

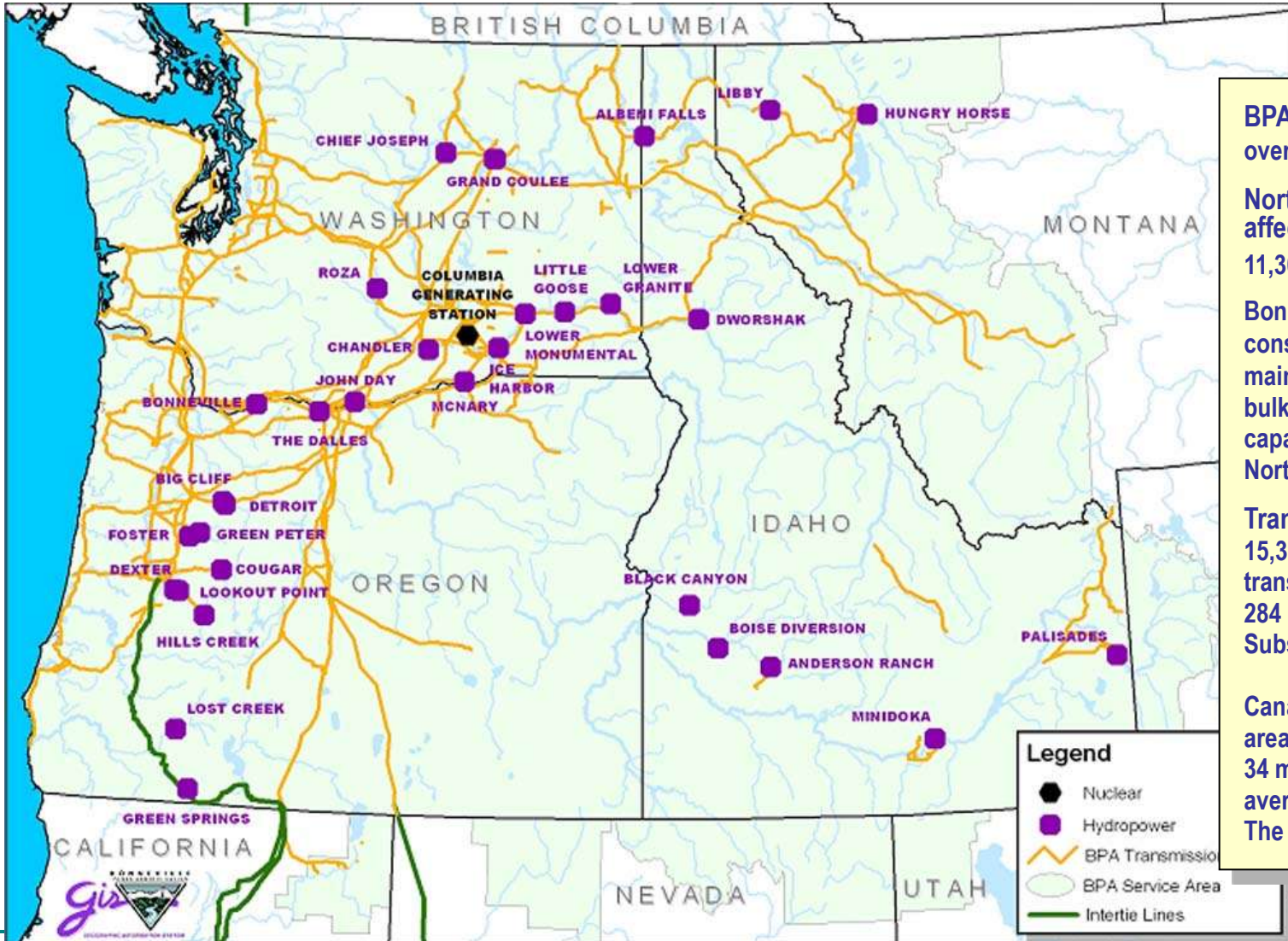
Pumped Storage and Integration of Renewable Resources



**NWHA Conference
February 18, 2010**



Federal Columbia River Power System Generation & Transmission – System Map



BPA's service area:
over 300,000 sq. miles

Northwest population affected:

11,300,885 people

Bonneville has constructed and maintains 75% of the bulk transmission capacity in the Pacific Northwest

Transmission System:
15,397 circuit miles of transmission line and 284 BPA-owned Substations

Canada has 15% of basin area but provides 30% of 34 million acre feet (maf) average annual flow at The Dalles



