A Regional Assessment of Energy Storage Systems for the Northwest Power Pool

Collaboration with the Bonneville Power Administration

Michael Kintner-Meyer, Ph.D.

Program Review
Energy Storage Systems Program (ESS)

Washington, DC
November 2, 2010

Funded by the Energy Storage Systems Program of the U.S. Department Of Energy through Pacific Northwest National Laboratories

Contact: email: Michael.Kintner-Meyer@pnl.gov
phone: 509.375.4306

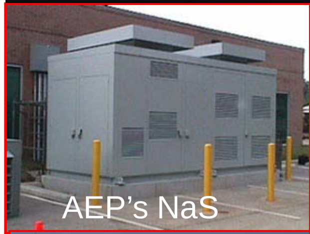
Pacific Northwest NATIONAL LABORATORY

Goal and Motivation to Collaborate with BPA

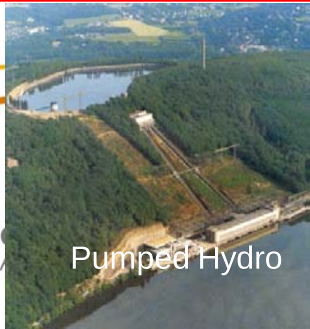
- Goal: Explore the following questions
  - Explore how much energy storage does the nation need?
  - What kind of storage?
  - Where to place it?
- Motivation for collaboration with BPA
  - BPA initiated analysis toward storage strategy
  - PNNL needed detailed data
- What questions do we address?
  - What are the likely balancing requirements for the NWPP in a 14.4 GW wind scenario for 2020 **(35% wind capacity compared to total installed, about 12% based on generation)**
  - Relative cost competitiveness of different energy storage compared with DR and GT
  - Optimal batteries sizes (right-sizing) and hybridizing
  - What are the energy arbitrage opportunities?
  - How much does location of storage matter?
- What questions did we <u>NOT</u> address
  - How much of the anticipated balancing requirements can be handled by existing capacity?

Scenario Definition:

- Balancing Services:
  - Scope: NWPP, 2019
    - Assume 14.4 GW of total installed capacity of wind.
      - Existing wind capacity 3.8 GW
      - Added capacity 10.7 GW
  - Technology choices
    - Combustion turbine
    - NAS batteries
    - Li-Ion batteries
    - Demand response
    - Pumped hydro

