Frequency Regulation Market
Pay for Performance

West Philly High PHEV

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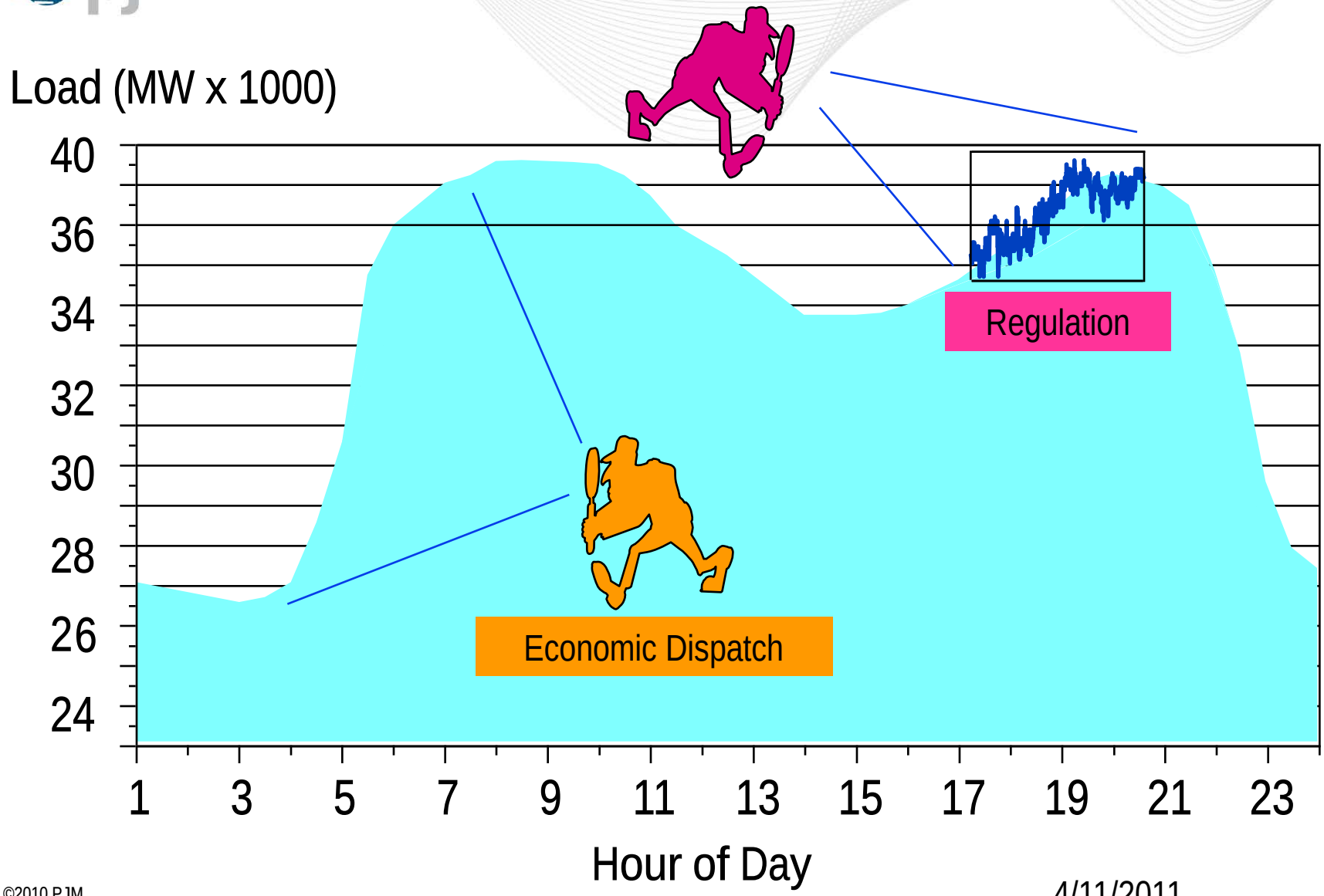
Regulation vs. Economic Dispatch



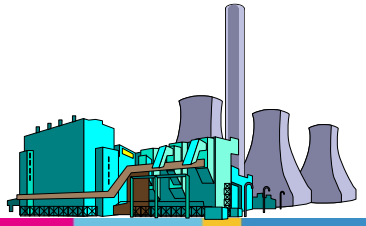
- Current PJM Regulation Market rules compensate all resources uniformly
  - No differentiation for resources that can respond more quickly and/or accurately
  - Compensation targeted to offset energy opportunity cost not to incent performance
- Two major implications of this methodology
  1. No incentive for resources to perform at a level any higher than the minimum required for full compensation.
  2. Limited the ability to use multiple regulation signals (fast/slow) as compensation does not recognize the unique capabilities of each resource.