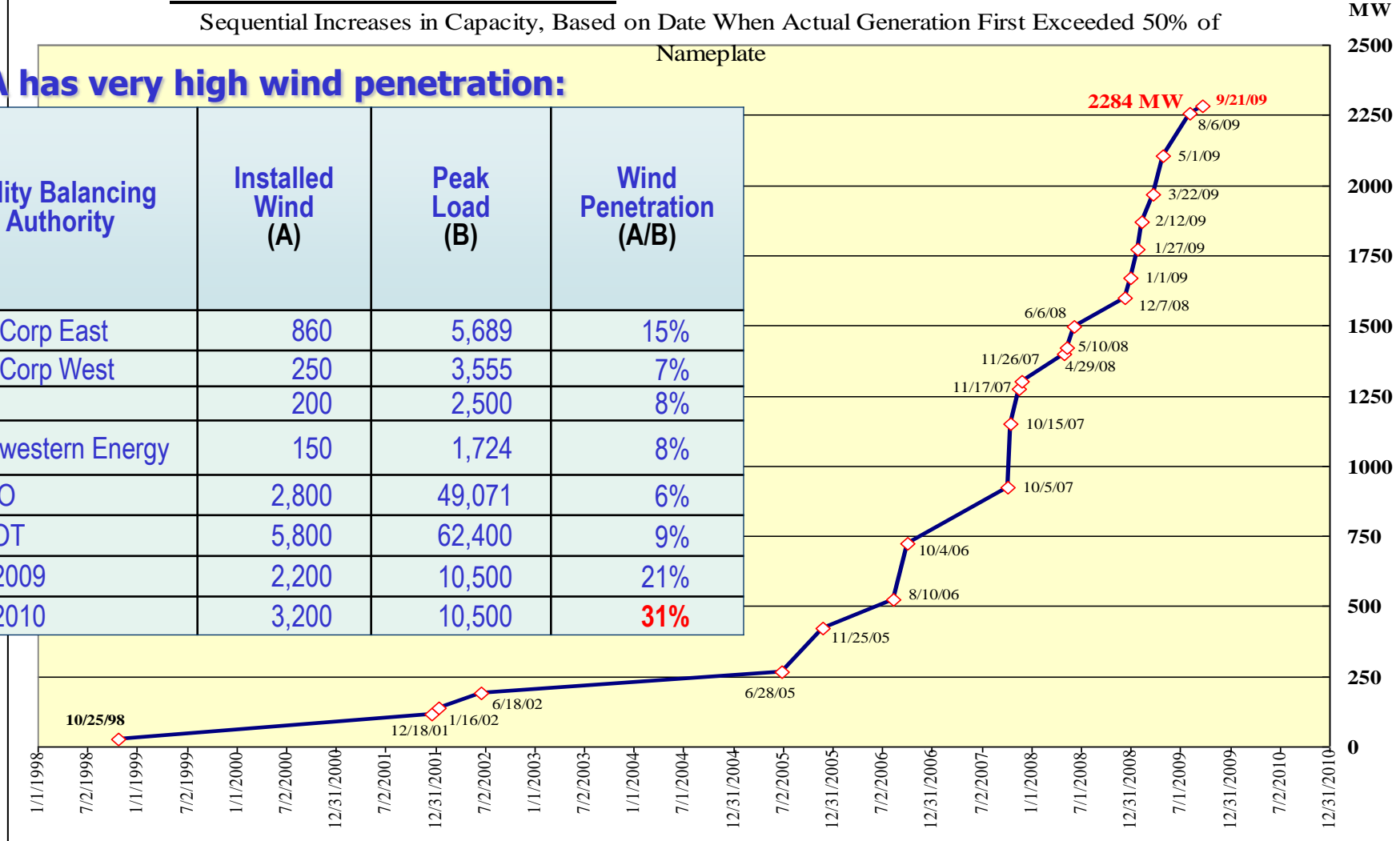
Wind Power is Growing Fast

WIND GENERATION CAPACITY IN THE BPA BALANCING AUTHORITY AREA

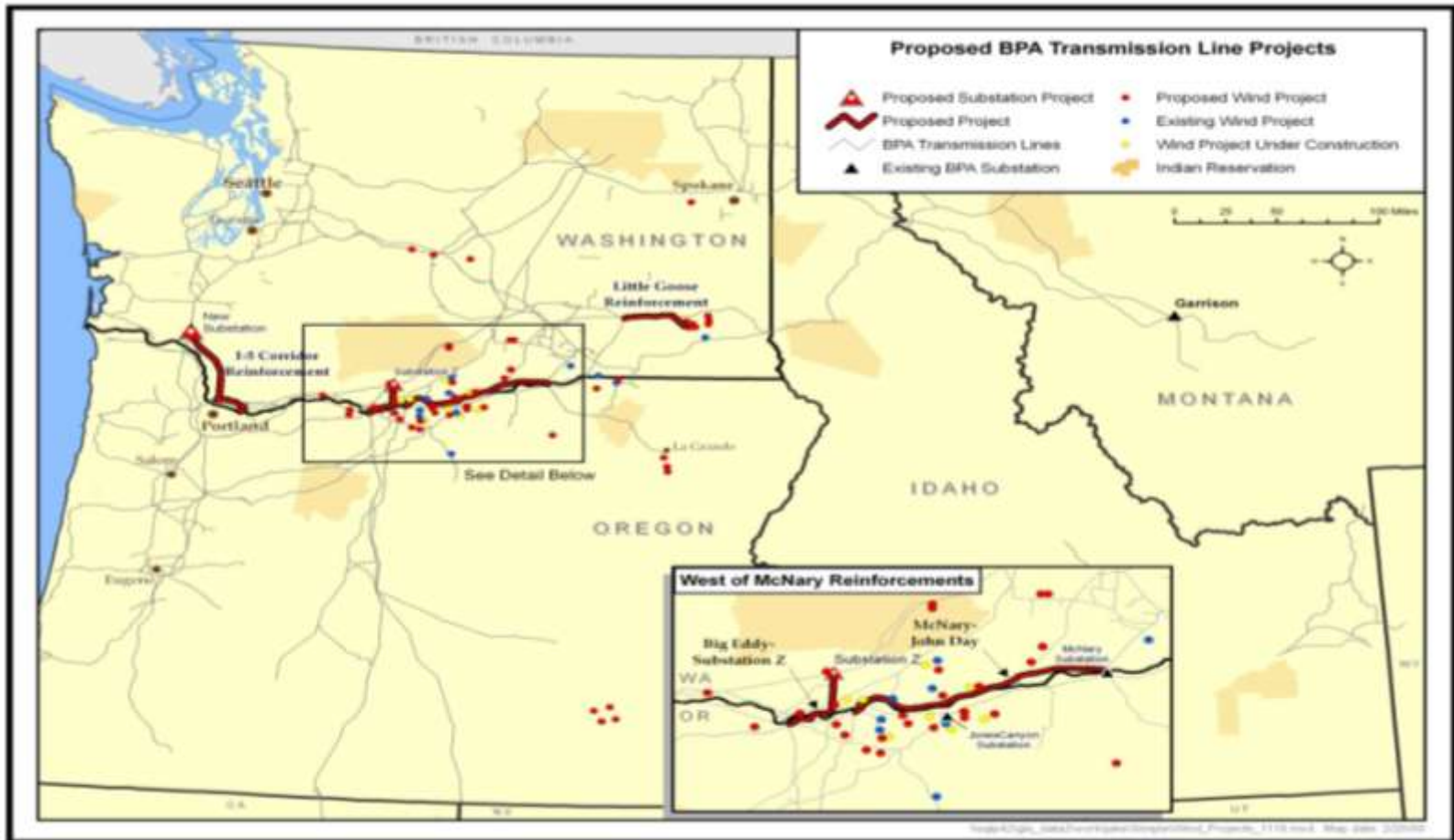
Sequential Increases in Capacity, Based on Date When Actual Generation First Exceeded 50% of Nameplate

BPA has very high wind penetration:

