Electric Vehicles and Wholesale Markets

Power Conditioning System Architectures for PEV Fleets as Grid Storage
The Pentagon
June 13, 2011

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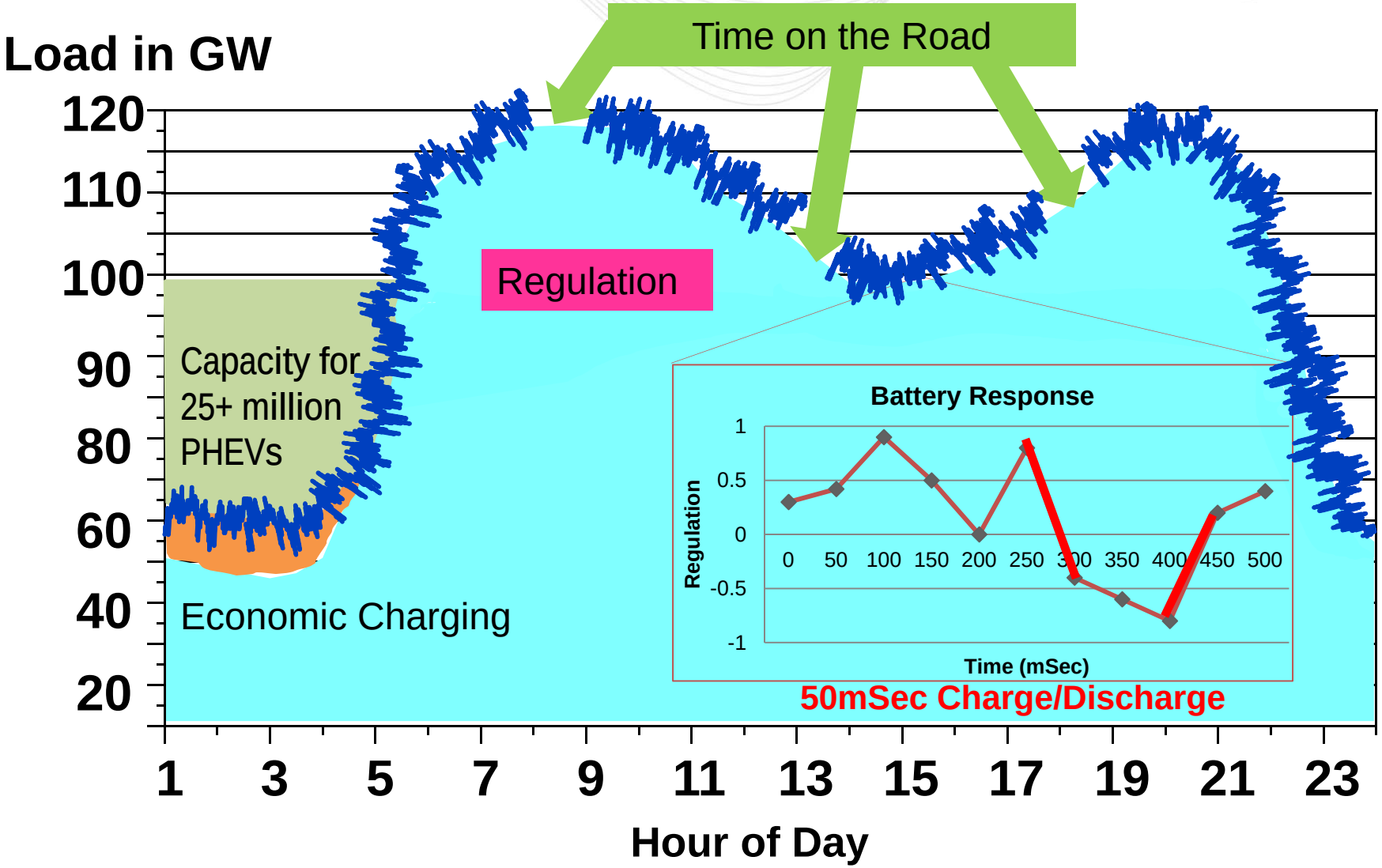
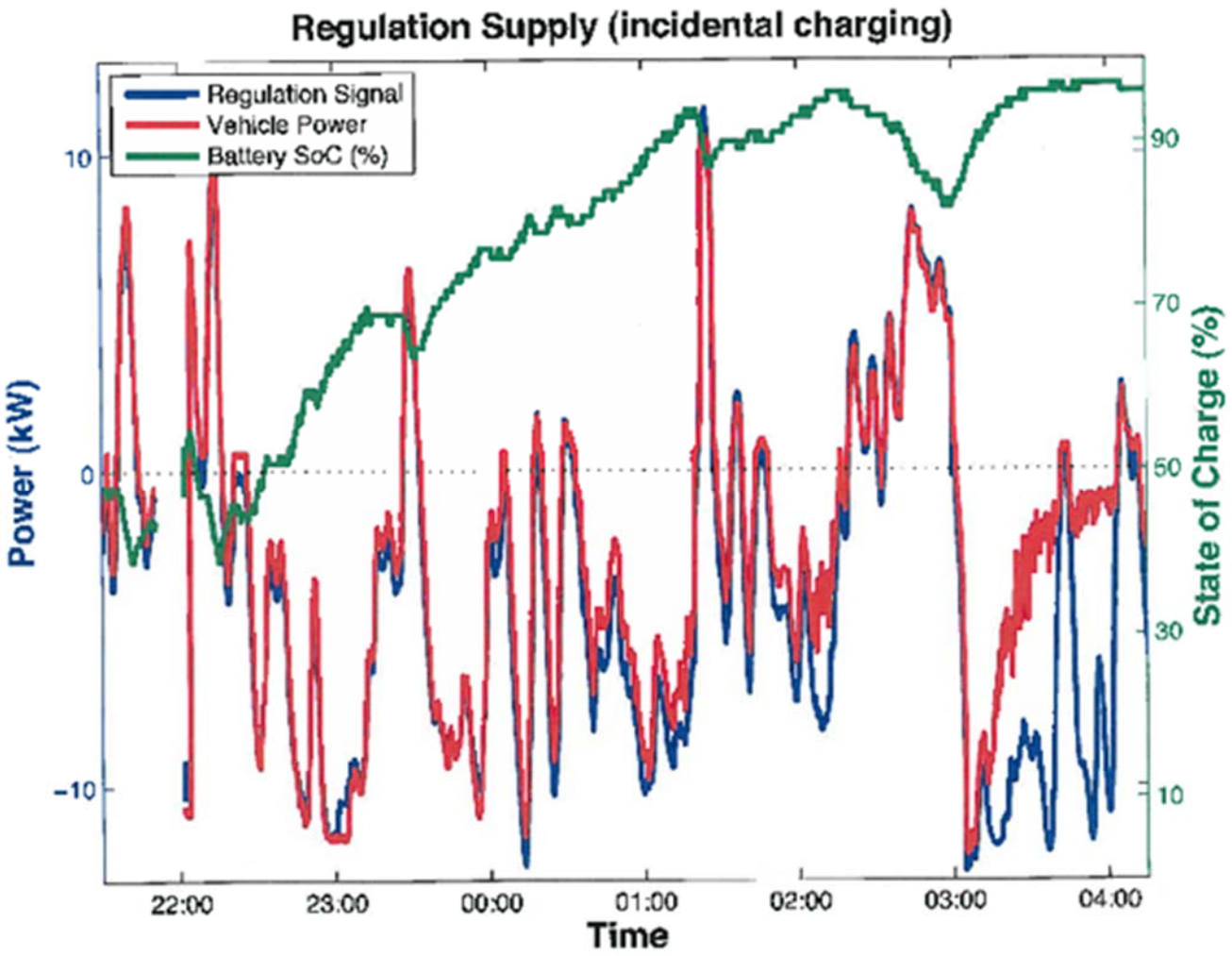
Grid Benefits – Regulation vs. Economic Dispatch