What is Regulation?

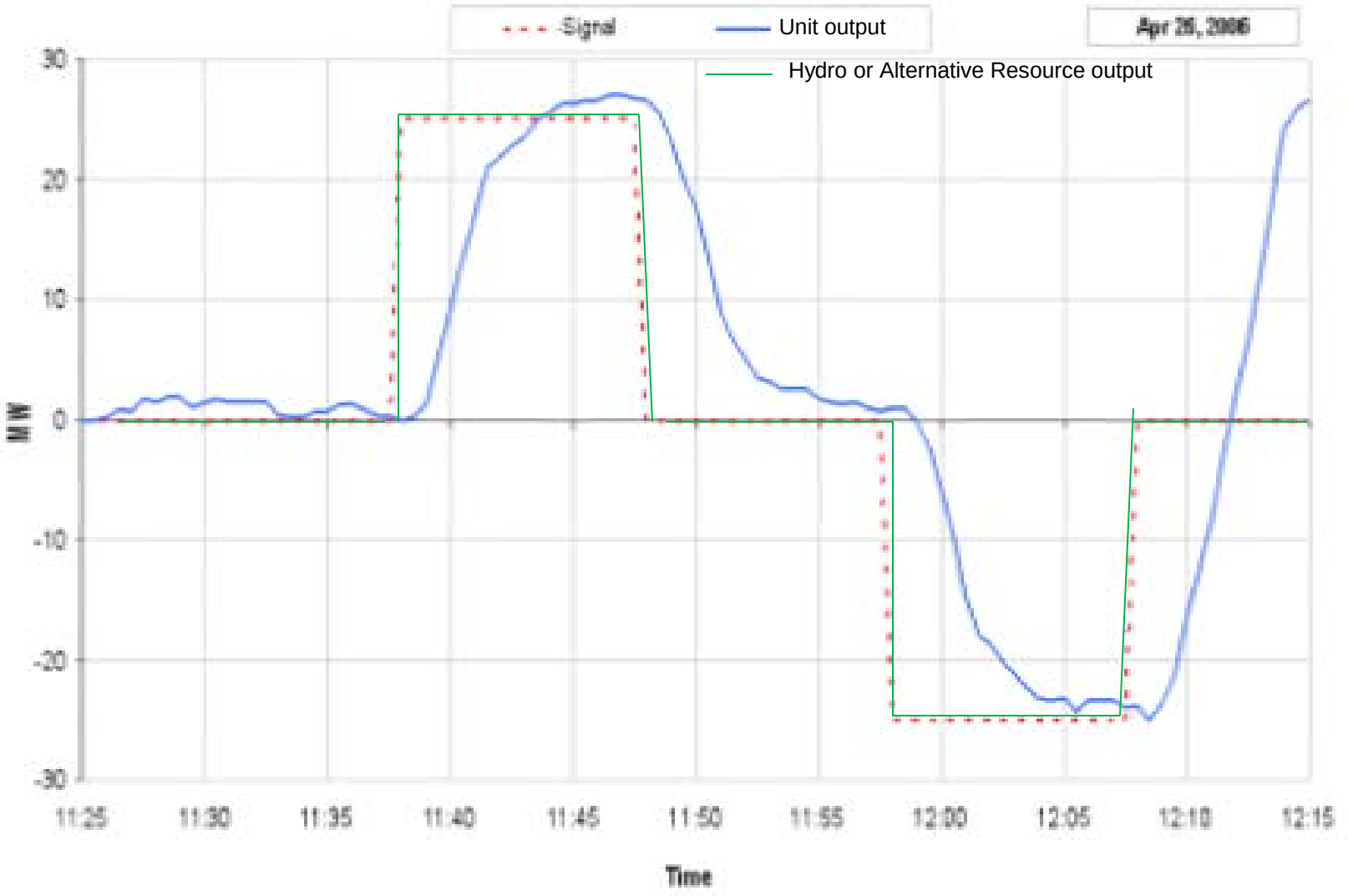
- **Definition:**
  - A variable amount of generation energy under automatic control which is independent of economic cost signal and is obtainable within five minutes
- **Regulation Control Signal**
  - Control signal sent by PJM to Resource owner
  - Sent every 2 seconds, Bounded by Regulation MW assignment
- **Requirement**
  - Real-time performance is not measured
  - Standardized regulation test accomplishes both certification steps