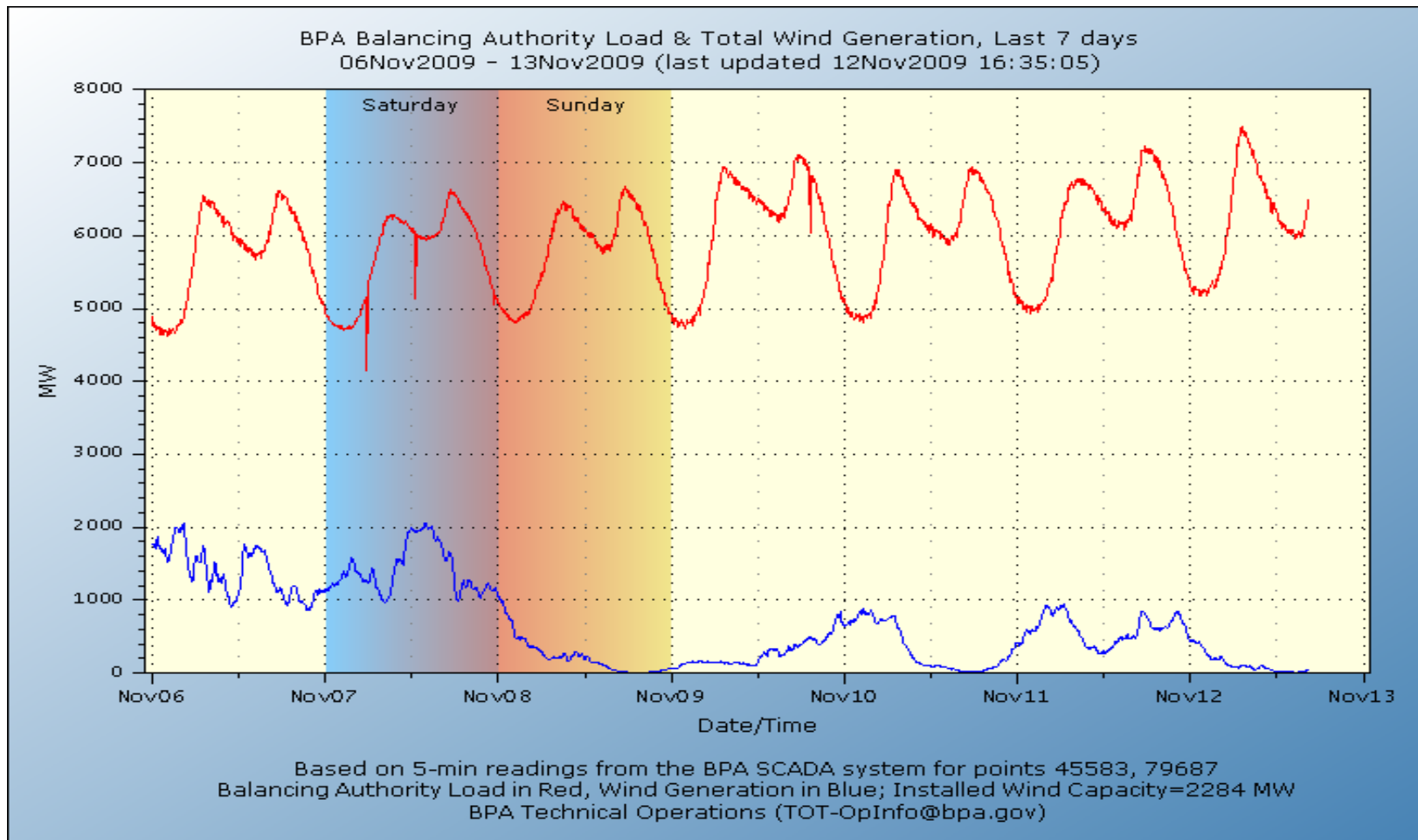
Utility Balancing Authority	Installed Wind (A)	Peak Load (B)	Wind Penetration (A/B)
PacifiCorp East	860	5,689	15%
PacifiCorp West	250	3,555	7%
PNM	200	2,500	8%
Northwestern Energy	150	1,724	8%
CAISO	2,800	49,071	6%
