Energy Storage Deployment in PJM

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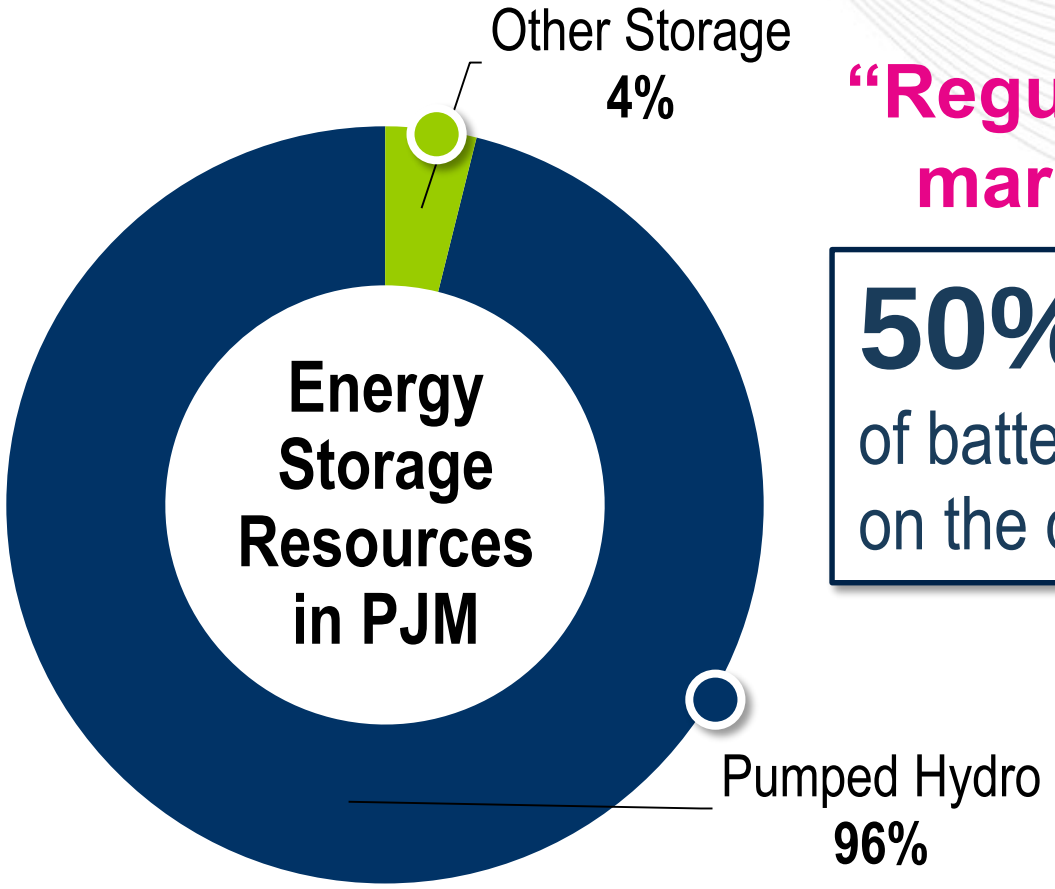
U.S. Department of Energy
Electricity Advisory Committee

Over 5 Gigawatts (GW) of Storage in ~180 GW PJM



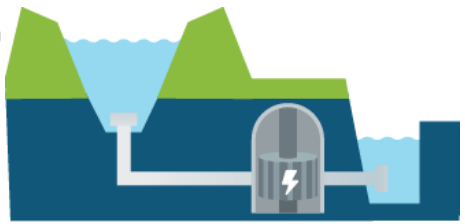
"Regulation market"

Other Storage is about ~300 MW of mostly batteries.

50% of batteries connected on the distribution system

50% Connected to the Bulk Electric System.

Pumped Hydro currently participates in capacity, energy, regulation and reserves.