❶ Generating unit certification

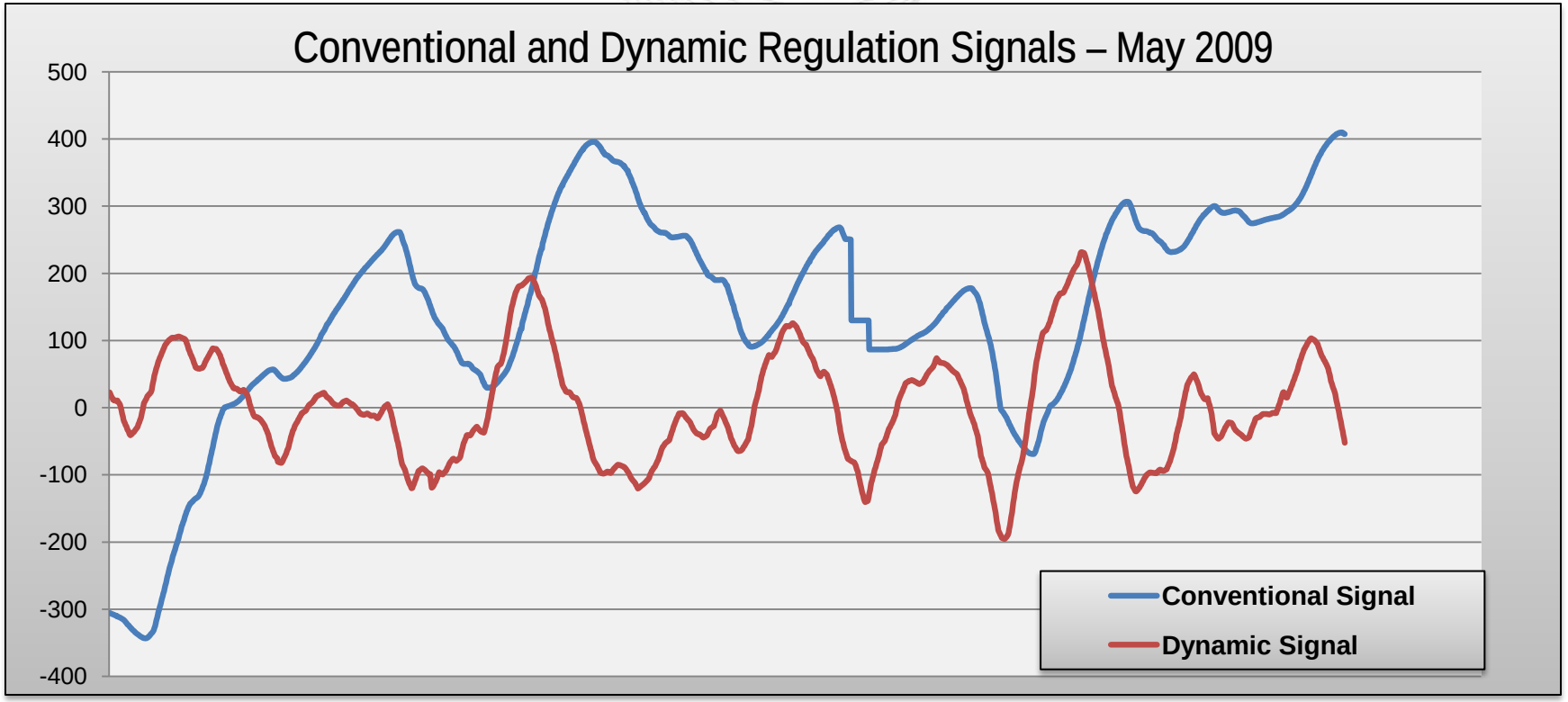
❷ Regulating capability verification



Typical Thermal Generator Response to Regulation Test Pattern



Example Regulation Signals



- Sample regulation signals for one hour
  - Existing *conventional* signal has 3 zero crossings
  - New *dynamic* signal has 19 zero crossings

- PJM has proposed to implement a Regulation Market Incentive Payment to address these issues.
- The incentive payment will be based on…
  1. the accuracy with which a resource followed the regulation signal during the hour.
  2. the quantity it moved during the hour it provided regulation.
  3. the highest cleared regulation offer price during the operating hour.
- Incentive payment will be in addition to current regulation market payments