ERCOT	5,800	62,400	9%
BPA 2009	2,200	10,500	21%
BPA 2010	3,200	10,500	31%



Wind farms are clustered along the Columbia River near existing BPA transmission and new transmission projects



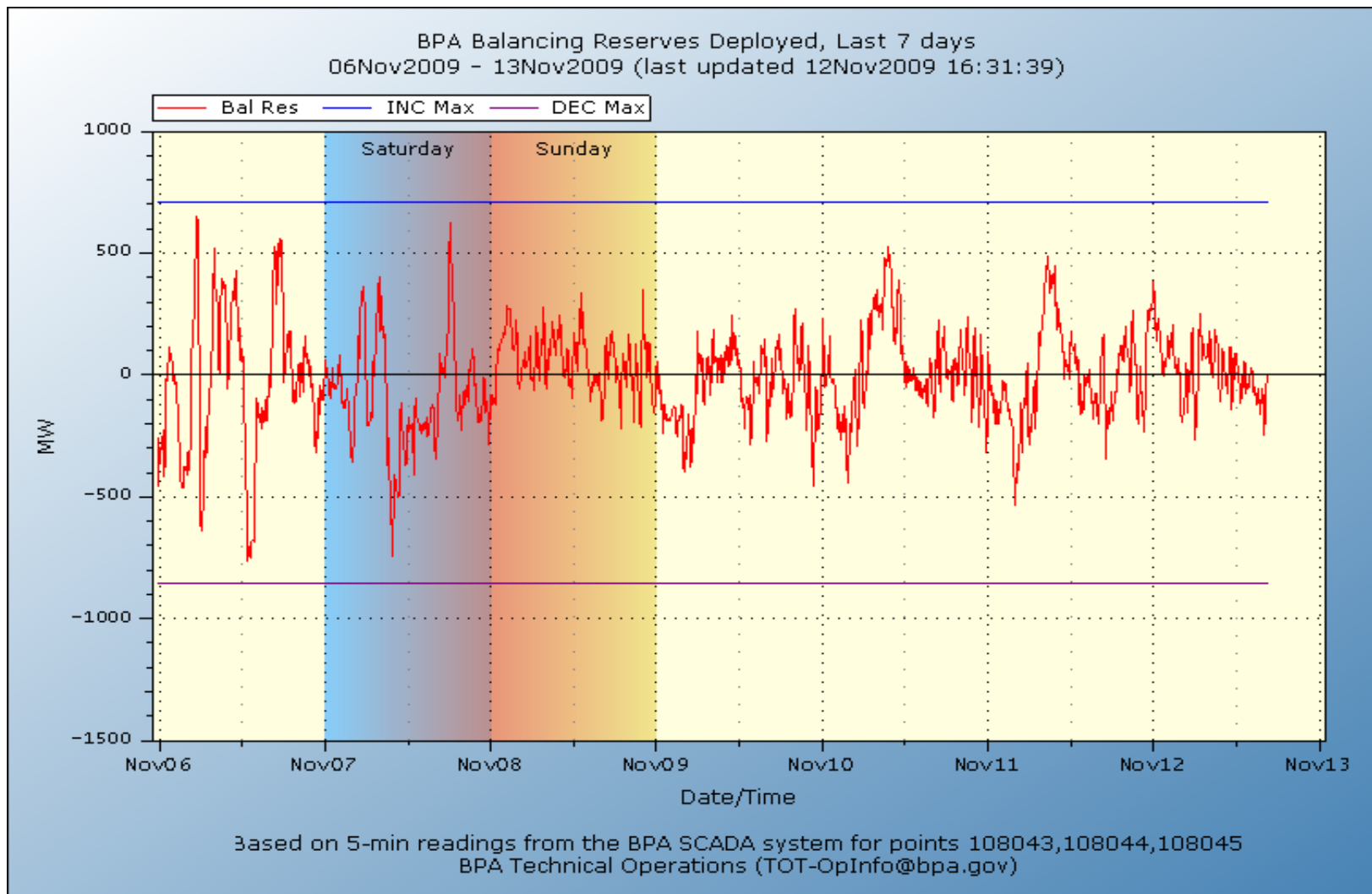
Recent Load and Wind Data (Nov 6 – Nov 12)