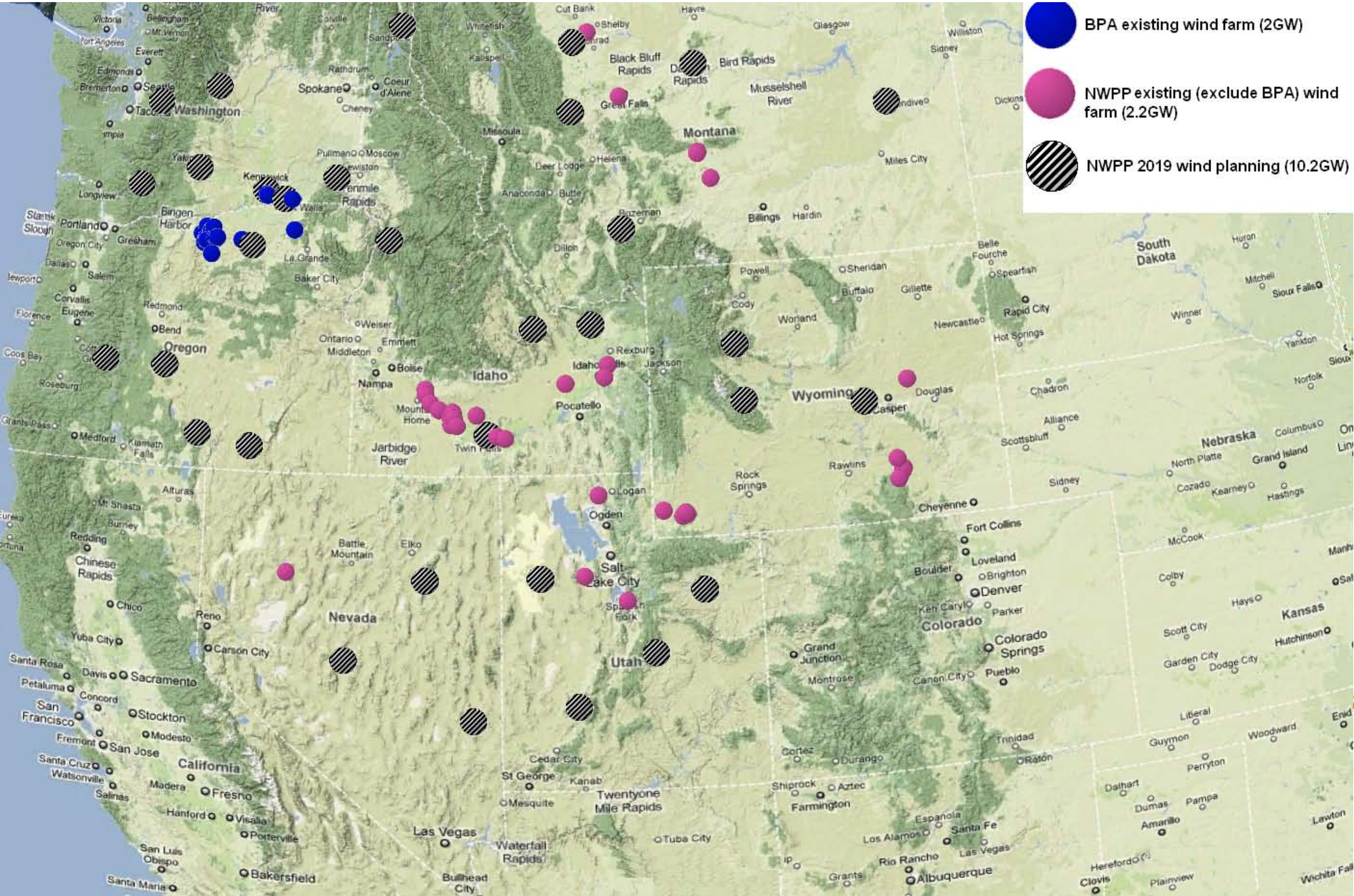


- Arbitrage:
  - Scope: NWPP, 2019, WECC's TEPPC* case
    - Assume 12 GW of total installed capacity of wind.
      - Existing wind capacity 3.8 GW
      - Added capacity 8.2 GW