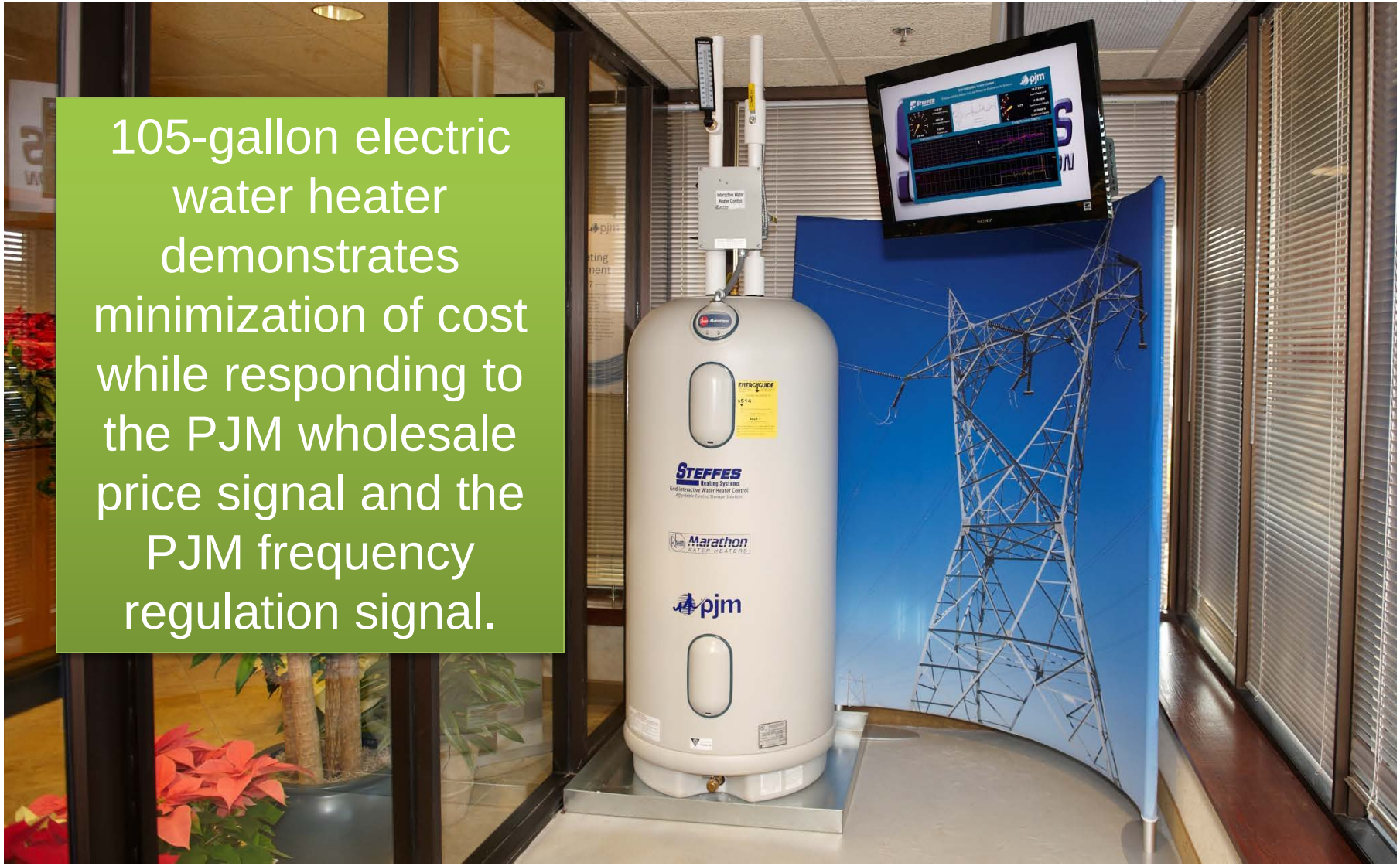
- **Accuracy:** High standards for accuracy will be required for eligibility to receive the payment.

- **Quantity:** PJM will analyze second-to-second changes in the regulation signal in comparison changes in resource output to determine how much the resource moved.

- **Offer Price:** Using the highest cleared offer price provides a market based method for determining the value of response to the regulation signal each hour.