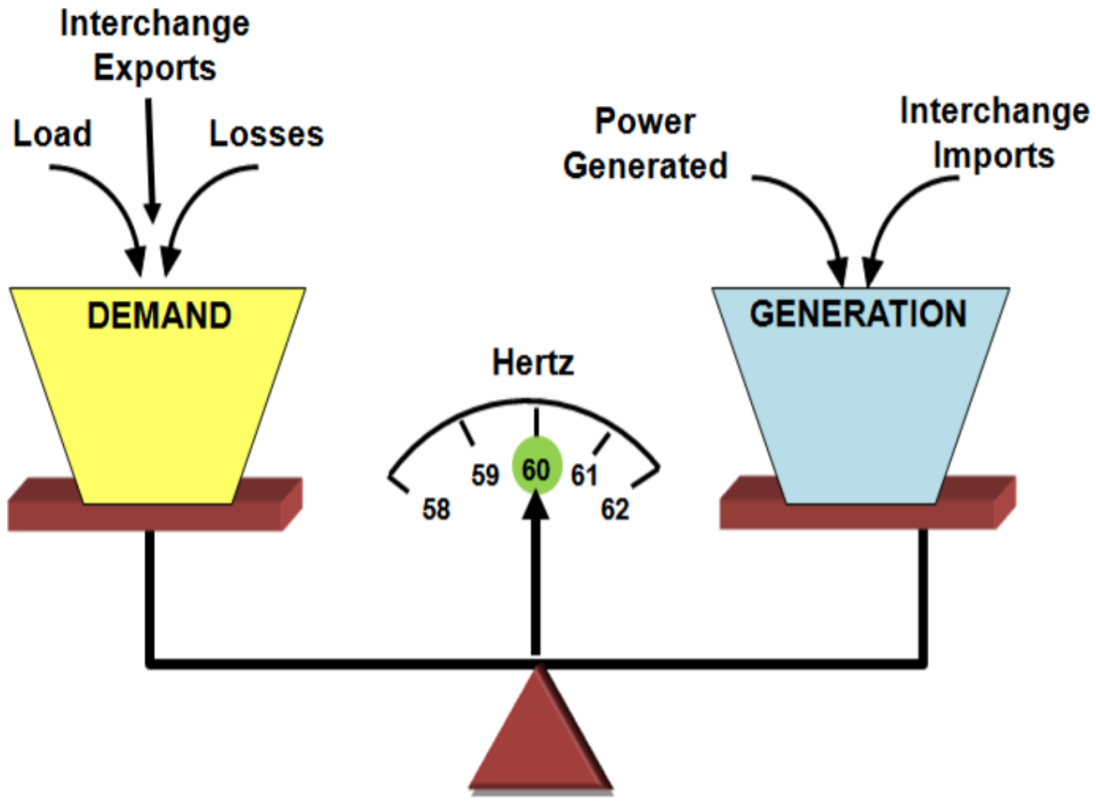


*** Data taken from Generation Queue and EIA 860*

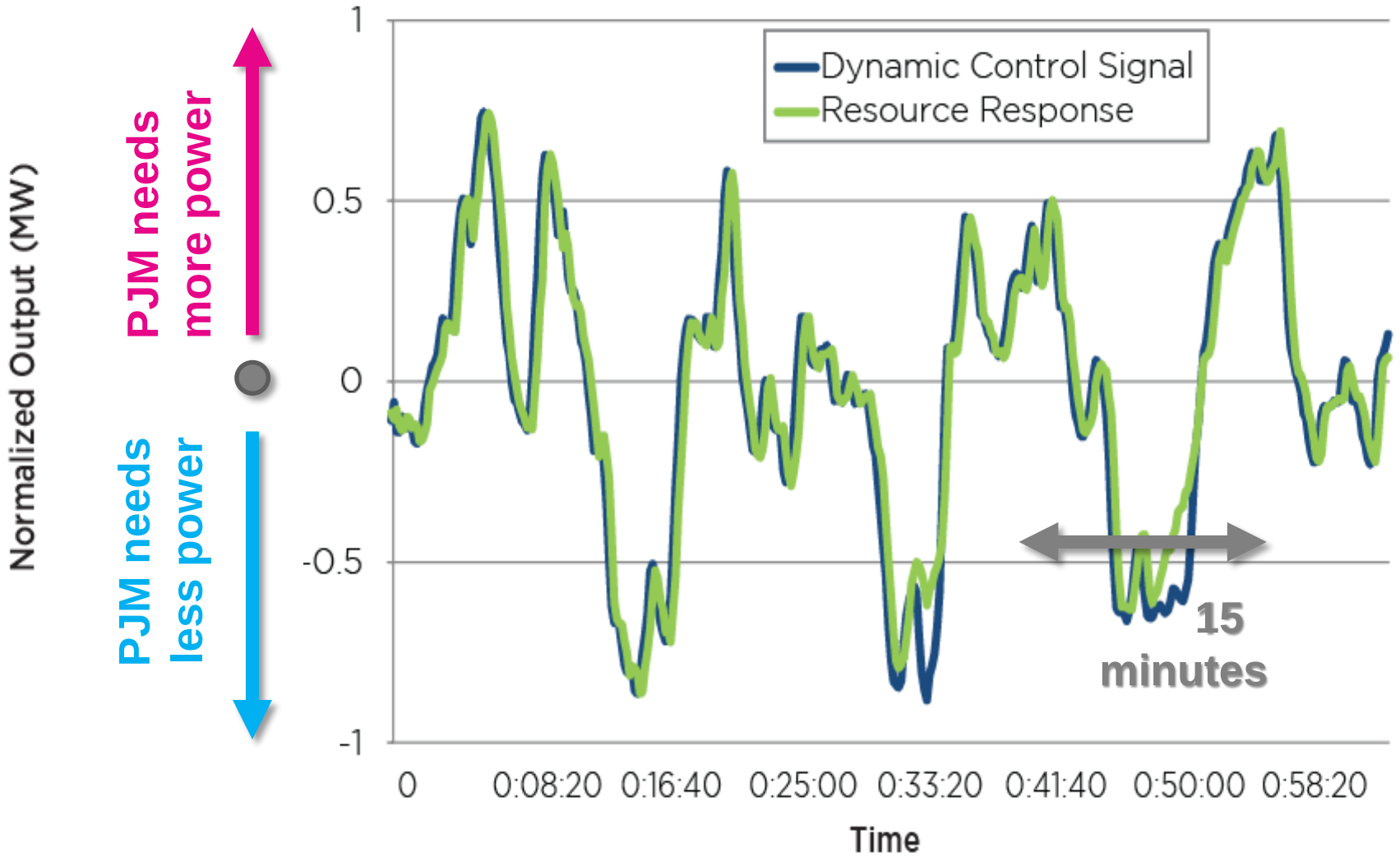
Regulation: actual imbalance vs. 10-min-ahead schedule

~Half the time, system actually needs a bit more power in real time than anticipated 10 minutes ahead of time. Half the time it needs <u>less</u> power.

