Market Potential for Water Heater Demand Management

Elliot Boardman
Executive Director
Peak Load Management Alliance
(561) 422-2244
eboardman@peaklma.com

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Outline

- US Electric Water Heating Market
- Methodology for Calculating Savings Potential
  - Standard Direct Load Control
  - Dedicated Off Peak Water Heating
- Savings Potential Results
- Connection to Renewable Energy
- Conclusions

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Electric Water Heating Market

Why target electric water heating?

- According to various sources, electric water heating constitutes about 40% of the US residential water heating market:
  - 2007 US Census: 42% residential electric water heating
  - 2005 RECS: 39% residential electric water heating
- This equates to over **53 million** homes

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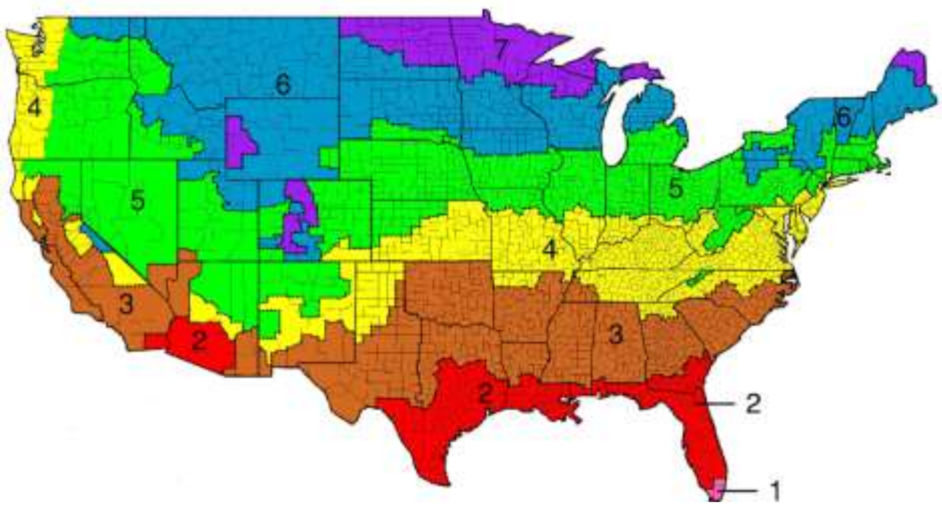
Quantifying Possible Savings

Savings Estimates for Direct Load Control

- Residential modeling software EnergyGauge was used to determine savings for a prototype home in several different weather zones throughout the US
- Locations selected consisted of 2 cities in each of the IECC designated primary climate zones

IECC Nationwide Climate Map



IECC Weather Zone	Locations Selected for Analysis
2	New Orleans, LA
2	Jacksonville, FL
3	Dallas, TX
3	Sacramento, CA
4	Washington DC
4	Seattle, WA
5	Denver, CO
5	Albany, NY
6	Burlington, VT
6	Minneapolis, MN

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Quantifying Possible Savings

Savings Estimates for Direct Load Control Continued

- Generic Home Model Used: single family, one story, 1850 sq ft home, 3 bedrooms, 2 bathrooms, etc (see full paper http://www.peaklma.com/documents/WaterHeaterDemandManagement.pdf for all model details)
- For each of the locations selected this same prototype home was simulated – The generic home model had a 50 gallon electric storage water heater
- For the direct load control demand savings, the hour of curtailment selected was from 4pm to 5pm
- Each of the hourly water heater load shapes for the various weather zones were reviewed for their simulation-assigned summer peak day at the hour of 4pm to 5pm

Quantifying Possible Savings

Savings Estimates for Direct Load Control Continued

Electric Water Heater Annual Energy Consumption and Water Heater Summer Peak Demand for Each Location Analyzed

Zone	Location	Annual Water Heater kWh Consumption	Summer Water Heater Peak Demand (hour ending 5pm)
2	New Orleans, LA	2,675	0.29
2	Jacksonville, FL	2,671	0.31
3	Dallas, TX	2,837	0.28
3	Sacramento, CA	3,141	0.35
4	Washington DC	3,515	0.39
4	Seattle, WA	3,650	0.46
5	Denver, CO	3,636	0.43
5	Albany, NY	3,847	0.46
6	Burlington, VT	4,027	0.49
6	Minneapolis, MN	4,317	0.51
	Average	**3,432**	**0.40**