- PJM believes that an incentive payment based on the quantity and accuracy of response to the regulation signal will
  - Improve overall performance of the regulation fleet.
  - Provide long-term cost benefits by requiring less regulation due to enhanced quality and diversity.
  - Eliminate need to increase ancillary service targets due to EPA restrictions and intermittent resource penetration
  - Facilitate growth in alternative technology resources capable of near instantaneous responses to control signals (batteries, flywheels, etc.)
  - Allow PJM to use multiple regulation signals to best capitalize on the unique attributes of all resources.

Water Heater



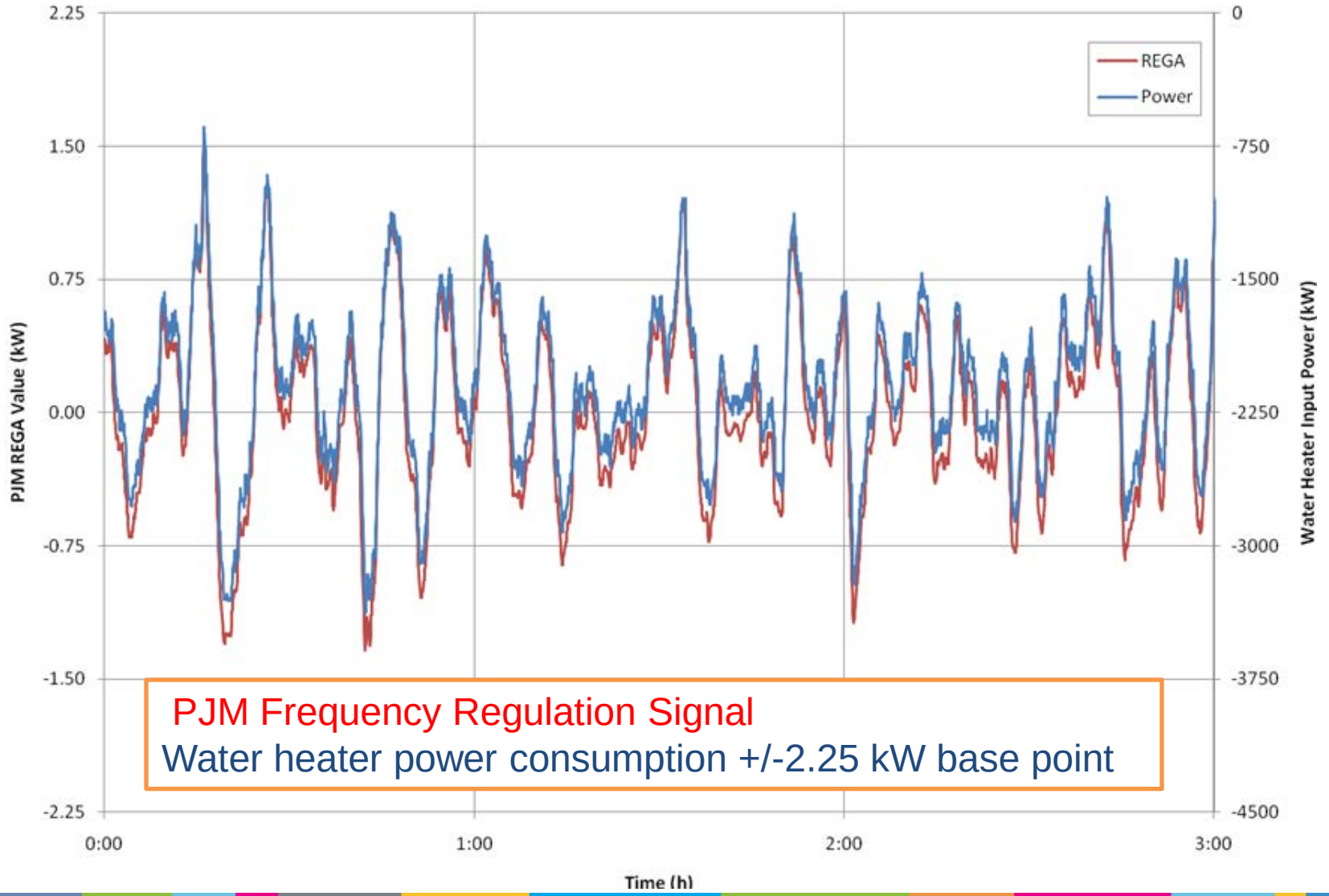
Water Heater – Optimization of LMP and Frequency Regulation

Charging during low LMP periods

Following PJM frequency regulation

Pilot water heater in use by PJM Technology Center

PJM Pilot Water Heater -- January 14, 2011; Midnight to 3:00 a.m.