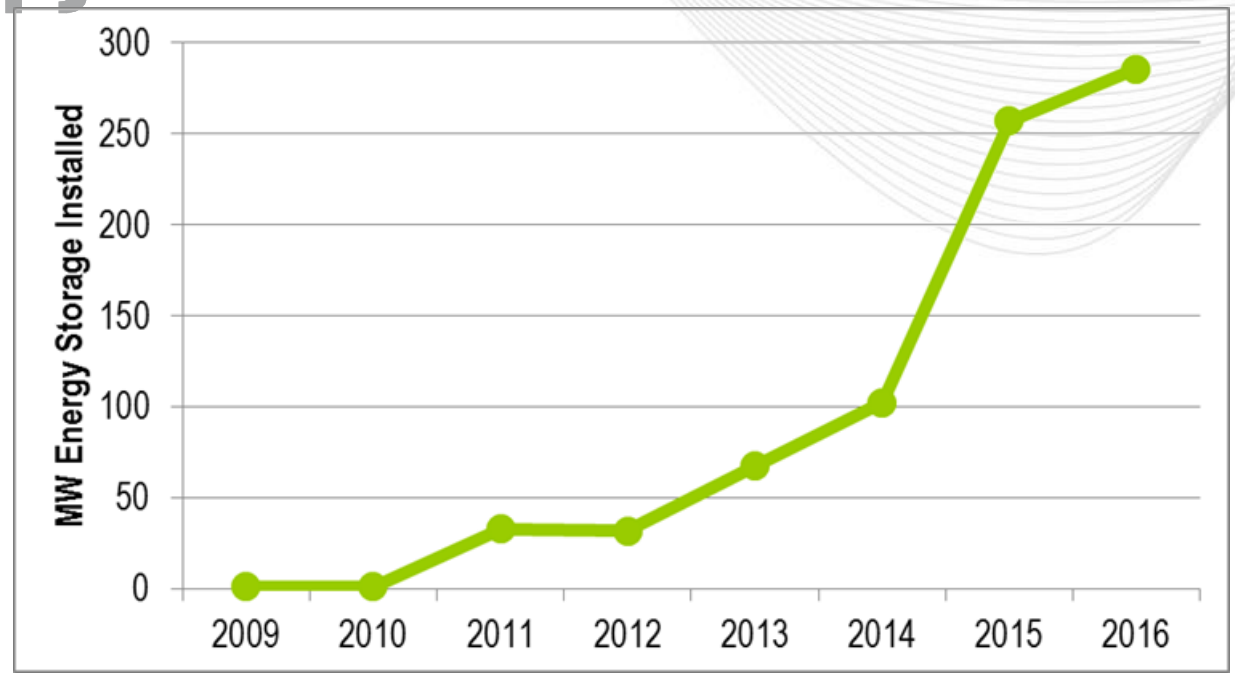
- "Balancing Authorities" (e.g., PJM) dispatch resources 10-15 minutes ahead of time.
- Δ anticipated vs. actual conditions show up as "Area Control Error" ("ACE"):
  - A. Net exports/imports across an entire Balancing Authority **too high or low** vs. schedule
  - B. Possible **change in interconnection system frequency** (e.g., Eastern, Western, ERCOT) vs. 60 Hz (or other schedule).
- Resources providing "Regulation" respond to 4-second PJM dispatch to manage ACE.



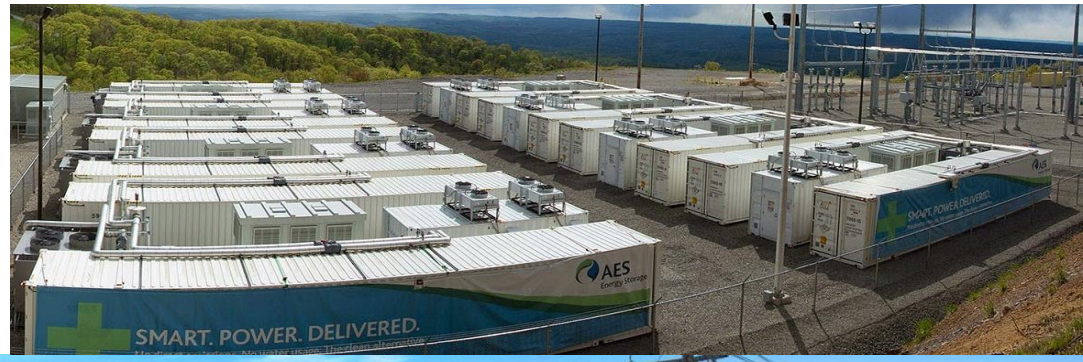
Example Fast Regulation Dispatch and Battery Response



Use Case: “Fast” Regulation in PJM



- Storage in PJM: “fast” Regulation* in 2008.
- Now, no more “fast” Regulation needed**.
- ~300 MW slow Regulation still on the table.