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Quantifying Possible Savings

Savings Estimates for Direct Load Control Continued

- Expected participation rates on a national scale can be estimated
  - The Federal Energy Regulatory Commission (FERC) released a study estimating that direct load control programs for residential central air conditioning could have participation rates as high as 25% without the benefit of any favorable pricing programs
  - In addition there was further estimates that with AMI participation could be expected to fall between 19-100%
- For purposes of this Water Heater Demand study, the 25% participation was used as a starting point, although participation rates could be potentially higher since water heater demand control has a less noticeable impact on a customer's comfort level, than air conditioner demand control.

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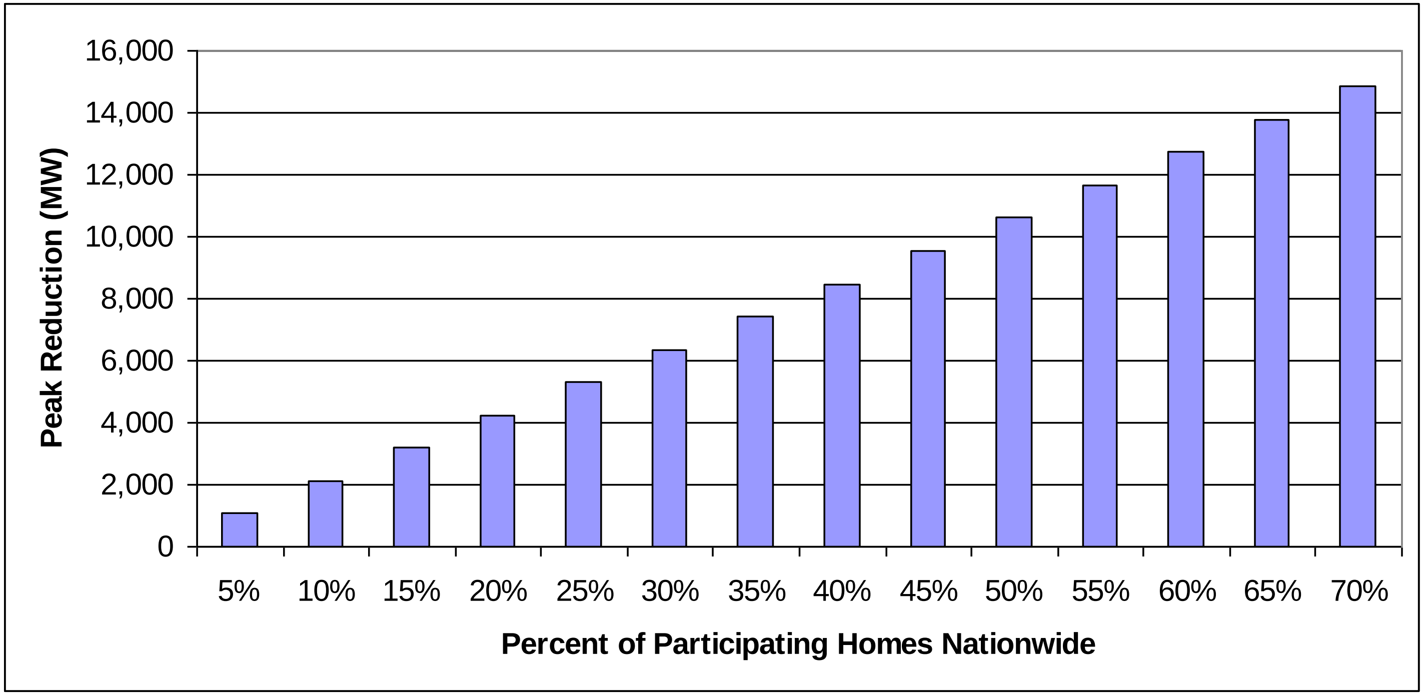
Quantifying Possible Savings

Savings Estimates for Direct Load Control Continued

- Applying the previous data discussed, assuming a market of about 53 million homes, with the average participant creating a 0.40 kW peak reduction, savings estimates were projected out over various participation rates. Note that if 25% were reached, that would indicate 5,300 MWs of peak demand reduction.



