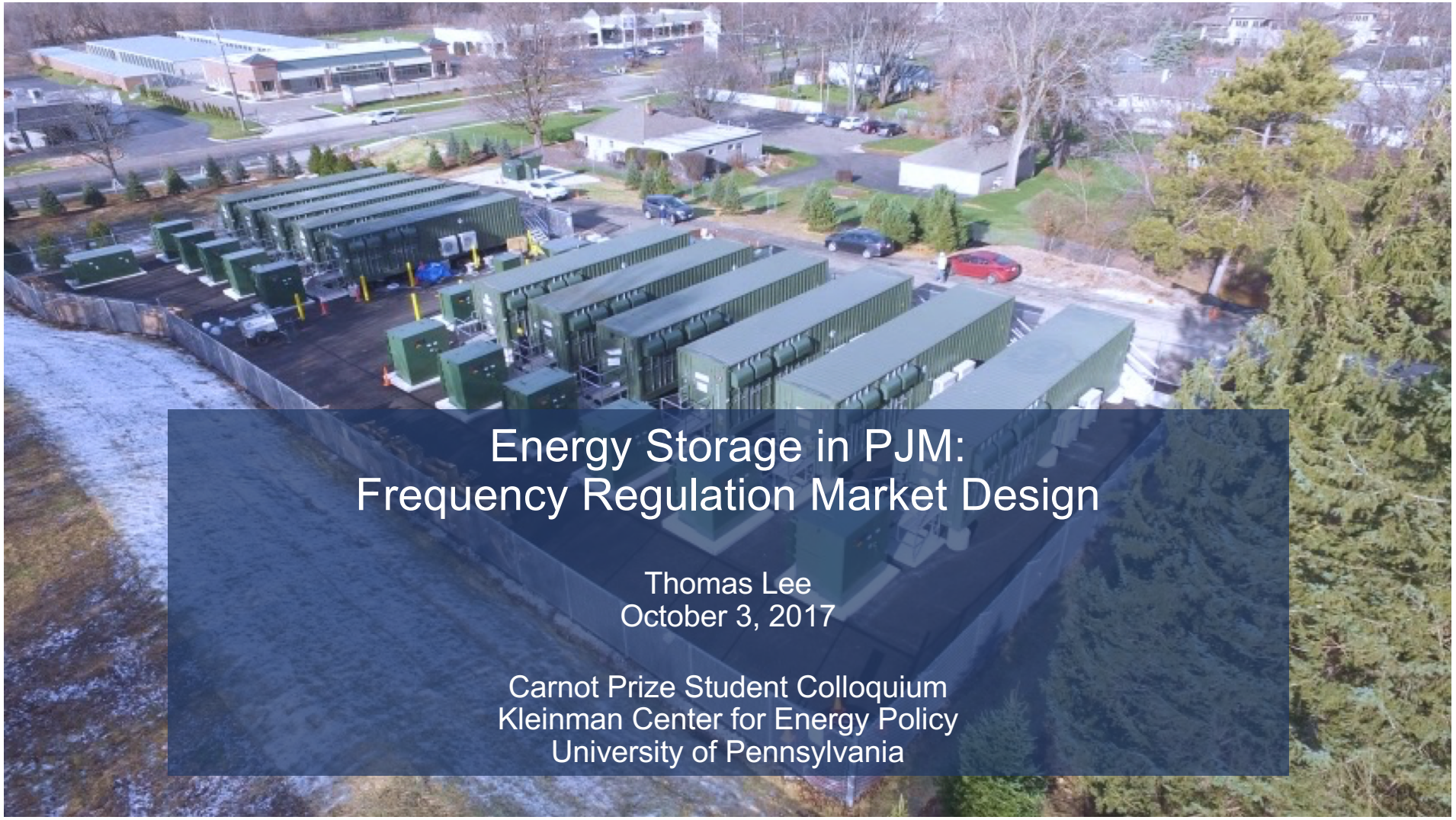
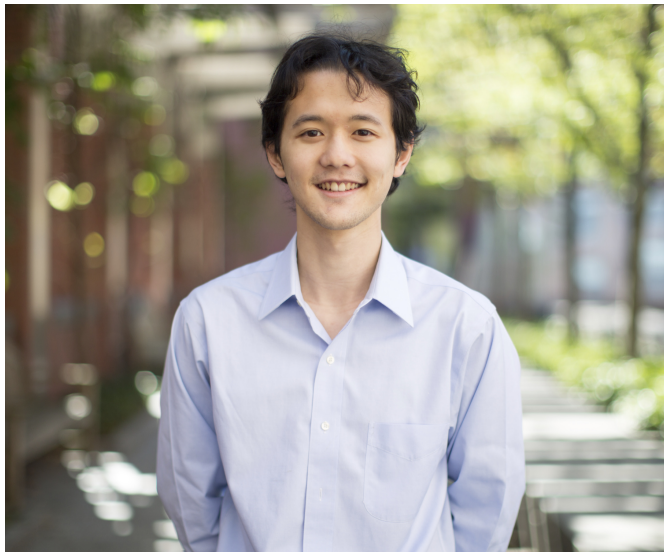