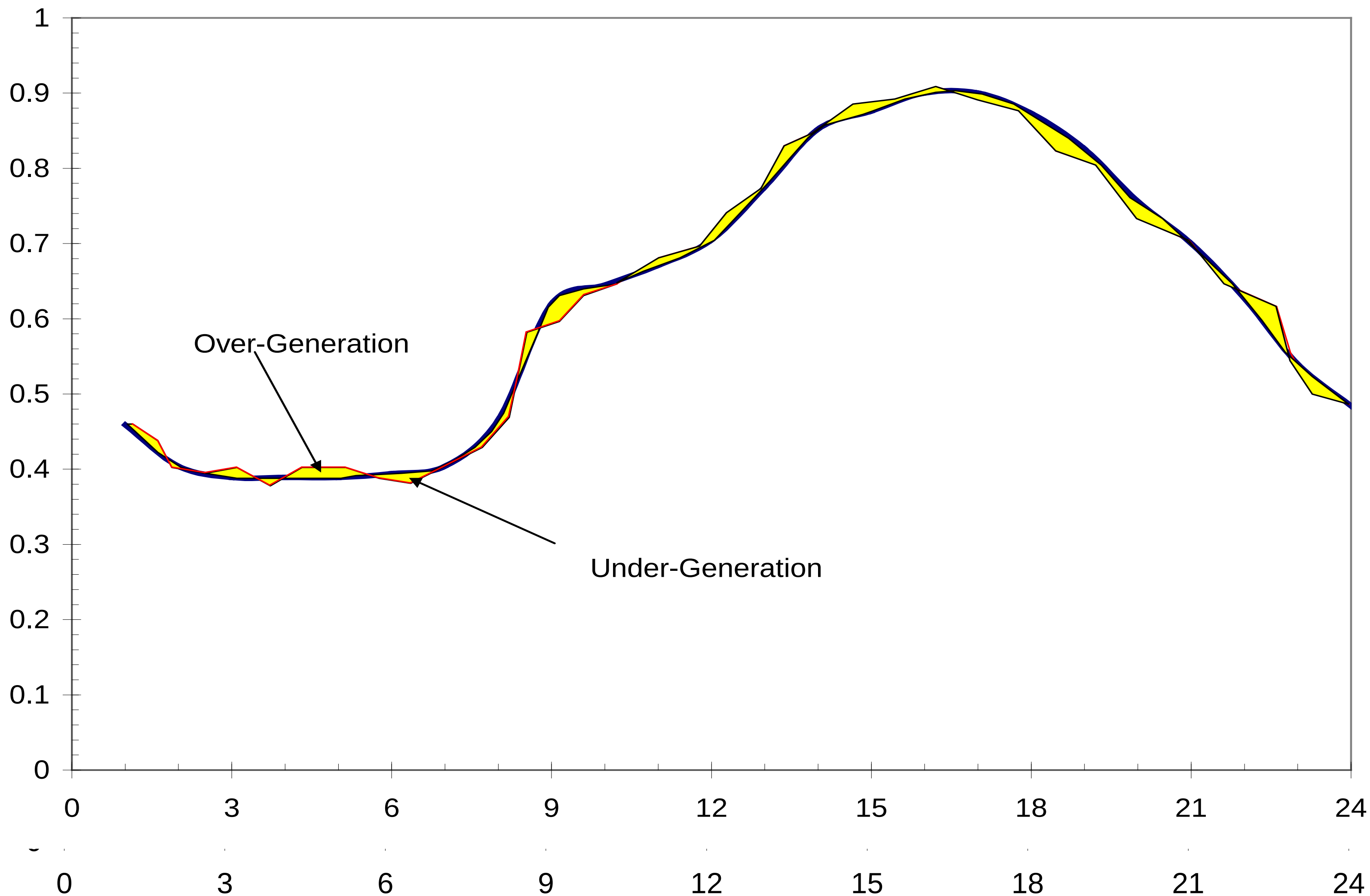


*TEPPC: Transmission Expansion Planning Policy Committee, WECC

Location of exiting and future wind plants



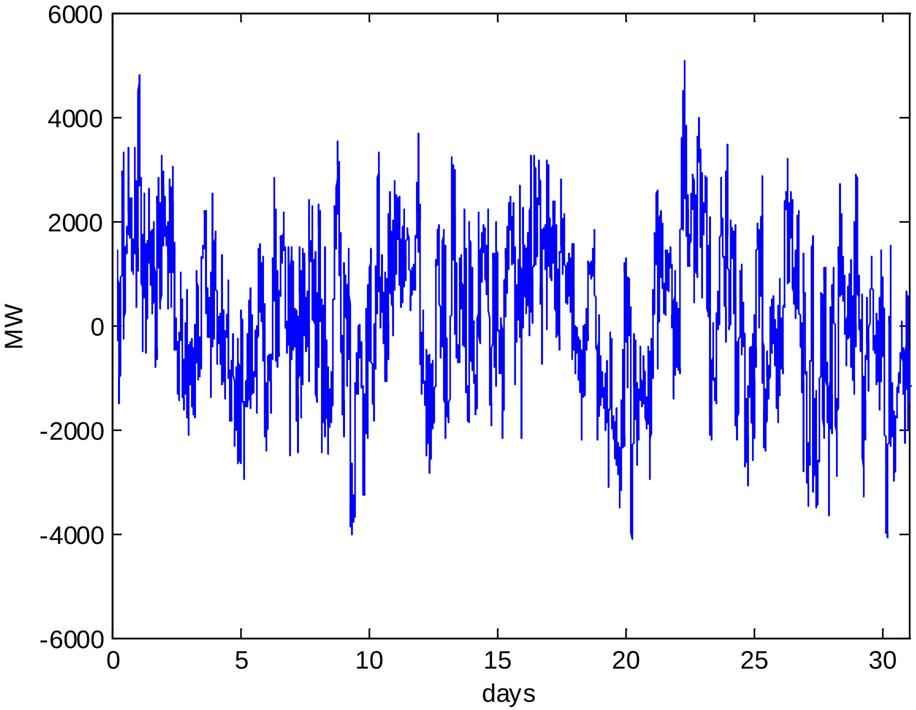
Approach for determining balancing requirements