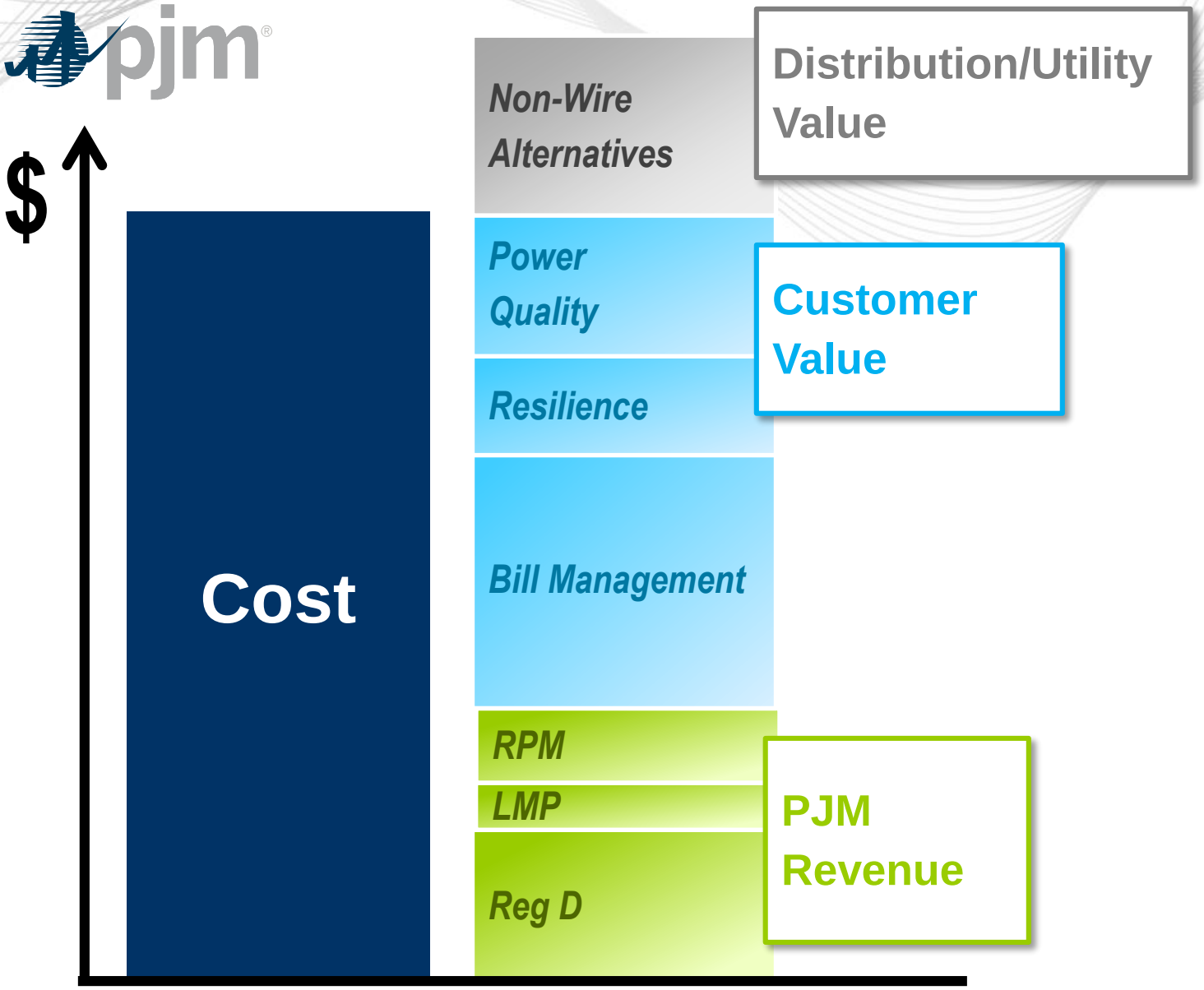


*AKA Frequency Regulation

**http://www.pjm.com/~/media/committees-groups/task-forces/rmistf/postings/regulation-market-whitepaper.ashx

**http://www.pjm.com/~/media/committees-groups/task-forces/rmistf/postings/rts-curve-points-updated.ashx

Multiple Use Storage



Village of Minster, OH

- Reducing Peak Load
- Voltage Control and Power Factor Correction
- Regulation (PJM Market)