Energy Storage in PJM: Frequency Regulation Market Design

Thomas Lee
October 3, 2017

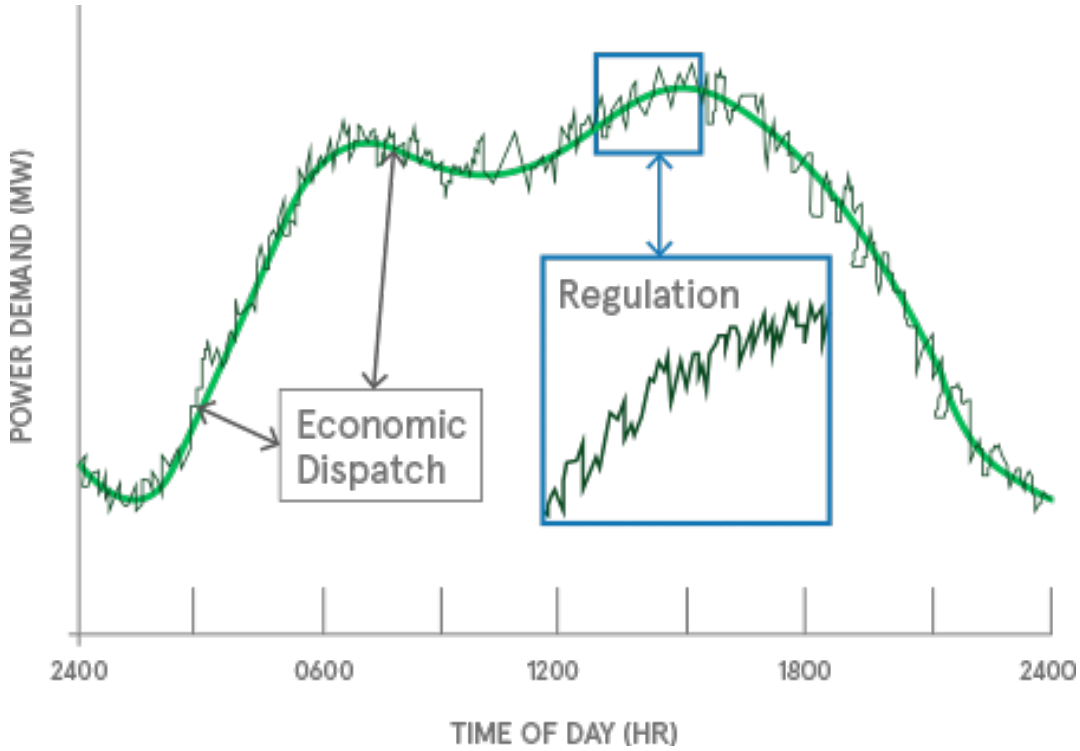
Carnot Prize Student Colloquium
Kleinman Center for Energy Policy
University of Pennsylvania

Thomas Lee



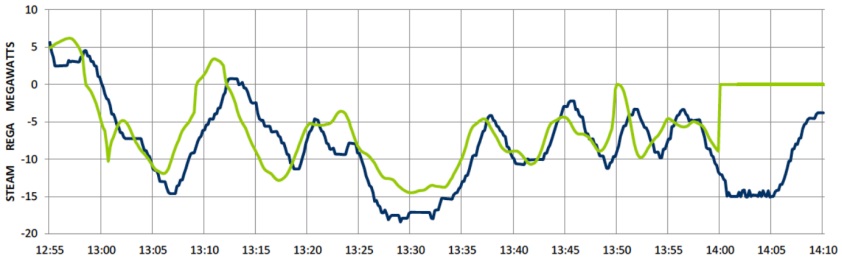
- BS, Economics; BAS, Computer Science; MSE, Electrical Engineering
- Wharton School;
  School of Engineering and Applied Science
- Employment: Kleinman Center for Energy Policy Research Assistant, AQR (Part-Time)

Frequency regulation manages area control error.