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Quantifying Possible Savings

Savings Estimates for Extended Curtailment Periods

- Great River Energy in Minnesota offers an Off-Peak Water Heating program to their customers, in addition to a typical direct load control program. The Off-Peak Water heating program permanently moves the demand of the participants to off-peak periods year-round.
- The Off-Peak Water Heating program cycles high-efficiency electric storage water heaters off over a 16 hour control period (this program does require customers to install larger capacity water heaters). In return, customers participating in this program receive a special off-peak rate.

Participation and Savings Estimates for Great River Energy's Water Heating Curtailment Programs

	Peak Shave Water Heating Program	**Off-Peak Water Heating Program**
Strategy	Peak Reduction	Valley Filling
Number of Customers	37,800	58,000
Peak Reduction Capability	~20 MW	50 MW Year Round
Curtailment Period	4-8 hours when curtailment is needed	7am to 11pm (16 hours) Monday-Friday

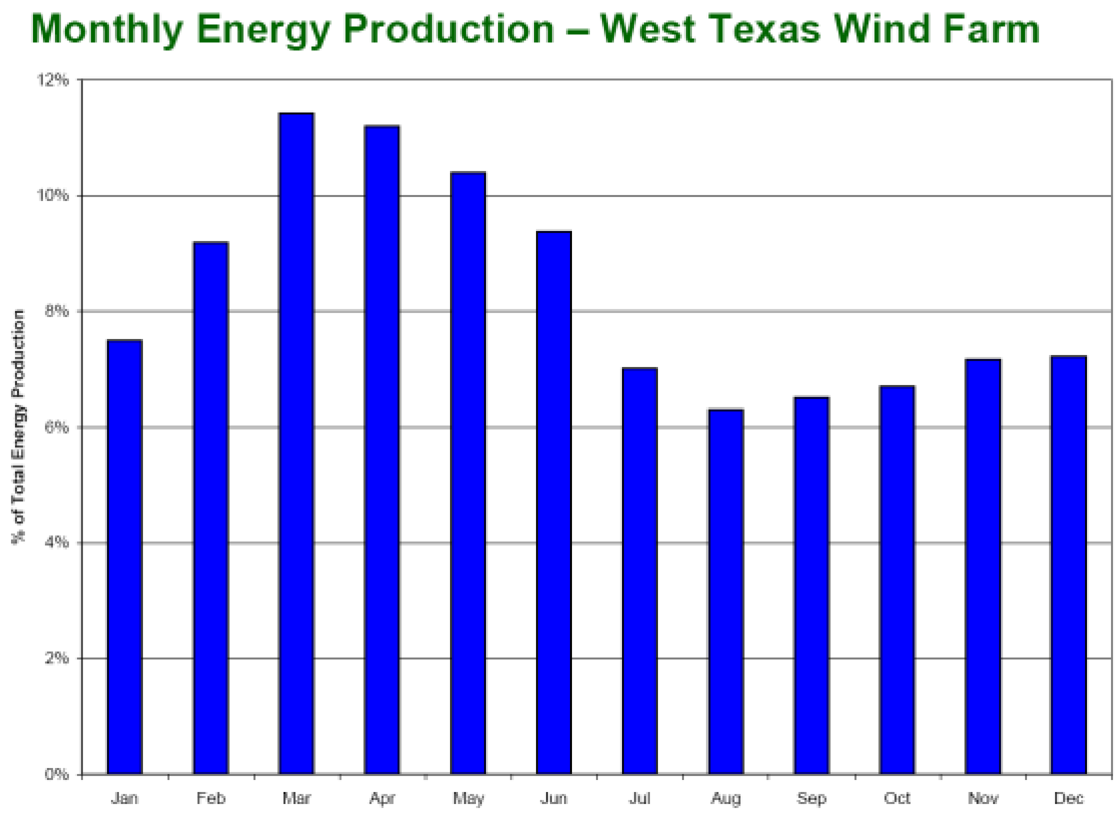
Renewable Energy Potential for Electric Water Heating

Contributing factors:

- Water heaters, unlike most home appliances, and HVAC equipment, are retaining and delivering hot water on a continuous year-round basis
- Water heaters can be effectively modified to operate only during off-peak hours
- Customers are less likely to notice a curtailment of their water heater, than their air conditioners

Renewable Energy Potential for Electric Water Heating

Renewable energy production doesn't always occur when we want it to!