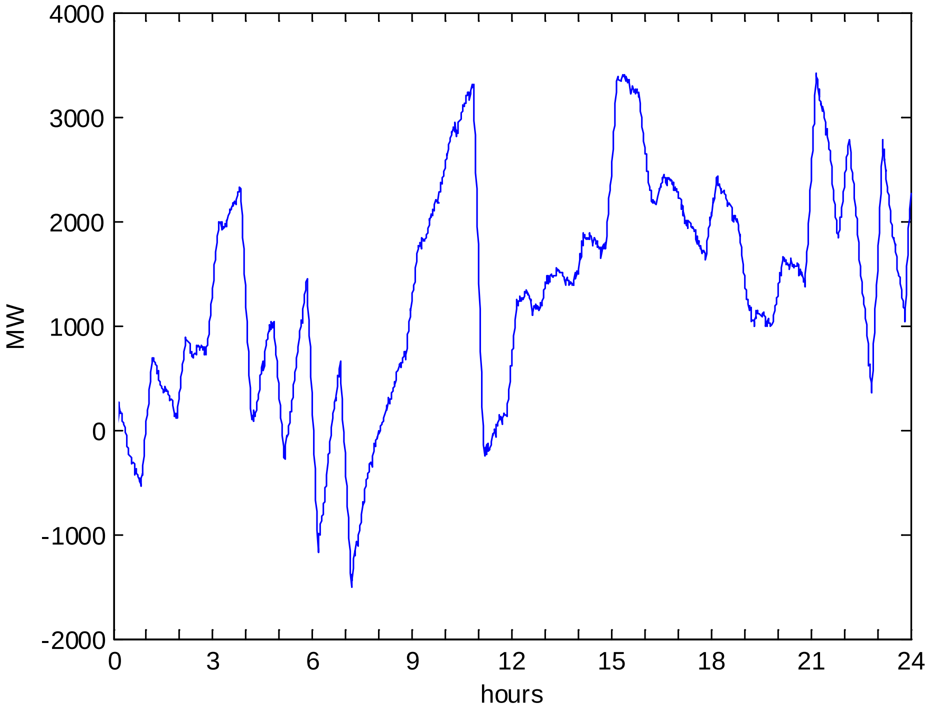
Pacific Northwest
NATIONAL LABORATORY

Resulting Total Balancing Signal

One Month



One Day

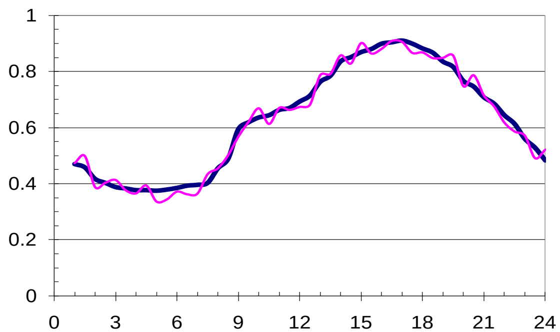


Pacific Northwest
NATIONAL LABORATORY

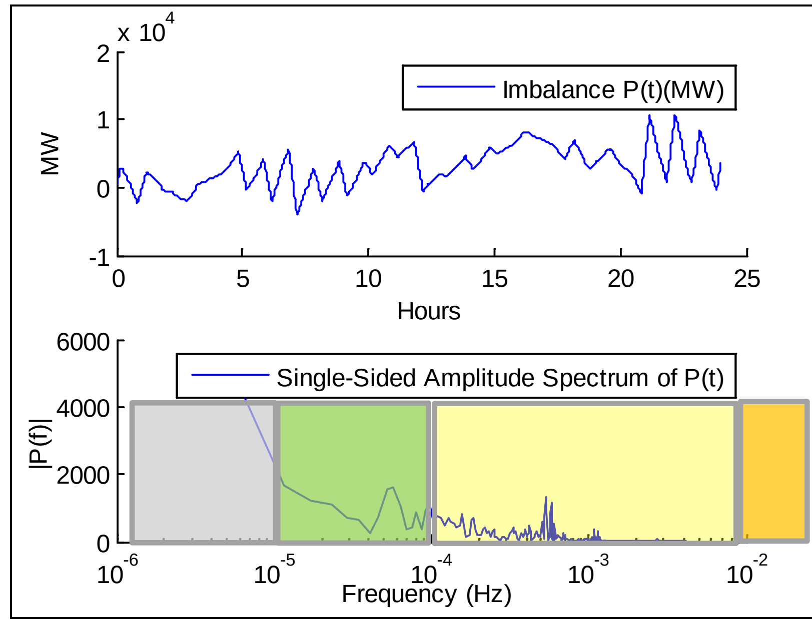
Determining Balancing Requirements

- **Spectral Analysis of the projected imbalance**

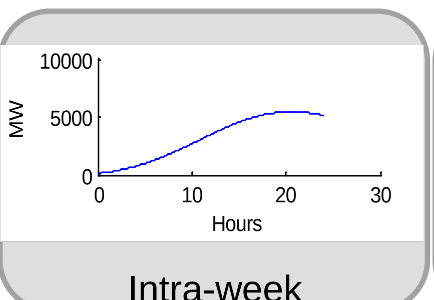