<http://www.transmission.bpa.gov/Business/Operations/Wind/reserves.aspx>

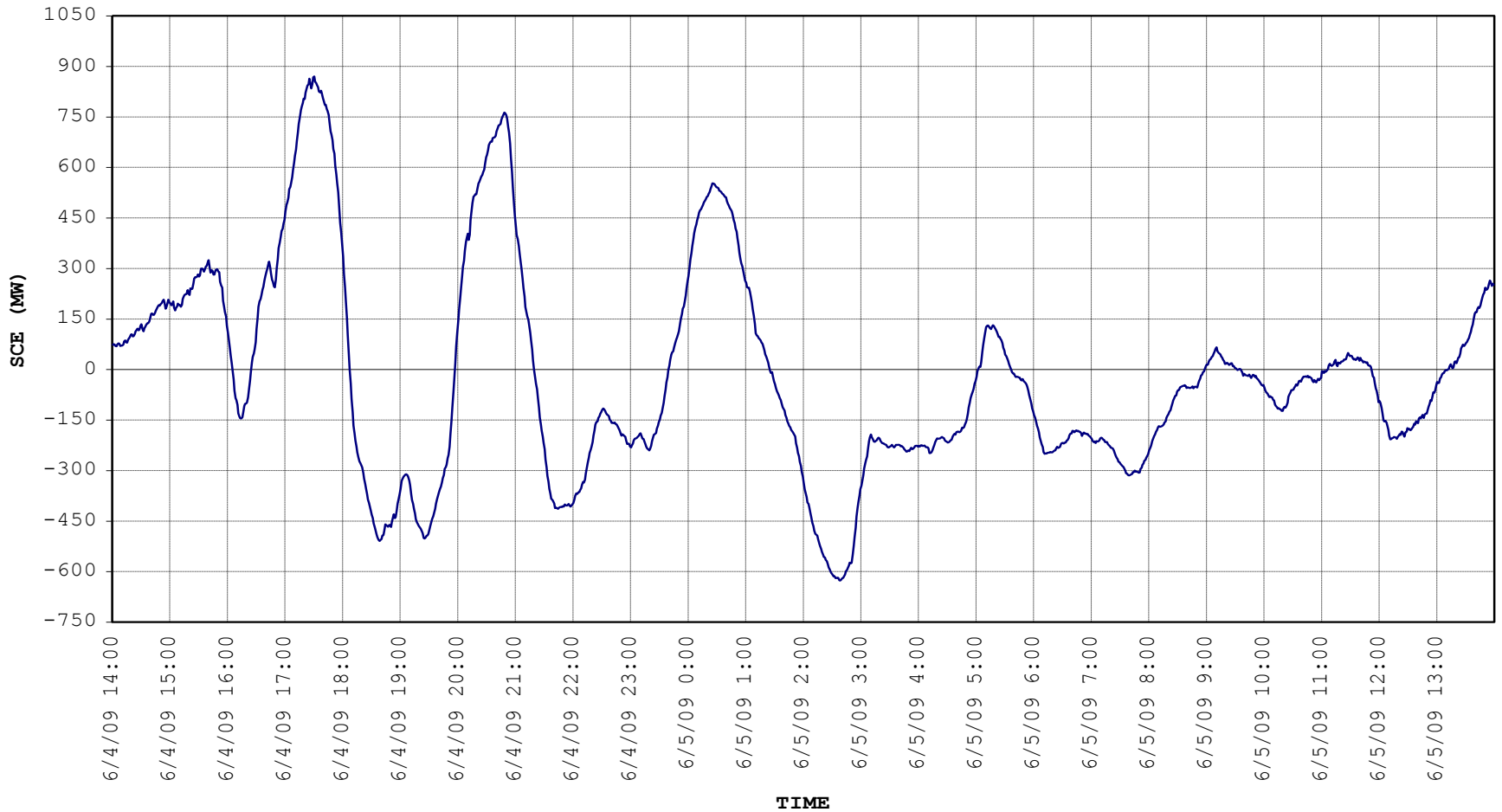


Balancing Reserves Deployed (Nov 6 – Nov 12)

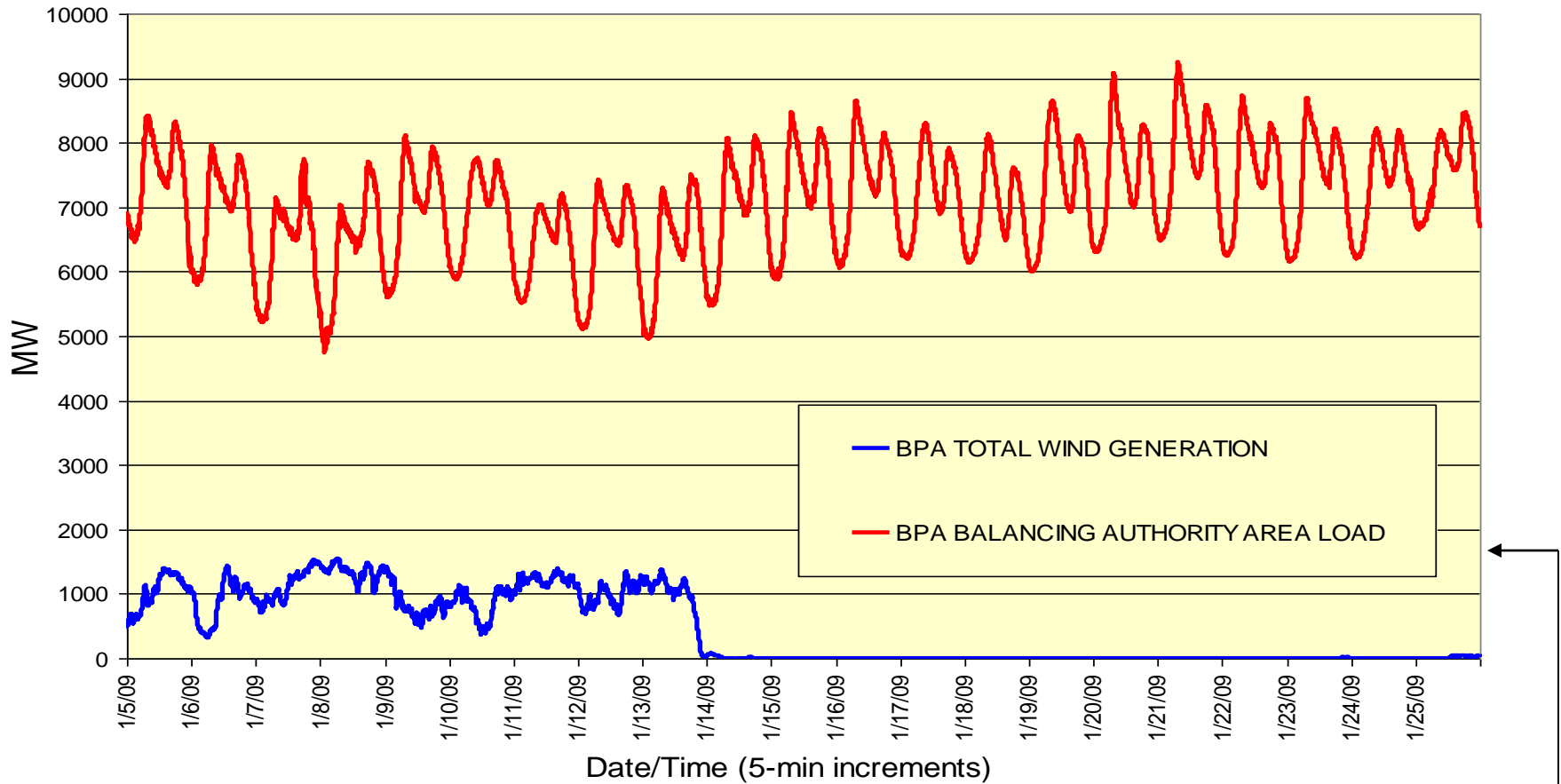


Wind Events: June 4-5, 2009

BAA WIND STATION CONTROL ERROR



BPA Balancing Authority Area Load & Total Wind Generation Jan. 5-25, 2009



Wind started coming back on Jan 26 and peaked at nearly 1600MW on Jan 29.