Balancing Renewable Energy Potential with Electric Water Heating

How to get to off-peak water heating:

- Requires installation of large capacity/high efficiency electric water heaters with a dedicated device with temperature and voltage control capability connected to a utility-controlled load control switch or AMI device
- The water heaters would need to be able to heat past conventional set point temperatures, which would require a thermostatically controlled mixing valve to be installed as well

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Conclusions

- Straight direct load control programs for water heating have the potential to provide significant demand reductions across the nation
- Due to volatility in renewable energy generation, such as wind energy, off-peak electric water heating could generate higher demand for renewable energy
- The success of any off-peak water heating program will be dependent on cost, and would be most beneficial for utilities that have high on-peak generation costs

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Questions?

eboardman@peaklma.com
(512) 422-2244

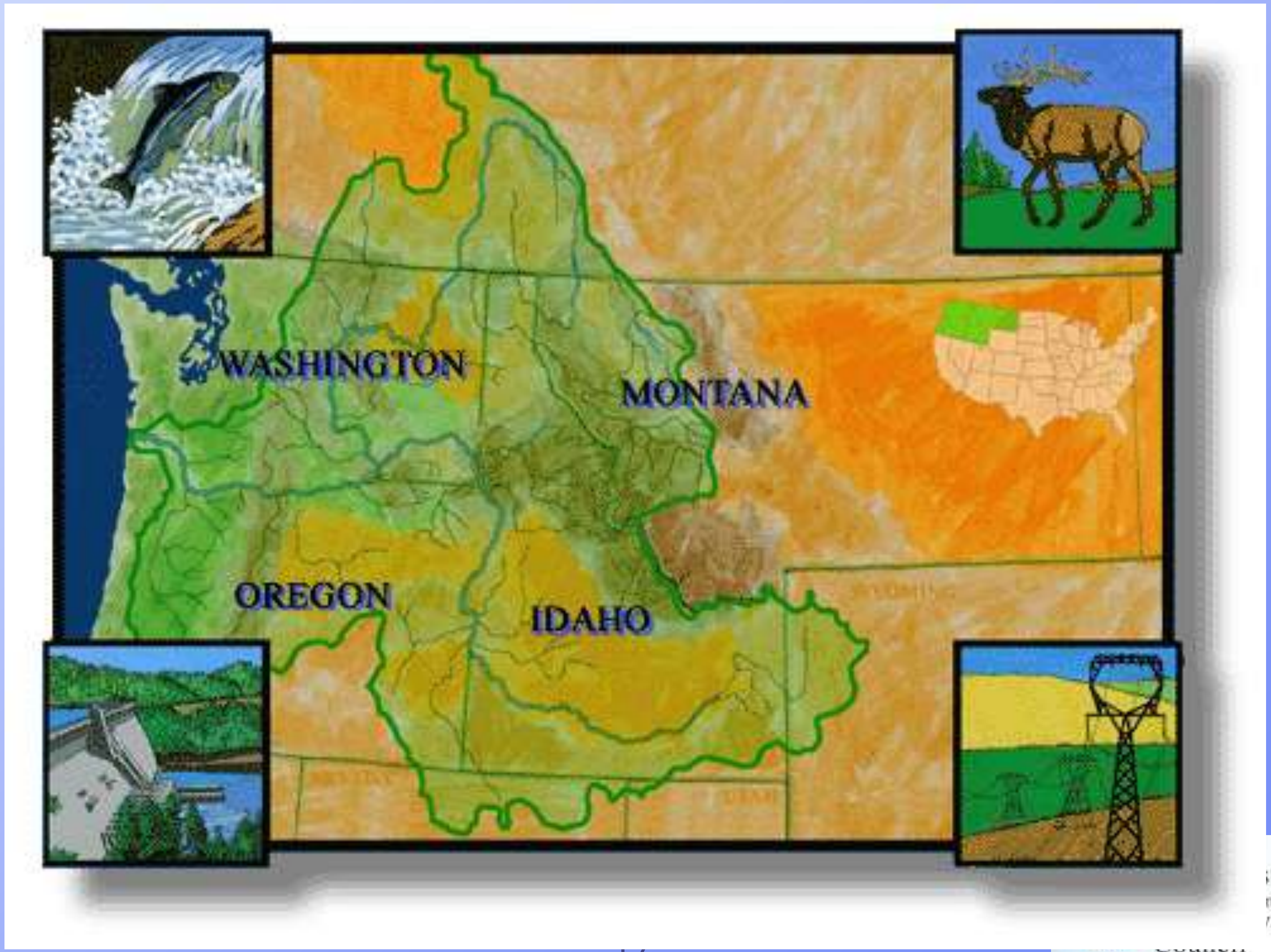
The following presentation was presented at the PLMA Fall 2011 Conference, November 2011 in Alexandria, Virginia