Imbalances superimposed with scheduled generation

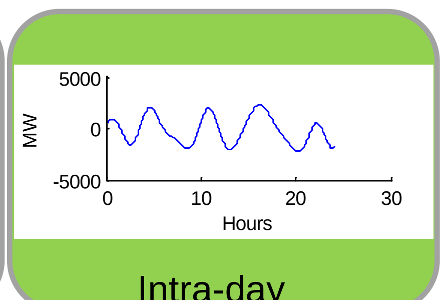


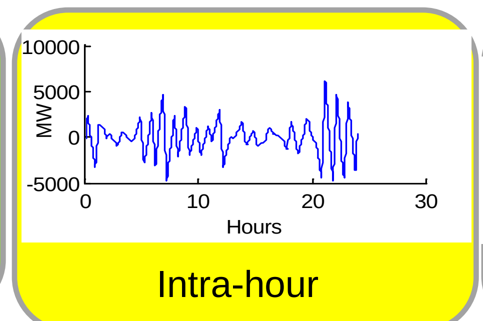
Isolate imbalance

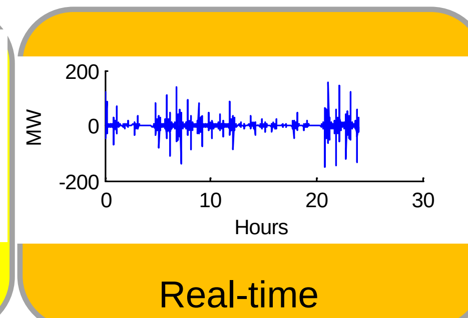


No.	Period	f_l (Hz)	f_u (Hz)	Period of f_l	Period of fu
1	Intra-week	0	1.15E-05	Inf.	24 hours
2	Intra-day	1.15E-05	1.36E-04	24 hours	2 hours
3	Intra-hour	1.36E-04	0.0073	2 hours	2 minutes
4	Real-time	0.0073	0.2	2 minutes	5 seconds