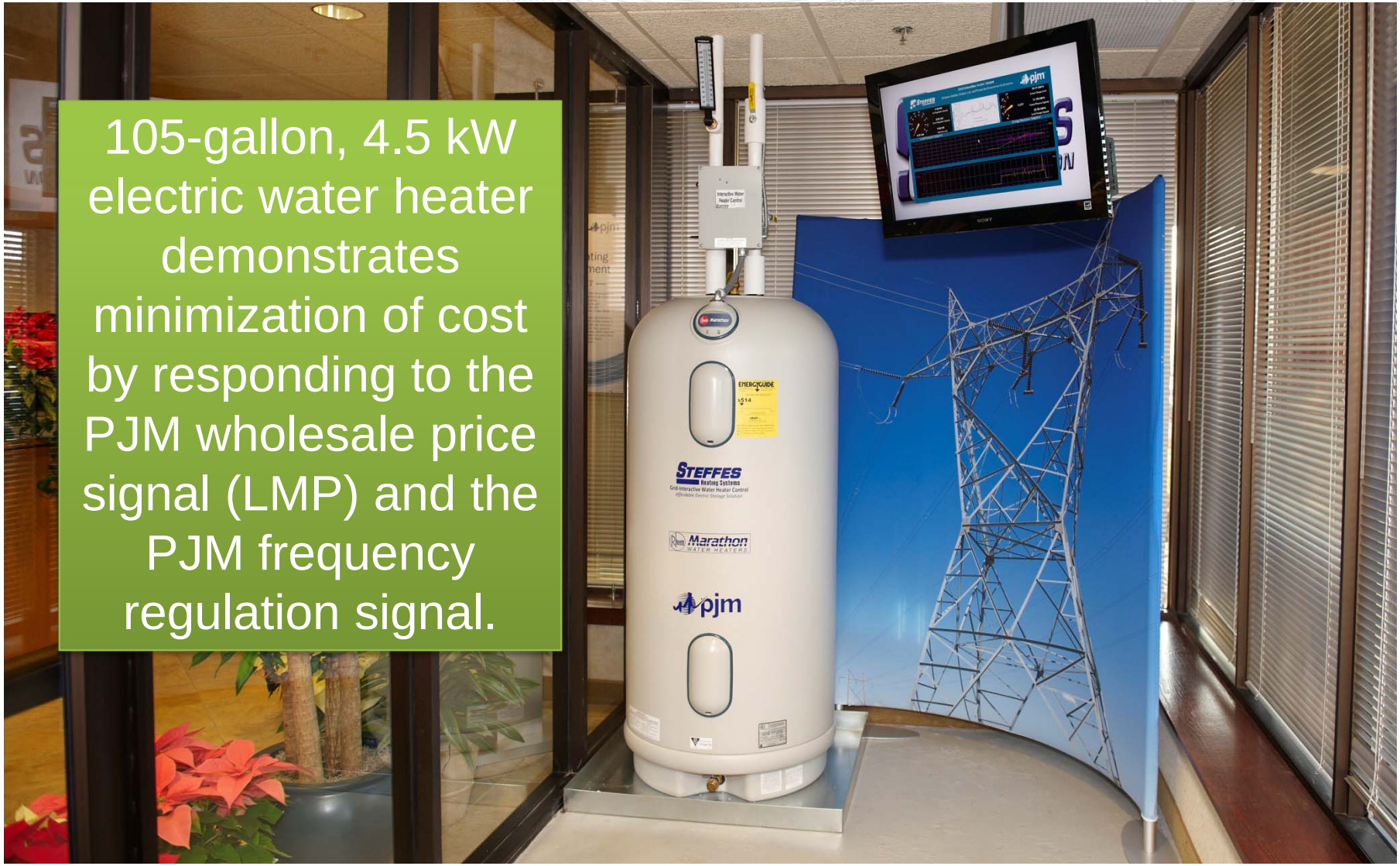
MAGICC – PJM's PHEV Demonstration Project