Wind Integration from Demand Response: Load that Moves Both Ways

PLMA Fall 2010 Conference, Nov. 9-10

Ken Corum & Ken Dragoon
NW Power and Conservation Council

The Pacific Northwest



System Operators' Job in the Operating Hour

- Given forecast load and scheduled generation,
- Match actual load, actual generation
  - Loads are uncertain and volatile
  - Generators, transmission are not perfectly reliable
  - Wind and solar are variable, increasing share of system

System Operators' Tools in the Operating Hour

- Resource reserves for balancing, e.g.
  - Simple cycle gas turbine or hydroelectric generator running at 80% of capacity
  - Capable of increasing to 100% and decreasing to 60% quickly
  - Balancing reserves = 20% up and down

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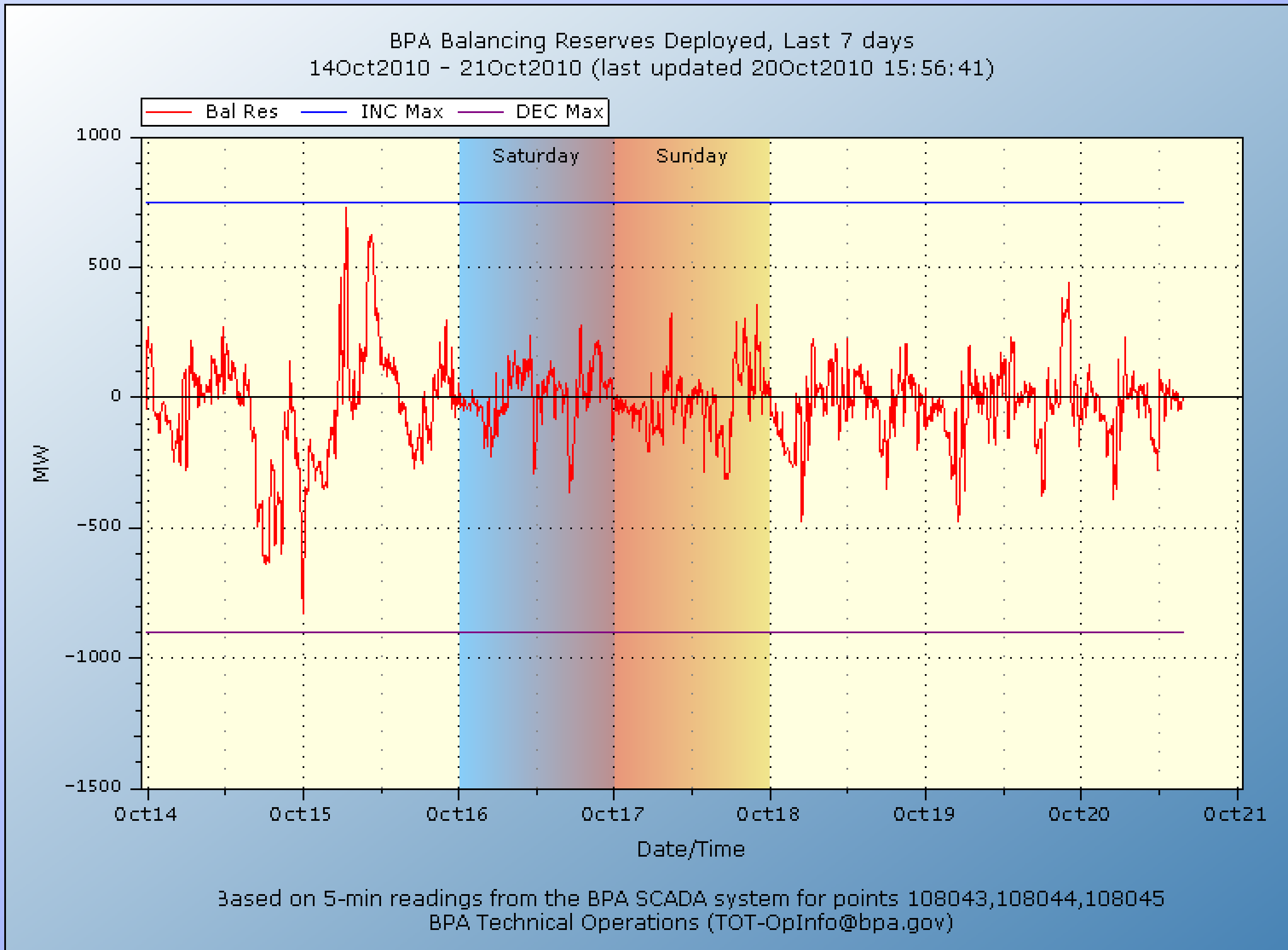
Balancing Services Deployed – BPA