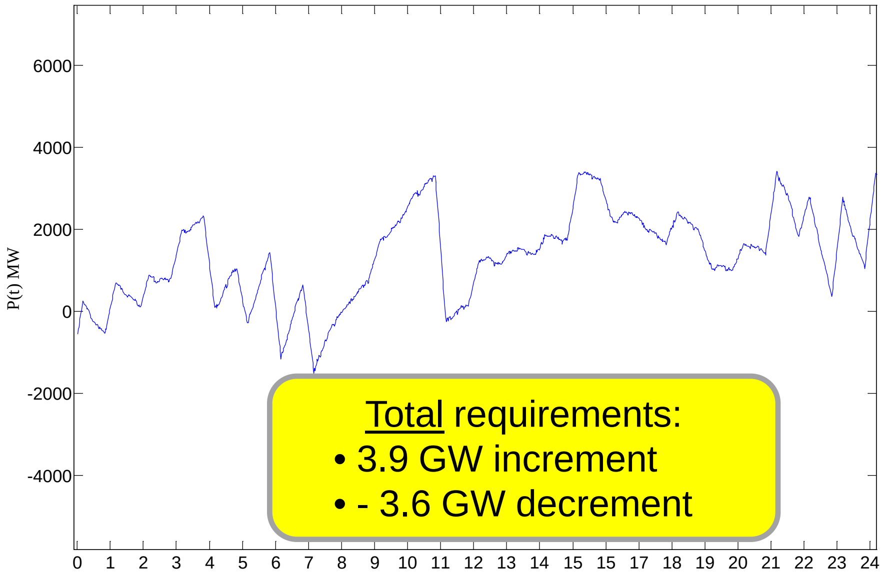




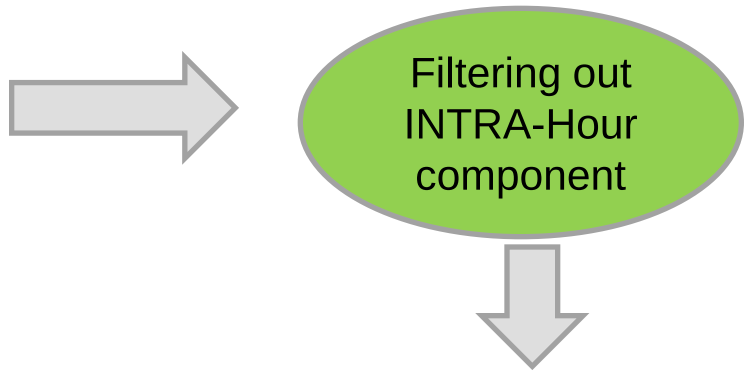


Total requirements for meeting 2019 balancing requirements in NWPP

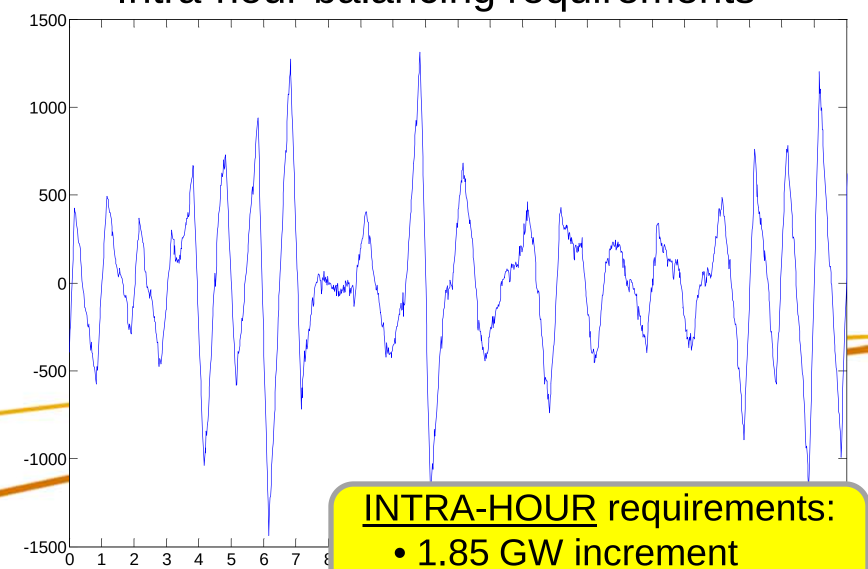
Total Balancing requirement of NWPP with 14.4 GW wind, selected day