- Mid-Atlantic Grid Interactive Car Consortium (MAGICC)
- Providing Regulation from 5 aggregated vehicles
- **Over three years experience**

MAGICC – PJM's PHEV Demonstration Project



Water Heater



Water Heater – Optimization of LMP and Frequency Regulation

Charging during low LMP periods

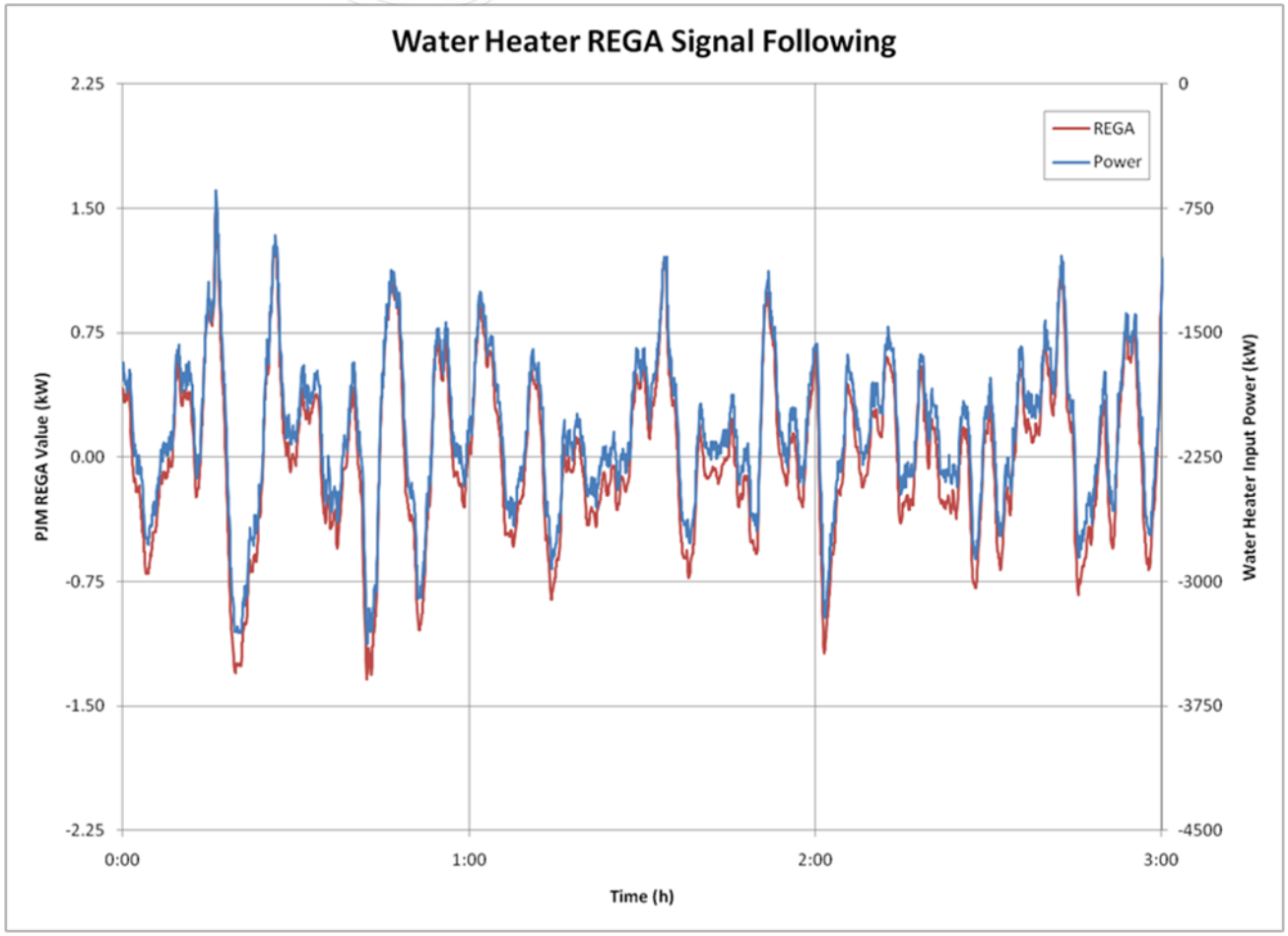
Following PJM Regulation signal

All while providing hot water to PJM Technology Center building

Fast Regulation: Speed Matters…

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



Market Opportunities

Market	Performance Requirements	Size	Value
Regulation	Full raise/lower within 5 minutes and hold for 5 minutes; new requirements for fast-response “pay for performance” market clearing process (coming 2012)	1% of forecasted peak load ~600 – 1,500 MW; 2010 average, 893 MW	2010, $18/MW-h
Synchronous Reserves	Respond within 10 minutes for a duration of 30 mintues	1,246 MW, average	2010, $10.55/MW-h
Economic Energy	N/A	Average real time load, 76,035 MW; System peak, +158 GW	Average, $47.65/MWh