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"Conventional" DR

- Reductions in load at or near peak
- Dozens of hours/year
- Mostly avoids capacity cost

DR for Balancing Reserves

- Includes both increases and decreases in load
- Needed virtually every hour of year
- Avoids capital and operating costs
- Requires quick response, flexibility

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So What Kind of DR Might Work?

- Water heating, w/ expanded energy storage, smart grid tech
- Cold storage warehouses
- Pumping into reservoirs
- Some electrochemical processes
- Ice storage for HVAC

Thermal Storage Water Heater - Decrease Load

- Delay recovery when hot water is used
- Stored water is stratified, so temp at tap remains stable
- 6-8 kWh typically stored in 50 gallon tank at 120^{o}F

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Thermal Storage Water Heater – Increase Load

- Increase storage temp
  - 170°F stores 6 kWh more than 120°F (50 gallon tank)
  - “Tempering valve” ensures hot water leaving tank = 120°F
  - Energy recovered when hot water used
    - heater off until tank temp = 120°F

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Thermal Storage Water Heater - Additional Services

- Reduce peaks/fill troughs
  - Avoid capacity costs and/or
  - Serve heavy-load hours at light-load hour prices
  - Standby losses on extra storage = 0.4%/hr (for perspective, pumped storage one-cycle loss = 20-25%)

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Pilots Testing Concept in Pacific Northwest - 1

- Water heaters
  - 100 conventional w/controls and communication
    - Control strategy creates “room” for energy
  - ~100 thermal storage w/ controls and communication
    - Allowing temps < 170^{o}F creates storage capacity

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PNW Pilots - 2

- Space heaters
  - Thermal storage, controls, communication
- Cold storage warehouses
  - Thermal storage (frozen food), controls, communication

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PNW Pilots – 3

- > Six utilities in Bonneville Power Administration pilot projects
- Recruitment and installations underway, results in fall 2012
- Potentially more in PNW Smart Grid Demonstration Project (BPA, Pacific Northwest National Lab, 11 regional utilities)

From here?

- Early days – pilots to prove concept
- Costs in quantity over time?
- Optimal mix of services from resource?
- > 3 million electric water heaters in PNW => thousands of potential MW

Questions?

- kcorum@nwcouncil.org

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Comparative Cost & Efficiency

Technology	Cost/kW	Efficiency
Extended Thermal Storage Water Heaters	$100-200*	98% (5-hour storage)[@]
CAES (above ground)	$700-800[#]	75%[@]
ZnBr Flow Cell	$425-1300[#]	70-75%[@]
Pb Acid Battery	$420-660[#]	
NaS Battery	$450-550[#]	89%[@]
Flywheel	$3360-3920[#]	
Pumped Storage	$1750-2500[@]	75-82%[@]

*Steffes Corporation
[#]EPRI
[@]NWPCC