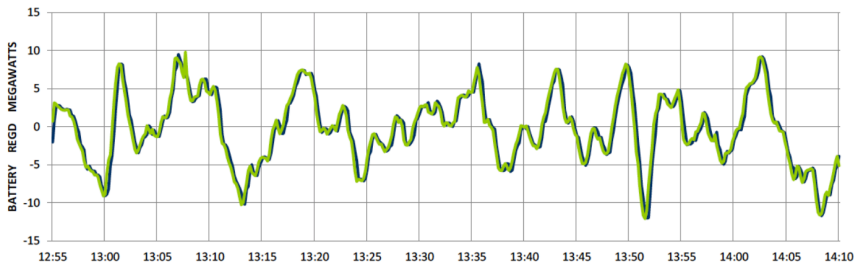


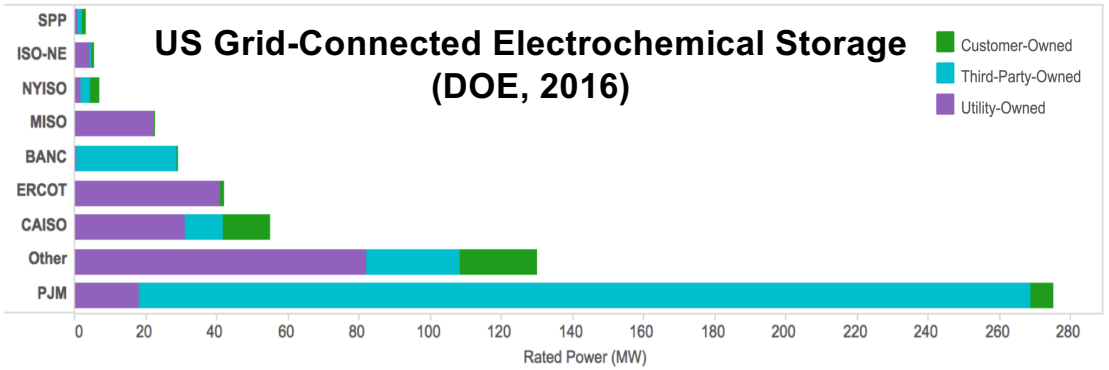
Energy storage is accurate, but has limited duration.

PJM RegA – Steam



PJM RegD – Battery



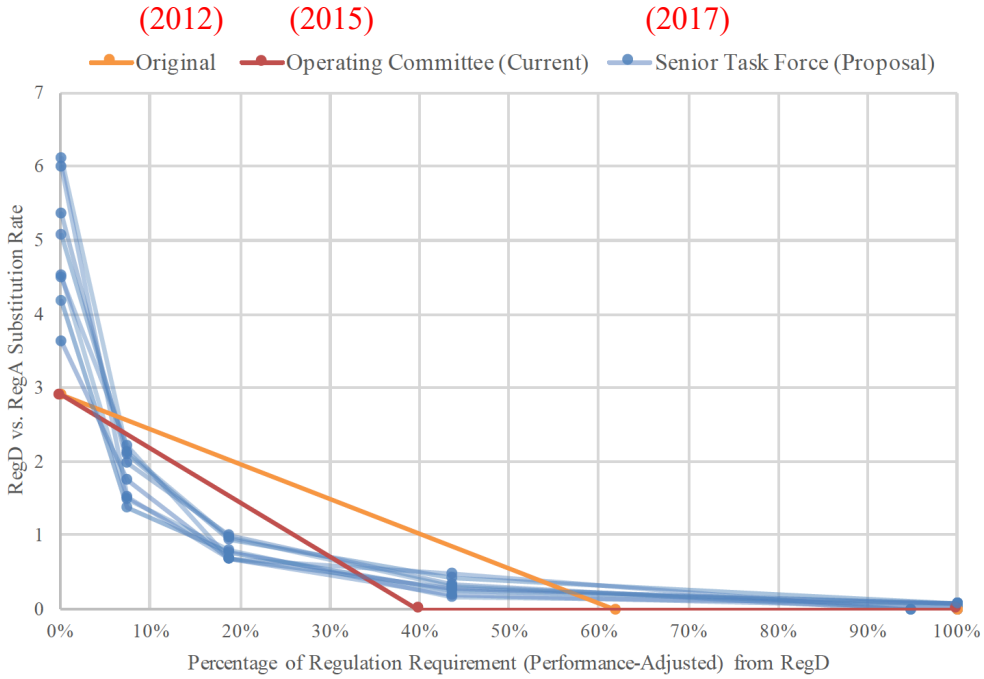


“Correct” market design can be hard.