Multi-use Examples

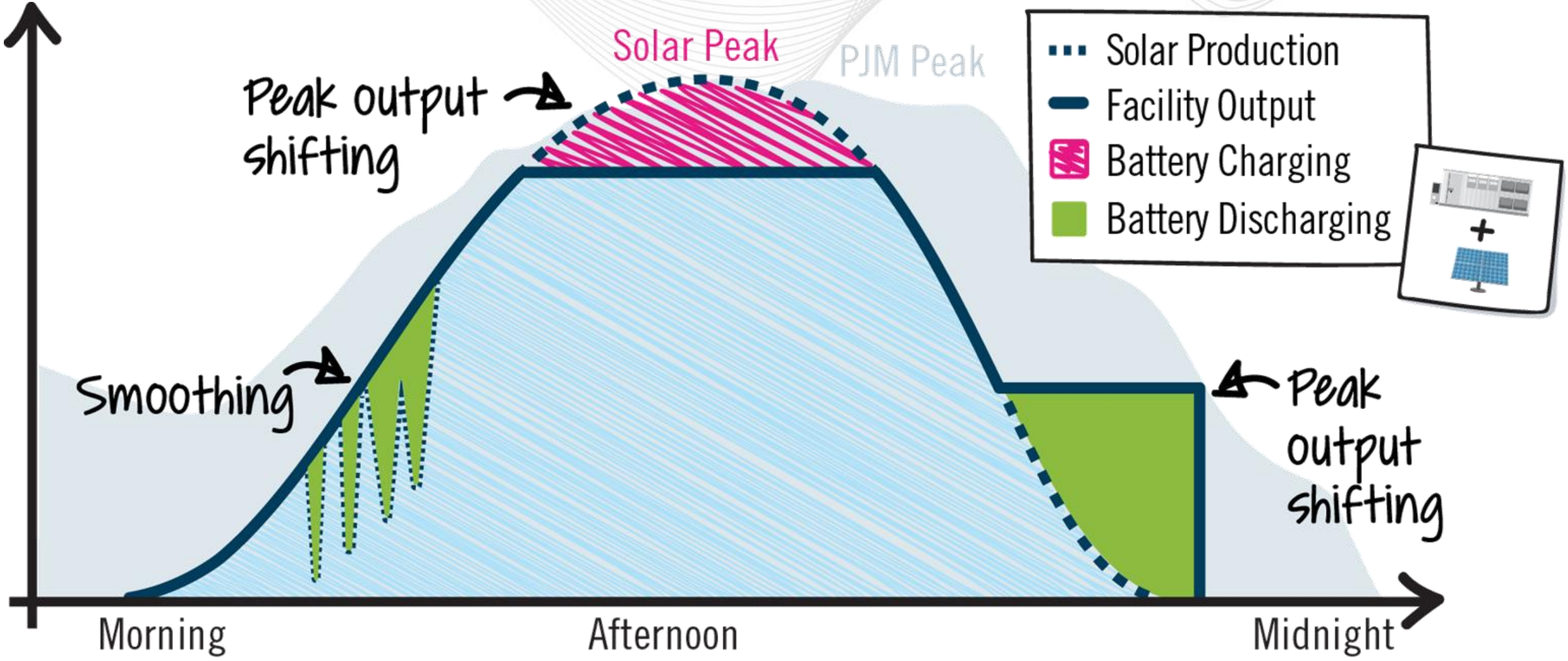
Grid Frequency Regulation from Microsoft data centers