Potentially more than the Federal Columbia River hydro system alone can handle



- **Demands on federal hydro power system:**
 - Serve load
 - Meet non-power requirements
 - Support variable generation

- **Current estimated independent support capability:**
 - 3,000 – 3,500 MW of wind generation (could be greater with new initiatives)

- **New tools required beyond this level.**



Long-Term Solutions

- Transmission additions to reach/blend diverse wind projects
- Continued scheduling improvements
- Explore virtual Balancing Area consolidation
- Enhanced storage capability:
 - **Batteries**
 - **Pumped storage**
 - Compressed air
 - Flywheels
 - Plug-in electric vehicles
- Conservation/Demand response/Smart Grid applications



BPA Technology Innovation Project 114

OSU Wind Integration Research, Demonstration, and Exploration

- Optimal sizing of energy storage:
 - As function of forecasting
 - As function of control



Energy Storage Matrix

	Batteries							Flywheels (low speed)	Super Capacitors
	Vanadium redox flow cells	Zinc Bromide	Polysulfide/Bromide (Renesis)	Sodium Sulphur	Lead Acid (PbA)	Nickel Cadmium	NIMH		
Instantaneous power output range (MW)	0.03 - 0.5 (up to 100 feasible)	0.2 - 1.8		1	10	40		250kW	1kW - 5kW
Total stored energy (MWh)	.25 - 5	0.4 - 1.8		7	40	4.0 - 7		25kWh	1 to 10 kWh
Number of charge/discharge cycles	more than 10k	1500 - 2500, possibly larger	More than 10k	2000 - 3000	500 - 800	less than 2000	up to 600	100k - 2000k	more than 10k (without degradation)
Discharge time (hrs)	6	0.5 - 4		up to 7	8	0.15 - 0.25	1	minutes	up to 1 minute
Charge times (hrs)	1 - 12 (varies)	1 - 12 (varies)		8	8	1 - 14 (can damage with rapid charge)		minutes	seconds
Maturity	low	Low		moderate	High	moderate	Low	high	high
Operating costs	20 \$/kW-yr	5k annual and up		20 \$/kW-yr	5 \$/kW-yr	5 \$/kW-yr		low	(5% of capital cost)/year
Capital cost per unit energy (\$/kWh)	600	400		250 - 600	200 - 630	600 - 900	3.5k	200 - 800	12,960 (estimated by PRI)
Capital cost per cycle (¢/kWh) 1hr/8hr	95/65	62/46		49/35	49-52/38-44	78/70		N/A	N/A
Efficiency (w/o power electronics)	0.6 - 0.8 (0.75)	0.6 - 0.8 (0.75)		0.75 - 0.86	0.6 - 0.65	0.8 - 0.85		0.78 - 0.90	0.95
Weight energy density (MJ/kg)	0.09	216			0.09 - 0.11	0.14 - 0.22	0.22	500	2
Volumetric energy density (MJ/L)				1.23			0.36		0.02 - 0.07
Hazards				pure sodium in contact with water, sealing 'fires'		may explode if short circuited, physically fragile, disposal		high speed, high temperature	
Maintenance Issues and Balance of Plant	Membrane lasts only 8 - 10 yrs			Life 12 - 20, economical with larger size		Life 10 - 15, high rate of self-discharge, memory effects	Sensitive to charging and dis-charging	Life 15-25,	
Other comments			Insufficient information		Extremely short lifetimes			Stacking possible	Stacking possible



Energy Storage

- ZnBr battery for short-medium timescale:
 - Many cycles
 - Energy capacity limited by infrastructure size
 - Fast response

- Supercapacitors or flywheels for very short timescale (power quality):
 - Low energy capacity
 - Very high power
 - Many cycles



Conclusions

- Supercapacitor or flywheel subsystem for instantaneous power delivery.
- Flow battery for medium timescale (few minutes to hours).
- Pumped hydro (and regular hydro) for long term energy storage.
- Forecasting and control are cheap, effective, and excellent return on investment.



