10/MWh
- The benefit of adding storage to a solar PV plant in CAISO or ERCOT, as measured by the storage value adder, is $13–$22/MWh
- **CAISO shows higher adder for solar proving how coupled BESS partially offset the PV solar value decline due to massive penetration of solar (Saturation effect)**
- The results also show that the coupled solar projects are preferable over coupled wind projects

The Non-Generation Resource (NGR) Model

- The NGR model allows Hybrids to participate in the markets and provide services while accounting for their unique capabilities and characteristics



Hybrid Resource Energy Market Analysis

- Hybrid resources avoid operating constraints and "**non-convex**" market characteristics, with no startup time, no min-run time, no min-down time, and fast, accurate, controllable, continuous ramping down to Pmin=0 MW
- Convex" refers to nondecreasing incremental energy offers, which provide significant economic and computational advantages for optimal market solutions
- **Hybrid resources offer one-part offers** (rather than three-part offers of conventional resources with startup costs and no-load costs) without advance commitment requirements, uplift payments or other constraints
- **The modeling of SOC is critical**
- **Capacity revenues for hybrid projects has skyrocketed and continues to increase as a portion of the overall revenue mix**

Data Center & AI Load Explosion (PJM 2025)

- +11.9 GW of data-center load forecasted for 2026
- Data centers = 93% of PJM's large-load growth
- Peak demand jump of 7 GW between 2024–2025
- Normal operations for these facilities raise serious concerns for balancing, frequency stability, voltage stability and market distortions
- Voltage stability & transmission infrastructure lag behind AI data center connection speed
- Transmission outage have disconnected very large data centers increasing dangerously system voltages and frequency (more than 1500 MWs)

Data Center & AI Load Explosion (PJM 2025)

- Another emerging reliability challenge is positioning resources, including BESS, so that the system can rebalance itself quickly in response to rapidly changing loads from AI and cryptocurrency- mining facilities
- We have also experiencing major market distortions
- Capacity costs have exploded in the PJM region
- Holding aside all other issues, data center AI load by itself resulted in an increase in the 2025/2026 auction revenues of $9,332 Billion or 174.3 percent
- The 2026/27 auction by including ~12 GW of forecast AI load increased total capacity-market revenues by over $7 billion (+82 %)

ECCO INTERNATIONAL
An Energy Consulting and Software Company

Data Center & AI Load Explosion (PJM 2025)

- The forecasted 2026/2027 auction revenues using an **unrestricted VRR curve** would have been more than $19 Billion, an increase of more than $3 Billion compared to the actual results; this 19.7 percent, compared to the actual auction results
- It is misleading to assert that the capacity market results are simply just a reflection of supply and demand
- The current and expected future growth in AI data center load are unique, unprecedented and uncertain and **threatens the core of our competitive energy markets**

Data Center & AI Load Explosion (PJM 2025)

- The extreme uncertainty in the load forecasts of large AI data center loads is also unique and unprecedented and raises questions about the meaning of clearing wholesale auctions
- Utility customers in seven PJM Interconnection states are being charged $4.4 Billion for transmission upgrades approved last year
- The costs for local transmission needed for data centers falls into a "**regulatory gap**," with the expenses for the upgrades typically being shared by all customers
- Costs should be assigned to the specific customer — or an appropriate rate class that is causing the costs — to avoid subsidization by all other customers

ECCO INTERNATIONAL
An Energy Consulting and Software Company

Lessons for Greece

- Forecast uncertainty will drive price volatility & inefficient entry signals
- Contrast: storage will stabilize short-run markets but AI load will destabilize long-run adequacy and security of supply
- Require data centers to procure new generation (**bring their own generator, bring their own MWs**, otherwise the energy markets are at a substantial risk) OR **Institute energy ratining**
- **Develop regulation** to ensure that infrastructure T&D costs are assigned to AI data centers to avoid subsidization by all other customers
- **Align capacity rules** with load-growth verification
- Enhance modeling of AI load profiles for planning accuracy

Distributed Flexibility & VPPs & Hybrid Systems

- The emergence of AI data centers has fostered the VPP market anchored in BESS systems (+33% program increase)
- VPPs offset AI peak demand and utility/VPP partnerships are rising
- VPPs can monetize flexibility from consumers and provide needed flexibility
- Storage and AI loads cluster at congested nodes → LMP divergence
- Growing need for nodal price granularity and co-optimized energy + reserves
- Grid-forming inverters to stabilize voltage and reduce reactive power deficits
- Locational flexibility markets to value behind-the-meter response

Key Messages

- BESS systems (especially Hybrids) improve reliability, frequency response, and grid resilience
- Data centers and AI loads create huge operational & planning problems, huge uncertainty and pose a major threat to energy markets by inflating market prices and distorting market signals (apply capacity premiums + energy ratining) OR bring your own MWs
- VPP integration and LDES deployment offer balancing mechanisms and reduce the AI data center risk
- Markets must reward flexibility, accurate forecasting, and localized response

Questions?