Ancillary Services from Campus Cogen

Frequency Regulation from Light Rail Battery

Energy & Frequency Regulation from Solar-Storage Microgrid

Solar-Storage Hybrids: ~ 4 Gigawatts in the PJM Queue



Thank you

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APPENDIX

Storage & Hybrids in the PJM Queue

~100 GW
natural gas + standalone renewable resources

~4 GW
hybrid renewables + storage

~2 GW
standalone storage

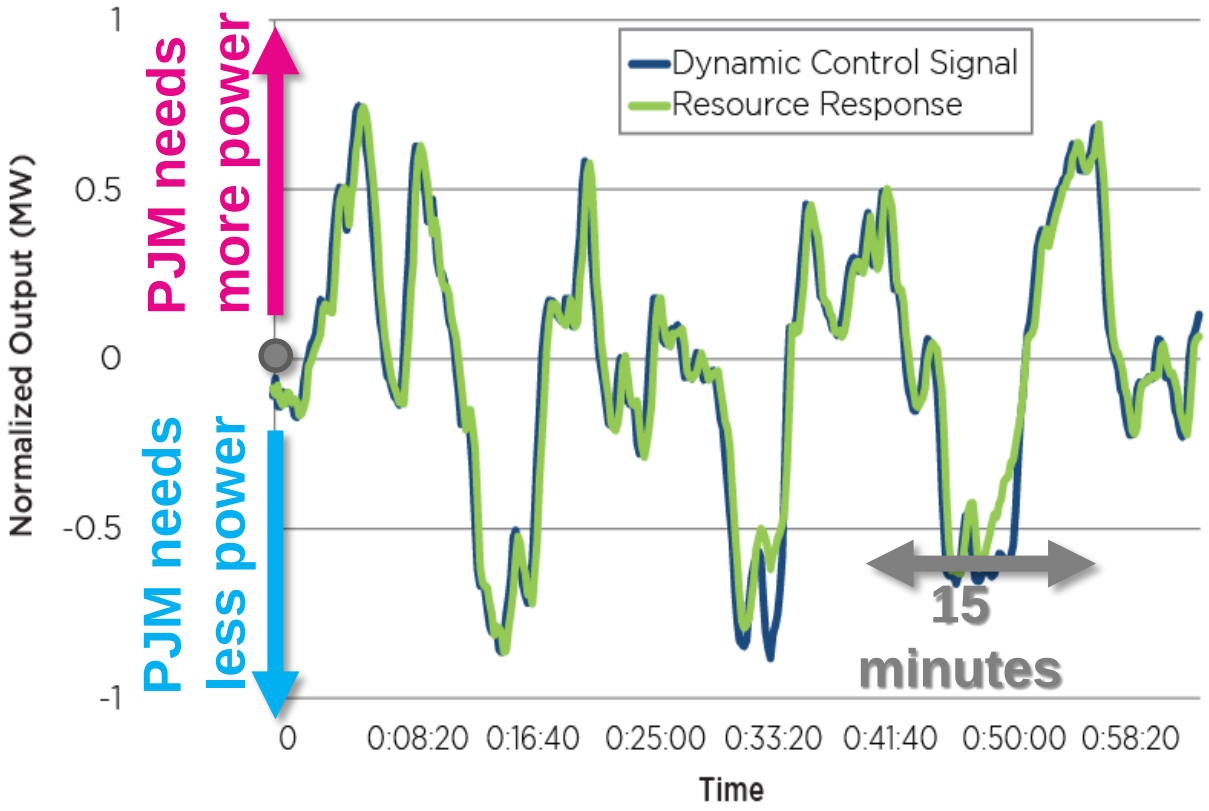
Hybrid Renewables + Storage

- Mostly >100 MW
- Several < 20 MW
- Several in between

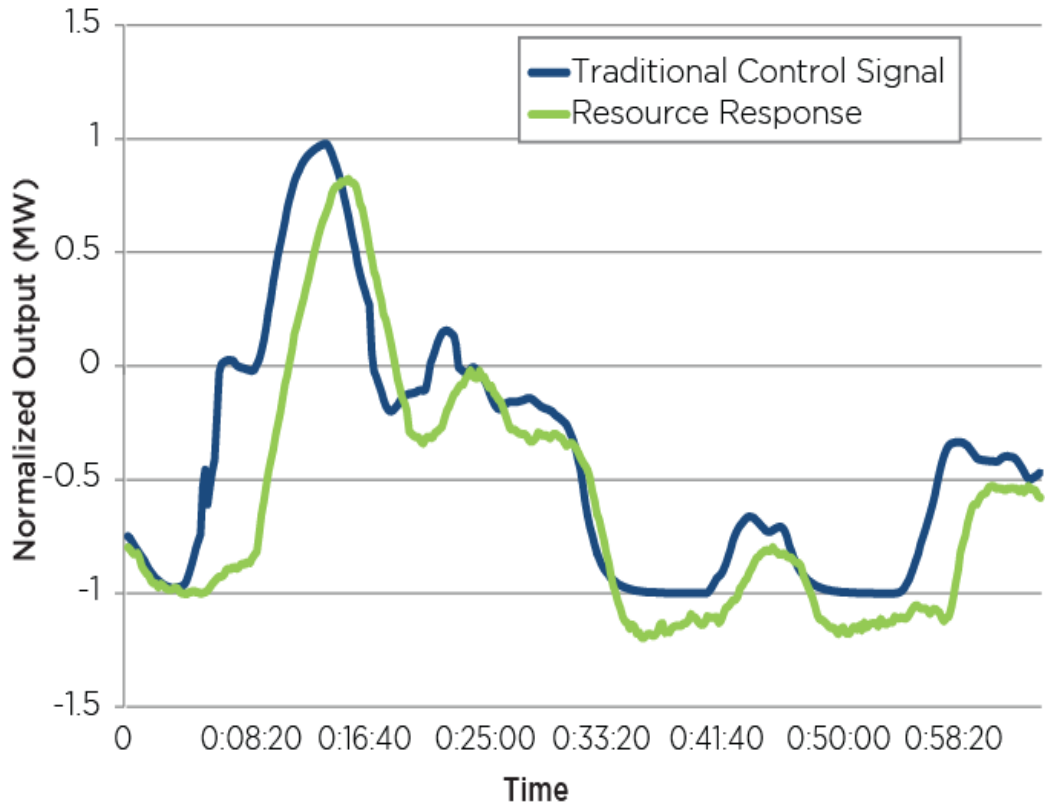
Standalone Storage

- Mostly < 20 MW
- Several >100 MW

Not All Megawatts are Created Equal: Speed vs. Sustain



Fast Regulation signal and battery response



Slow Regulation signal and power plant response

University of Delaware/NRG Vehicle-to-Grid Resource

Example of electric vehicles generating ancillary services revenue

Balance of Power

The numbers behind the University of Delaware program using cars as a money-making reserve for the electric grid

Cars used	23 (19 all-electric Mini E's, 3 modified Scion xB's, 1 experimental Honda Accord plug-in hybrid)
What they do	Store or discharge electricity according to grid needs
Special equipment needed	Control board, $200-$300 per car
Power of car batteries	12 kilowatts per vehicle*
Minimum capacity needed for a grid "bank"	100 kilowatts/9 cars
Time connected to grid	24/7 except when being driven
Average daily driving time	About an hour per car
Monthly revenue per car from grid operator	About $150
Monthly electricity cost/car	About $40
Monthly profit	About $110 per car/$2,500 total

*For Minis and Scions. Honda power not disclosed.

Source: University of Delaware

The Wall Street Journal

EVAN KRAPE/UNIVERSITY OF DELAWARE

https://www.wsj.com/articles/electric-vehicles-sell-power-back-to-the-grid-1411937796

Growth in Demand-side Regulation