BPA and Pumped Storage

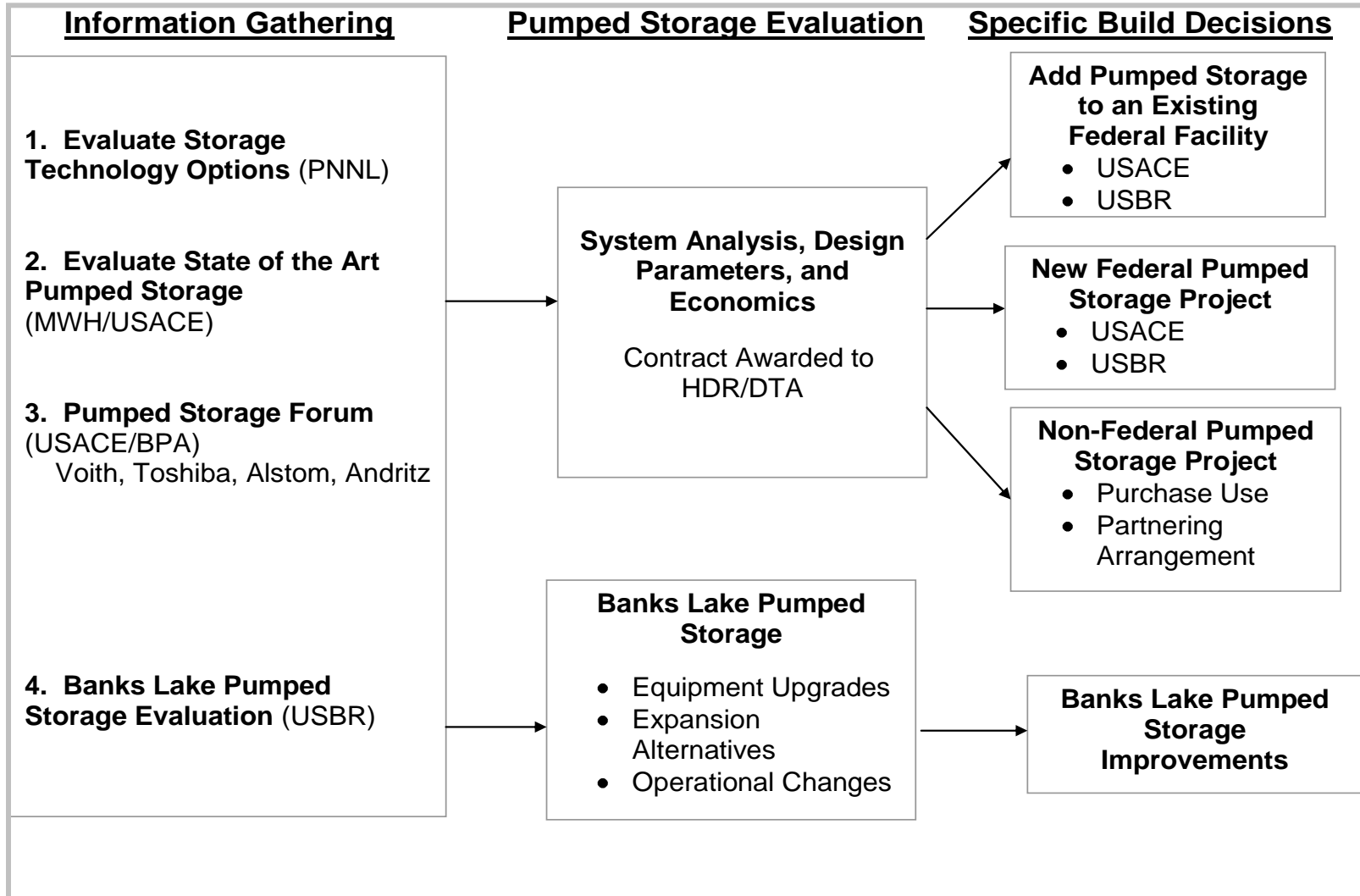


Energy Storage for Support of Wind Integration

- “I want to assure you the Administration places a priority on improving the Nation's capabilities to integrate renewable resources into its electricity supply. I support the full exploration of pumped storage potential in the context of providing necessary intermittent renewable integration services. Pumped storage has unique potential in the Pacific Northwest where a higher percentage of wind generation has already been integrated into the region's transmission system than anywhere else in the Nation.”
 - *U.S. Energy Secretary Steven Chu,*
in a letter to the Governors of Oregon, Washington, Idaho, and Montana; July 10, 2009
- The Northwest Power and Conservation Council draft 6th Power Plan points out that pumped storage is one of the few storage concepts with “bulk” storage potential.
- BPA’s draft Resource Program considers that pumped storage could provide BPA with a unique opportunity to return flexibility to the Federal hydro system.



BPA Pumped Storage Evaluation – Overall Plan



Questions ?