PJM Frequency Regulation Signal

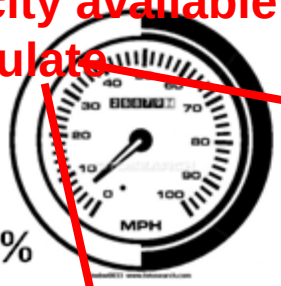
Water heater power consumption +/-2.25 kW base point

STEFFES GRID-INTERACTIVE WATER HEATER CONTROL

Enhance Reliability, Reduce Costs, and Protect the Environment for Everyone

LOAD RESOURCE SNAPSHOT

THERMAL BATTERY LOAD



0.22 kW
UP-REGULATION CAPACITY

4.28 kW
DOWN-REGULATION CAPACITY

4.50 kW
MAXIMUM LOAD

Capacity available to regulate

ENERGY RESOURCE SNAPSHOT

THERMAL BATTERY CHARGE LEVEL

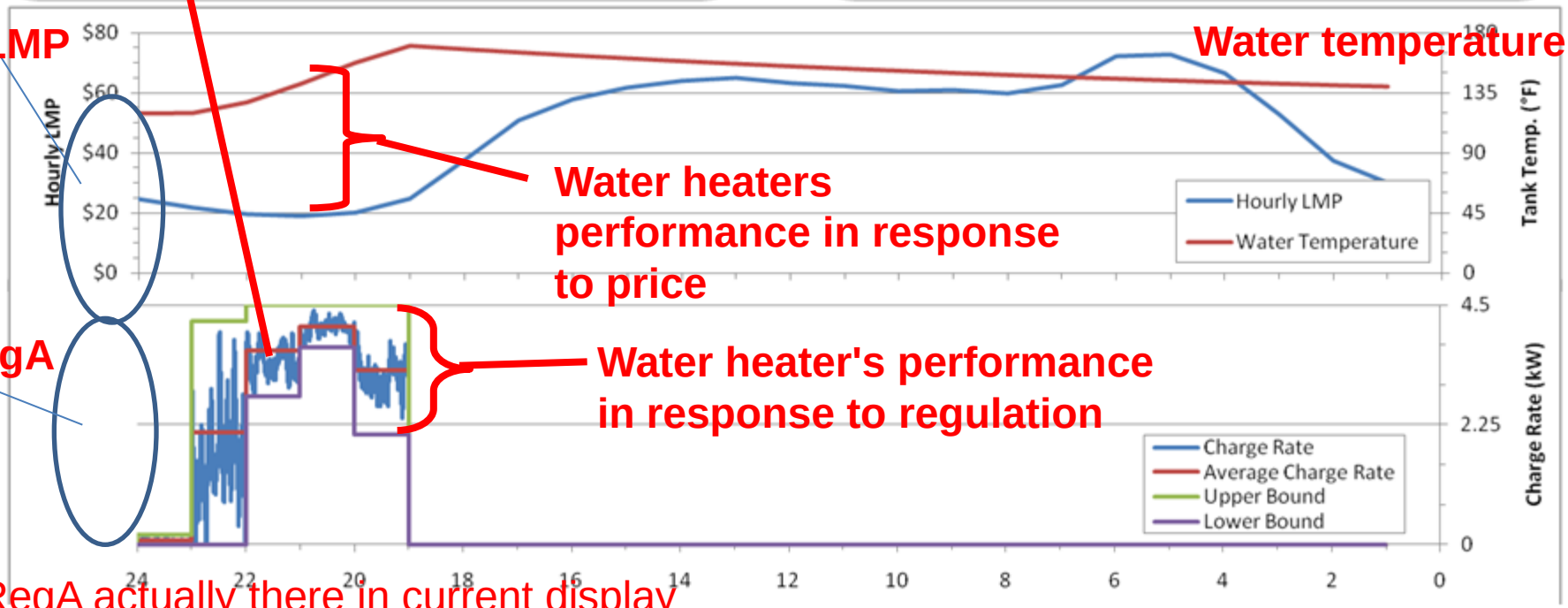
14.2 kW·h
CURRENT CHARGE LEVEL

11.8 kW·h
CURRENT RESERVE CAPACITY

26.0 kW·h
TOTAL STORAGE CAPACITY

LMP

Water temperature



Water heaters performance in response to price

RegA

Water heater's performance in response to regulation

RegA actually there in current display

AES Grid-Scale Energy Storage System