<u>Total</u> requirements:
- 3.9 GW increment
- - 3.6 GW decrement



Intra-hour balancing requirements

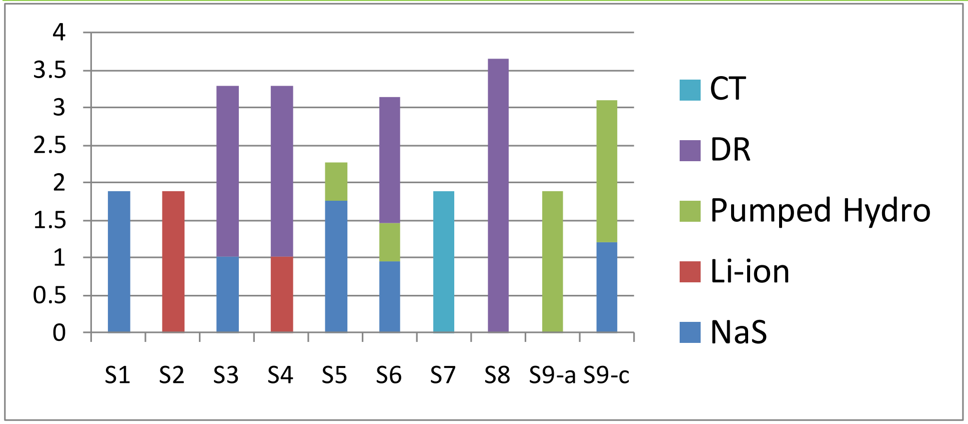


<u>INTRA-HOUR</u> requirements:
- 1.85 GW increment
- -1.85 GW decrement

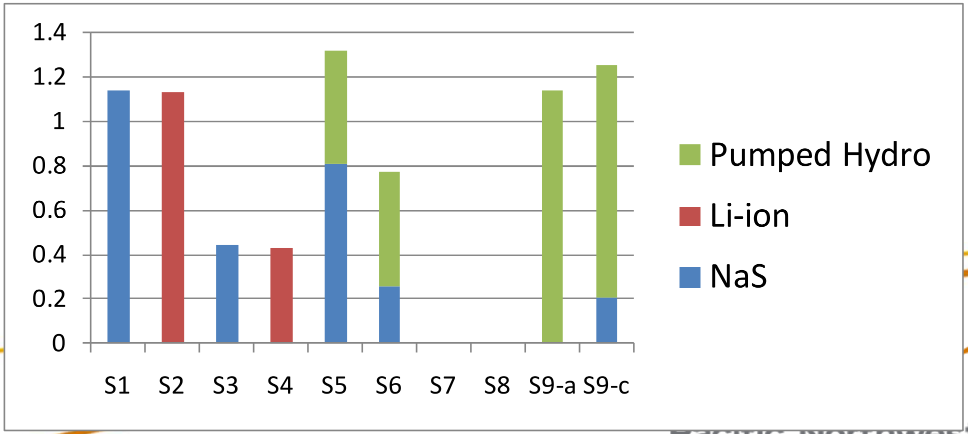
Total requirements for meeting 2019 balancing requirements in NWPP

Scenario	Technology
S1	NaS
S2	Li-ion
S3	NaS
	DR
S4	Li-ion
	DR
S5	Pumped Hydro
	NaS
S6	Pumped Hydro
	DR
	NaS
S7	CT
S8	DR
S9-a	Pumped Hydro, Changeover delay = 0
S9-c	Pumped Hydro, Changeover delay = 4 min
	NaS

Power capacity of all technologies to meet balancing requirement (**GW**)



Energy storage sizes to meet balancing requirement (**GWh**)



Cost Performance Characteristics

Parameter	NaS battery	Li-ion battery	Pumped hydro	Combustion turbine	Combined cycle	Demand response
Battery Capital cost $/kWh	415(230)	1000 (510)				
System Capital cost $/kW			1750 (1890)	695 (723)	Not used	489
PCS ($/kW)	200 (150)	200 (150)				
BOP ($/kW)	100	100				
O&M fixed $/kW-year	0.46	0.46	4.6	12.75	13.79	
O&M fixed $/kW-year (PCS)	2	2				
O&M variable cents/kWh	0.7	0.7	0.4	0.376	0.217	
Round trip efficiency	0.78	0.80	0.81	0.315		

Results of LCC Analysis

- NaS: $415/kWh
  $3,000/kW
- Li-Ion: $1000/kWh
  $2,350/kW
- Pumped H: $1,750/kW
- DR: $489/kW
- CT: $695/kW

C1: Combustion Turbine
C2: NaS
C3: Li-ion
C4: PH multiple mode change
C5: PH 2 mode change
C6: DR
C7: NaS + DR
C8: Li-ion + DR
C9: PH multiple MC + NaS
C10: PH 2MC + NaS
C11: PH multiple MC+NaS+DR

Pacific Northwest
NATIONAL LABORATORY

Preliminary Conclusions

- For a 14+ GW Wind scenario in the NWPP will increase the balancing requirements. Estimated size:
  - Around 2 **GW** power output
  - Above 1 **GWh** energy requirements (if energy storage is used)
- Life-cycle cost results have large capital component
- Overall competitiveness depends on price assumptions trading off: learning curves versus material cost projections
- Na-S is competitive
- DR can reduce size of Pumped Storage
- Arbitrage
  - Location of storage does matter. Distributed placement of storage appeared to have higher system benefits

Future Work

Programmatic and Policy Questions To Address:

1. What regional differences are important to capture / reflect in storage decisions? =>National assessment of market size for energy storage
2. How much do consolidations of Balancing Authorities influence need for energy storage?
3. How much do load and wind forecasting improvements influence the need for energy storage?
4. What regulatory innovations (market, reliability standards etc.) will be needed to incent industry and consumers to embrace grid transformation and fully capture the benefits of energy storage and smart grid concepts?