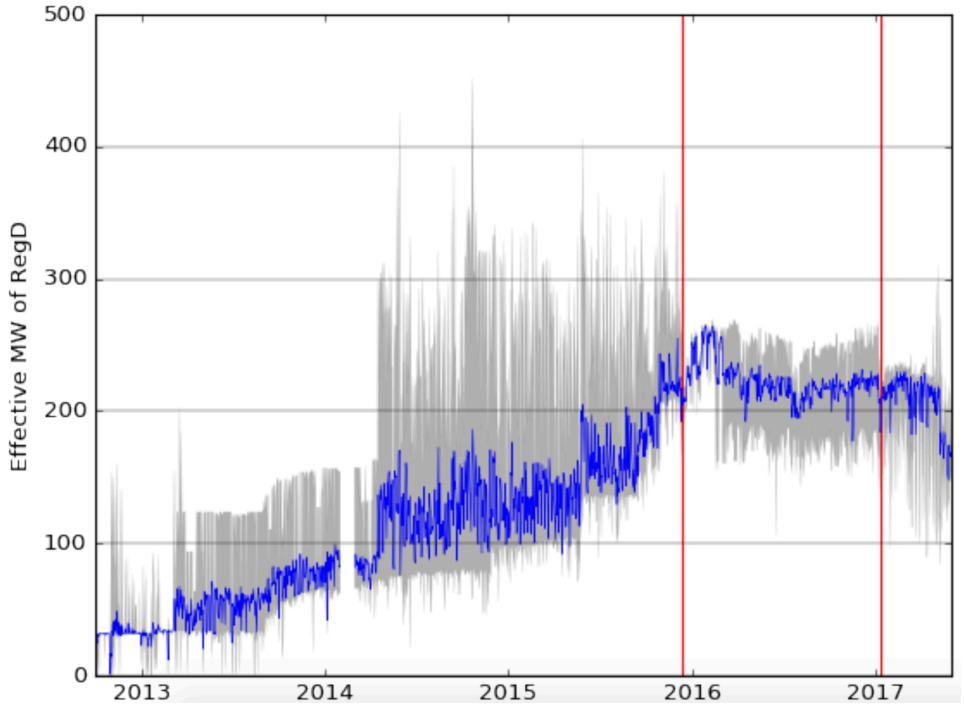
$$\begin{aligned} &\text{Minimize} && P_A A + P_D D \\ &\text{Subject to} && B(A, D) = K_{Reg} \end{aligned}$$

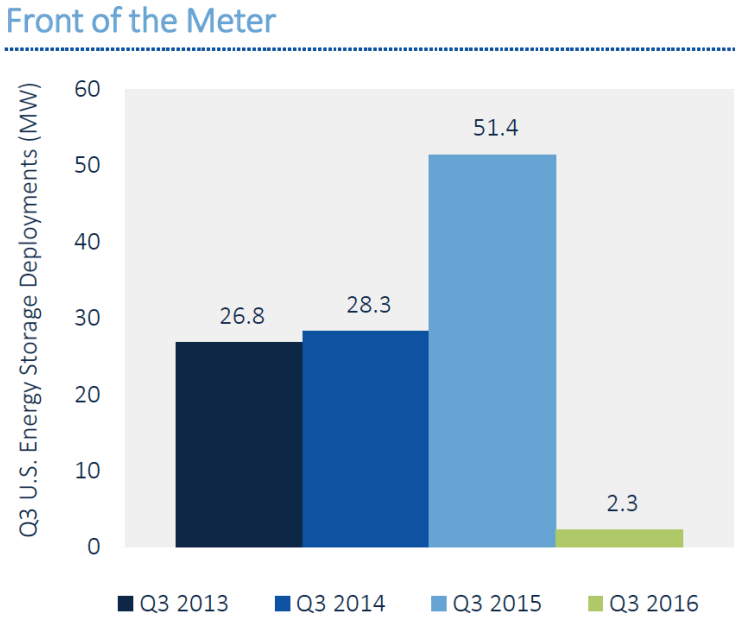
$$\lambda^* = \frac{P_A}{MB_A} = \frac{P_D}{MB_D}$$

Efficient solution equalizes ”bang for buck”.



PJM changes reduced storage participation in FR.





Policy Takeaways

- Ancillary services enable more renewables
- Tradeoffs between: