Planning in a Cascading Hydro System with Significant Wind Penetration

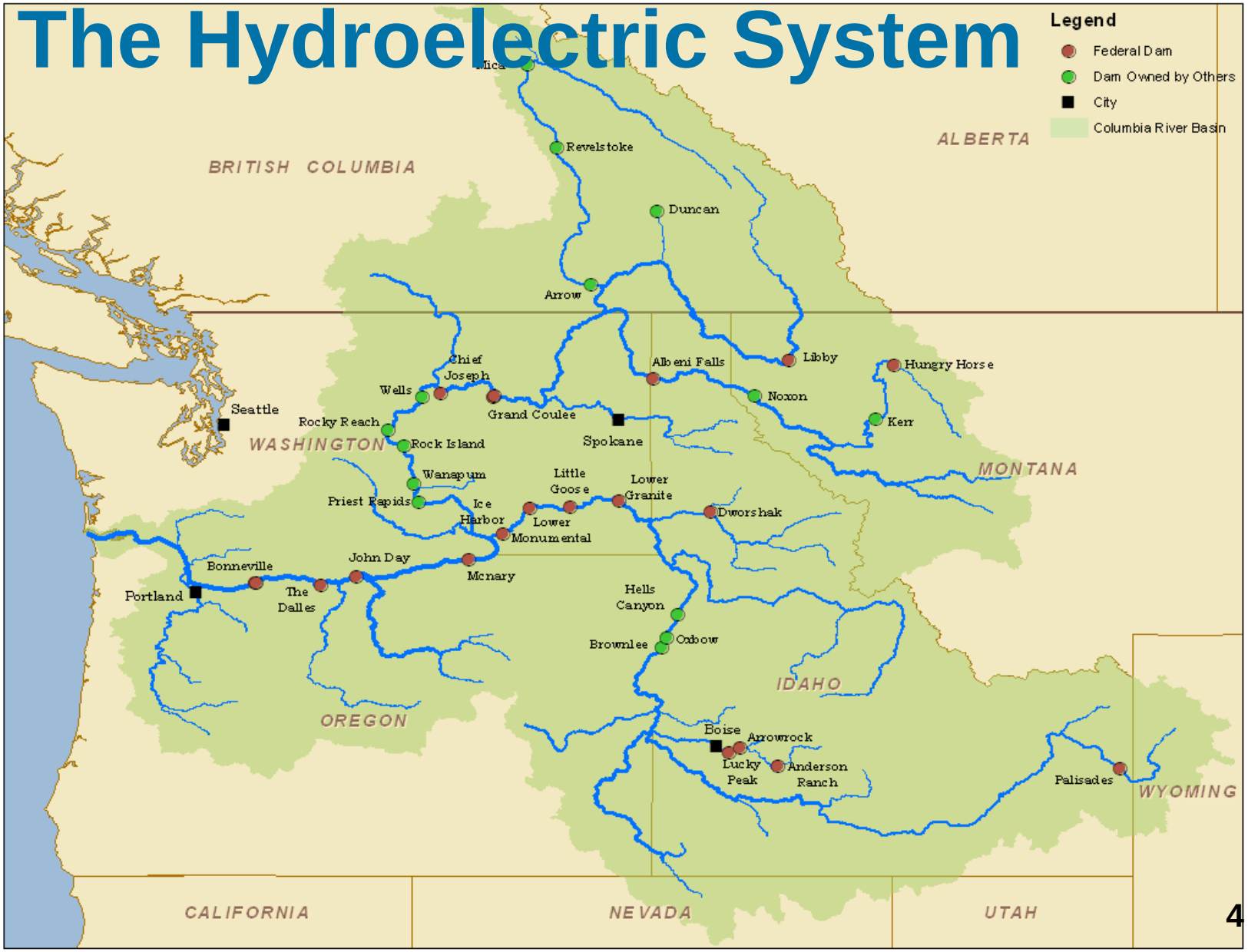
Federal Columbia River Hydro

- Over 20,000 MW Nameplate of Federal hydroelectric generation
- Average Annual Runoff 132 maf (million acre feet)

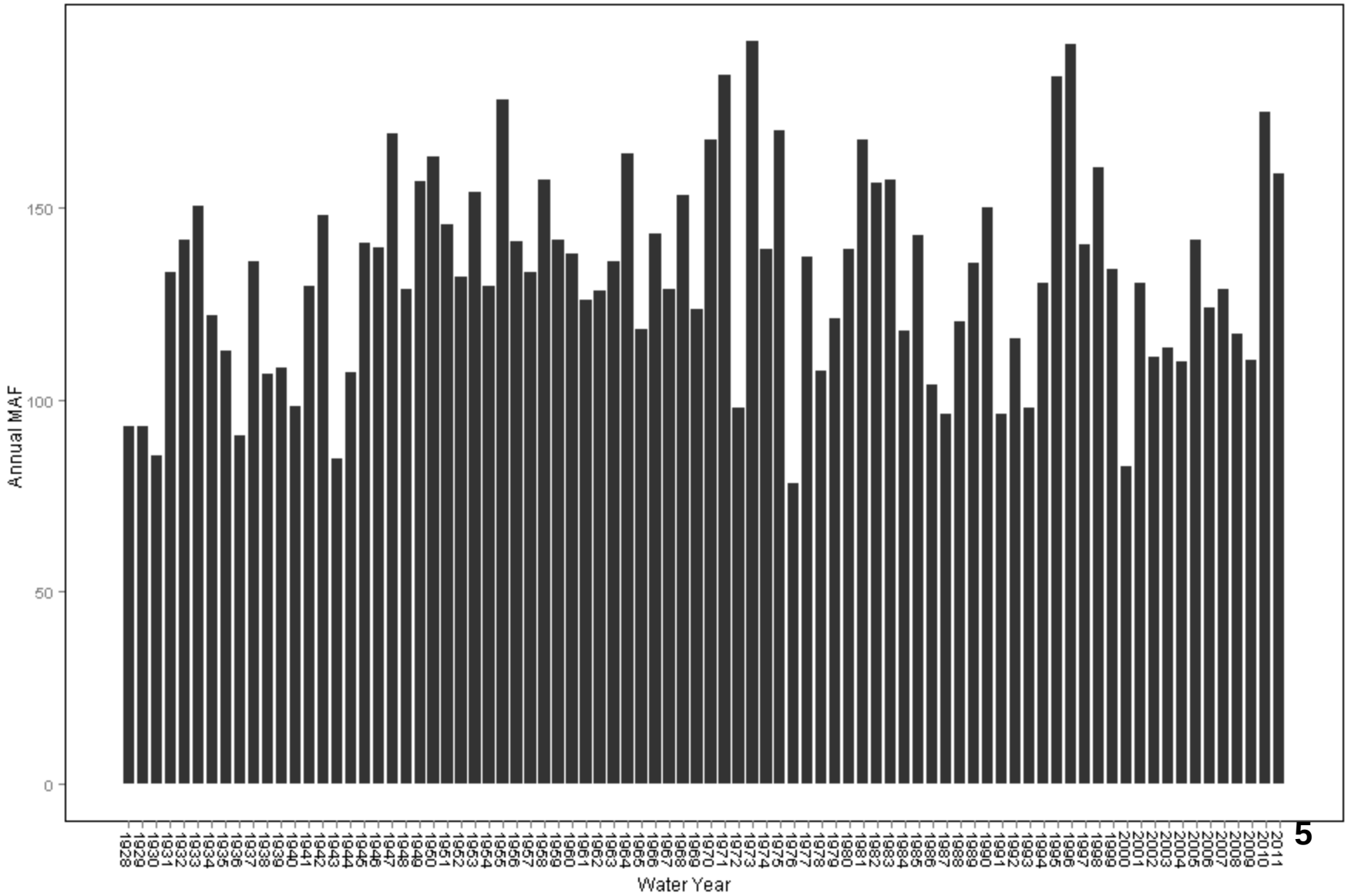
Grand Coulee

- 6,765 MW Nameplate
- Irrigates over 600,000 acres
- 9.3 maf storage

The Hydroelectric System

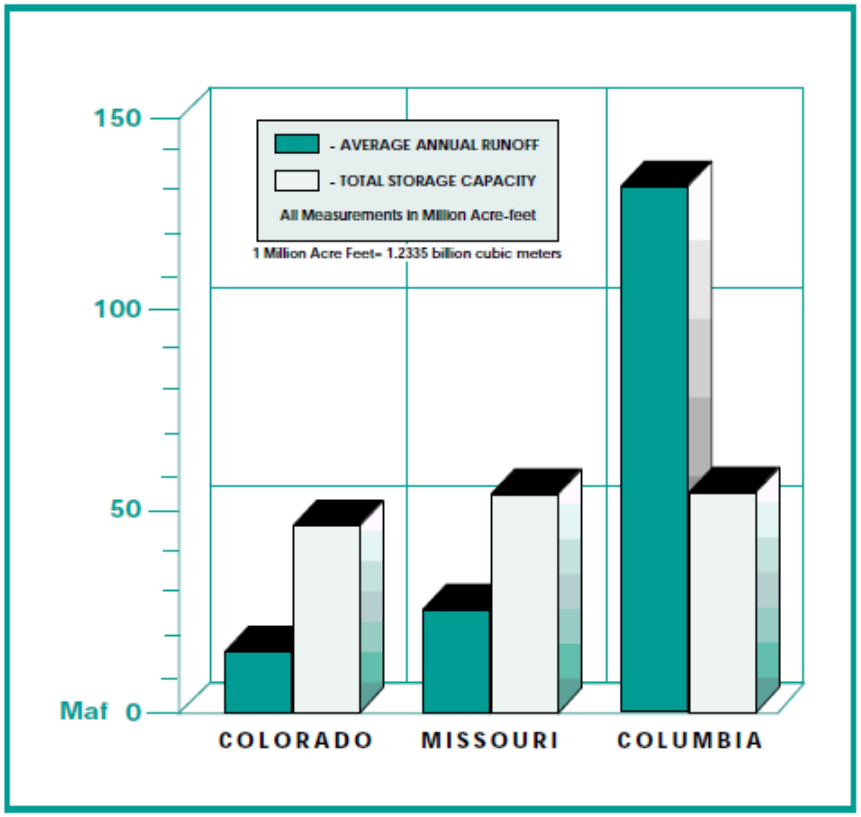


Power = f(Water)

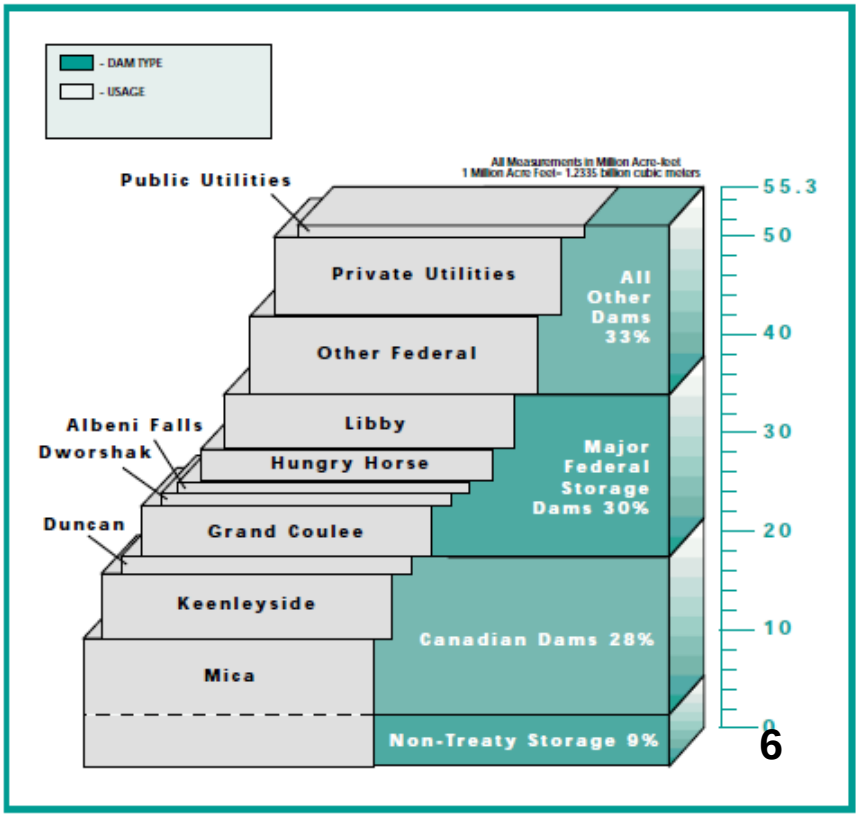


Hydro System Storage

Columbia River Runoff and Storage Compared to the Colorado and Missouri Rivers



Columbia River System Storage Space



Modeling Runoff

- Long-term LOLP reliability modeling
- Within Year Ensemble Streamflow Prediction (ESP)
- 2 to 3 week energy optimization based on weather forecasted loads and streamflows
- Next day Heavy Load Hour (HLH) optimization

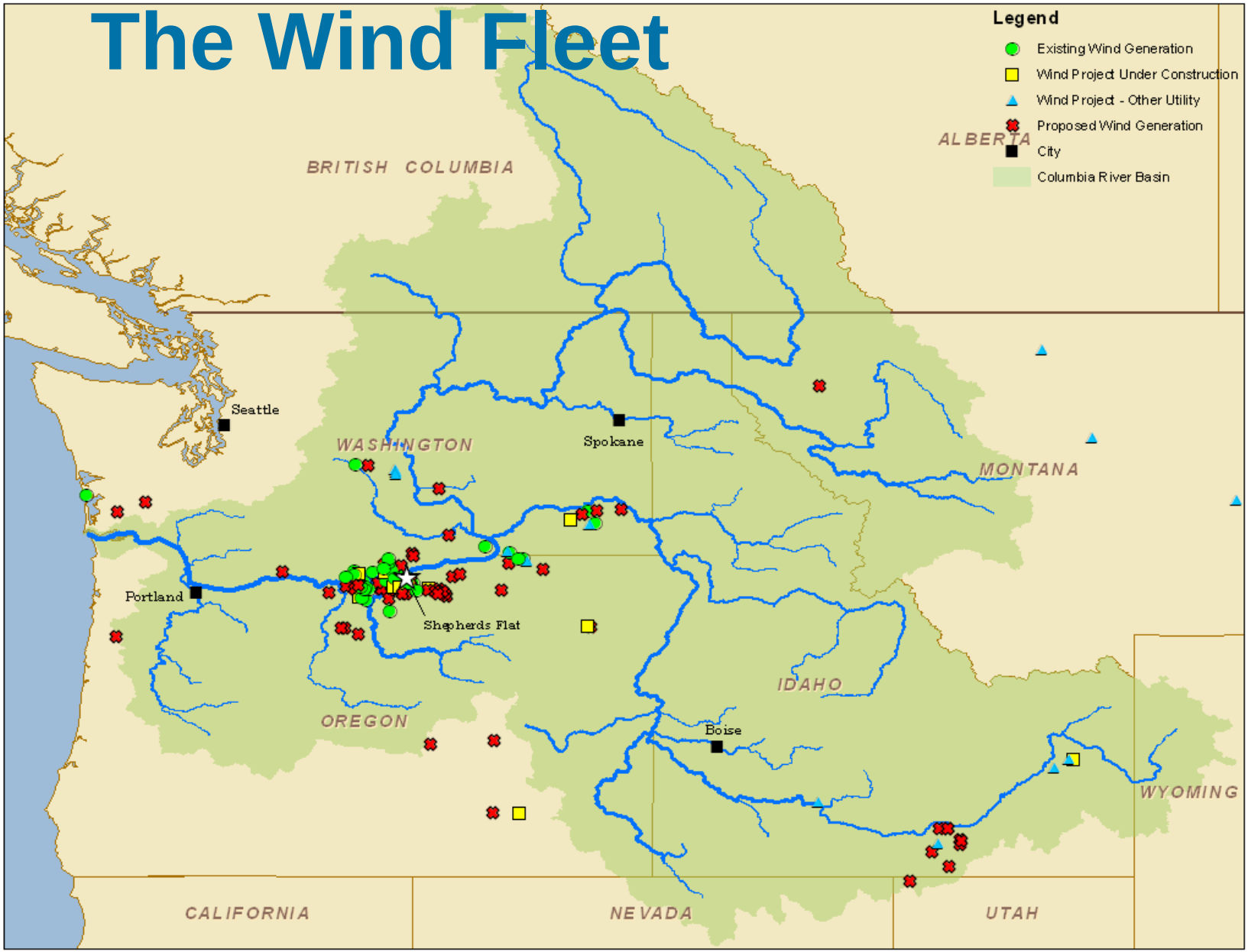
Northwest Wind Power Generation

- Around 4700 MW connected to the federal transmission system
- Wind output in the BPA balancing authority has exceeded hydro generation and supplied up to 87% of the BA load

Shepherds Flat

- 845 MW Nameplate
- 338 GE 2.5 MW Turbines

The Wind Fleet



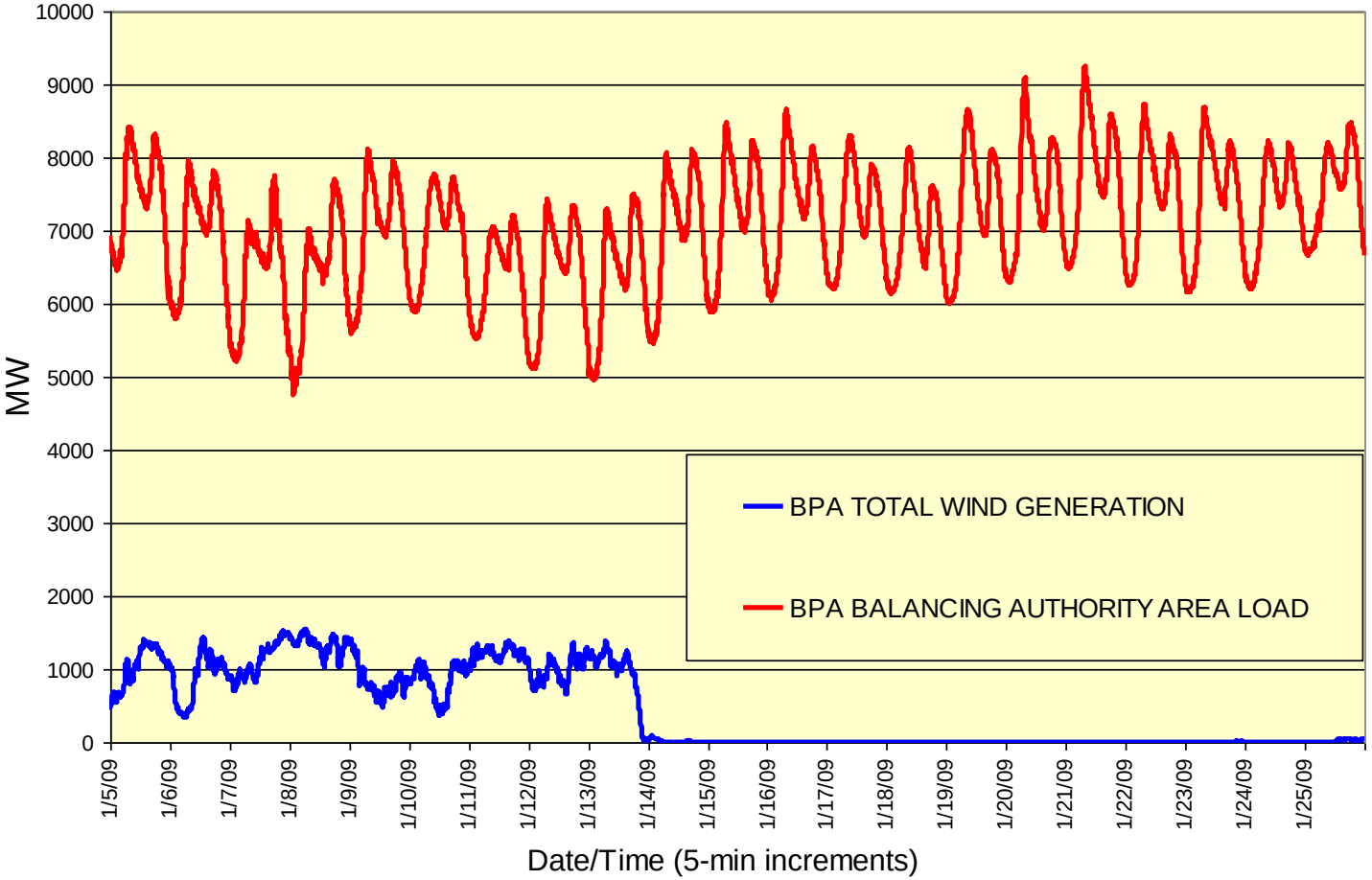
Wind SCE and Balancing Reserves

Operational Challenges

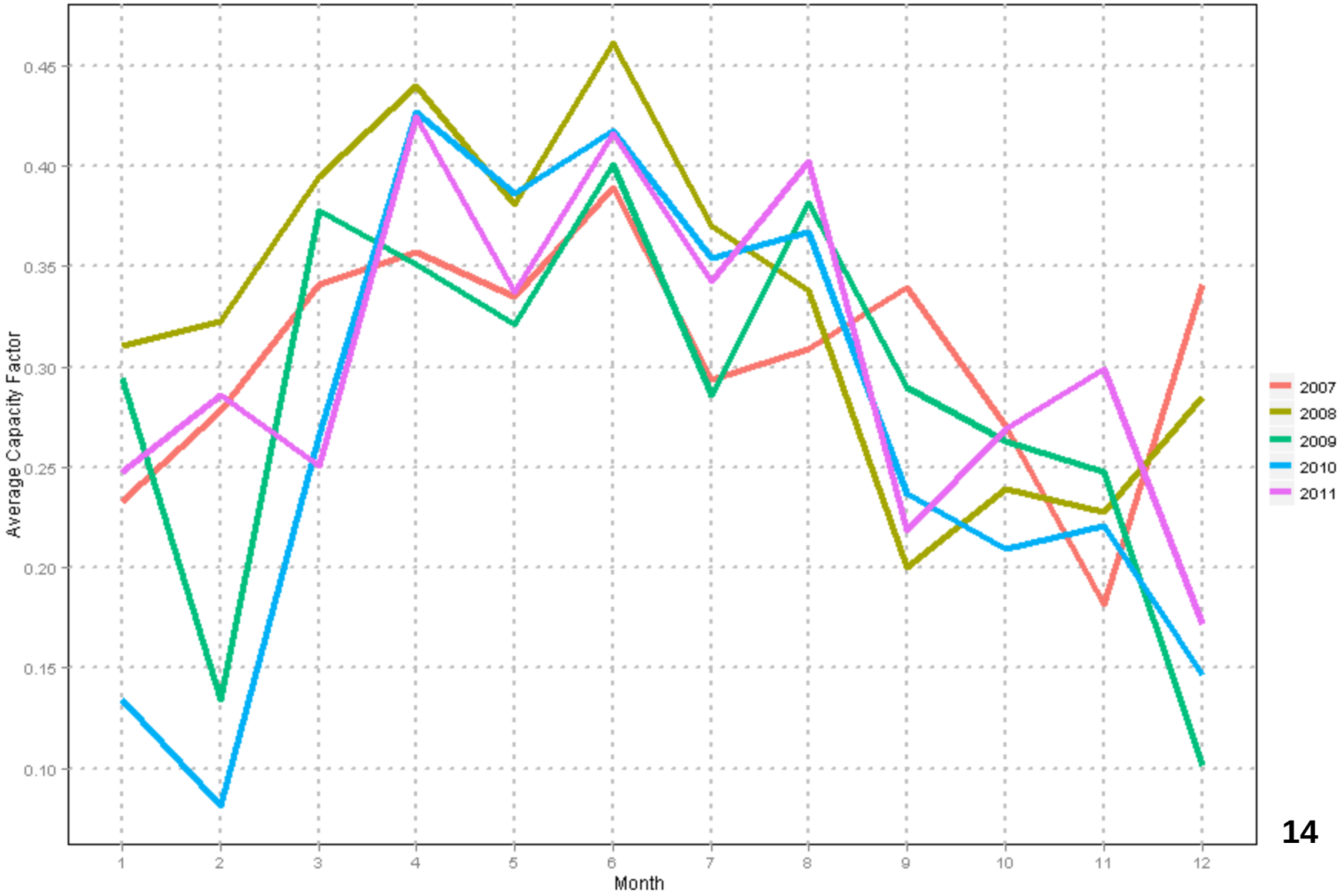
- Balancing Reserves
- Fish Operations
- Oversupply

Reliability Concerns

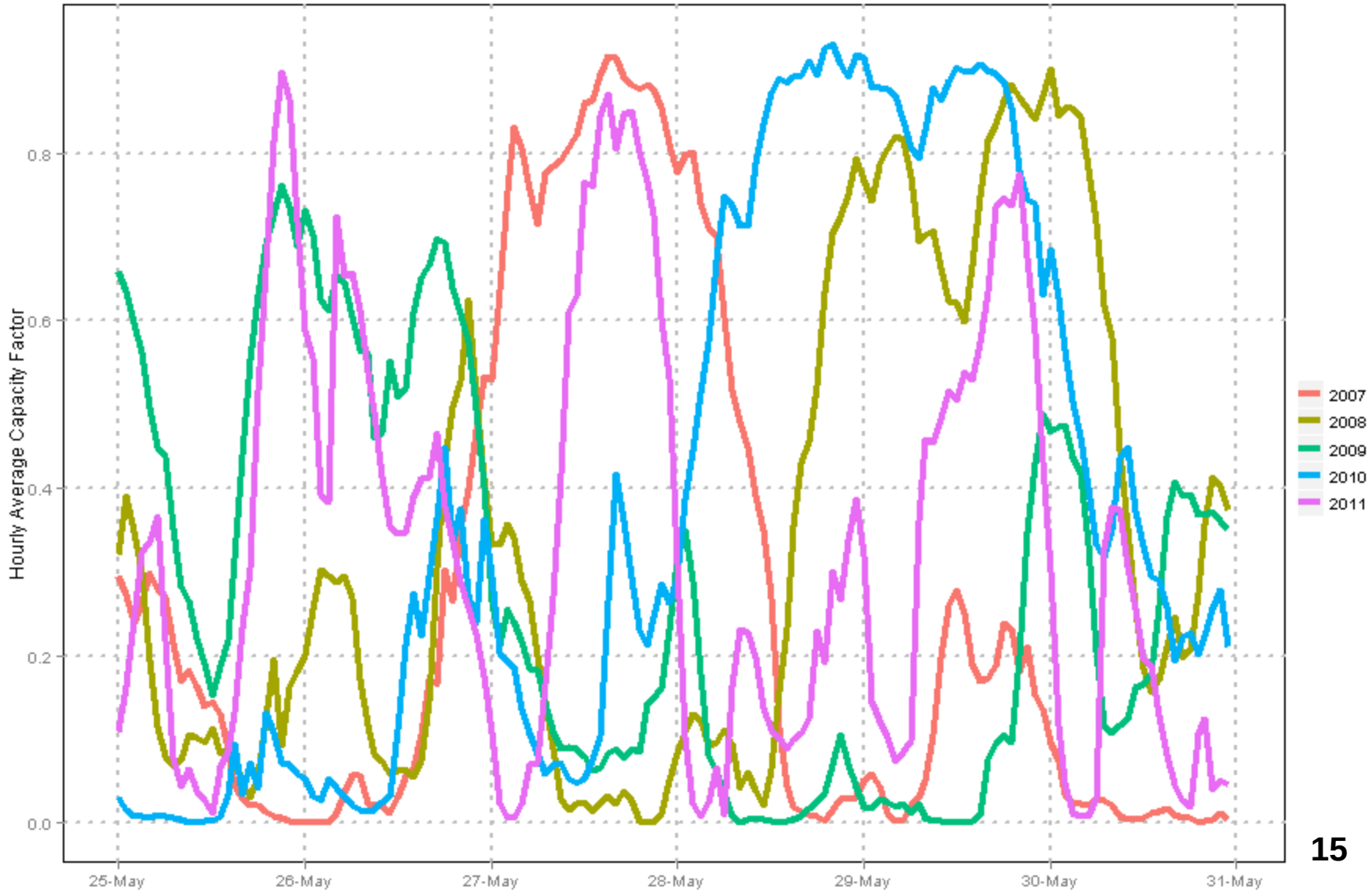
BPA Balancing Authority Area Load & Total Wind Generation
Jan. 5-25, 2009



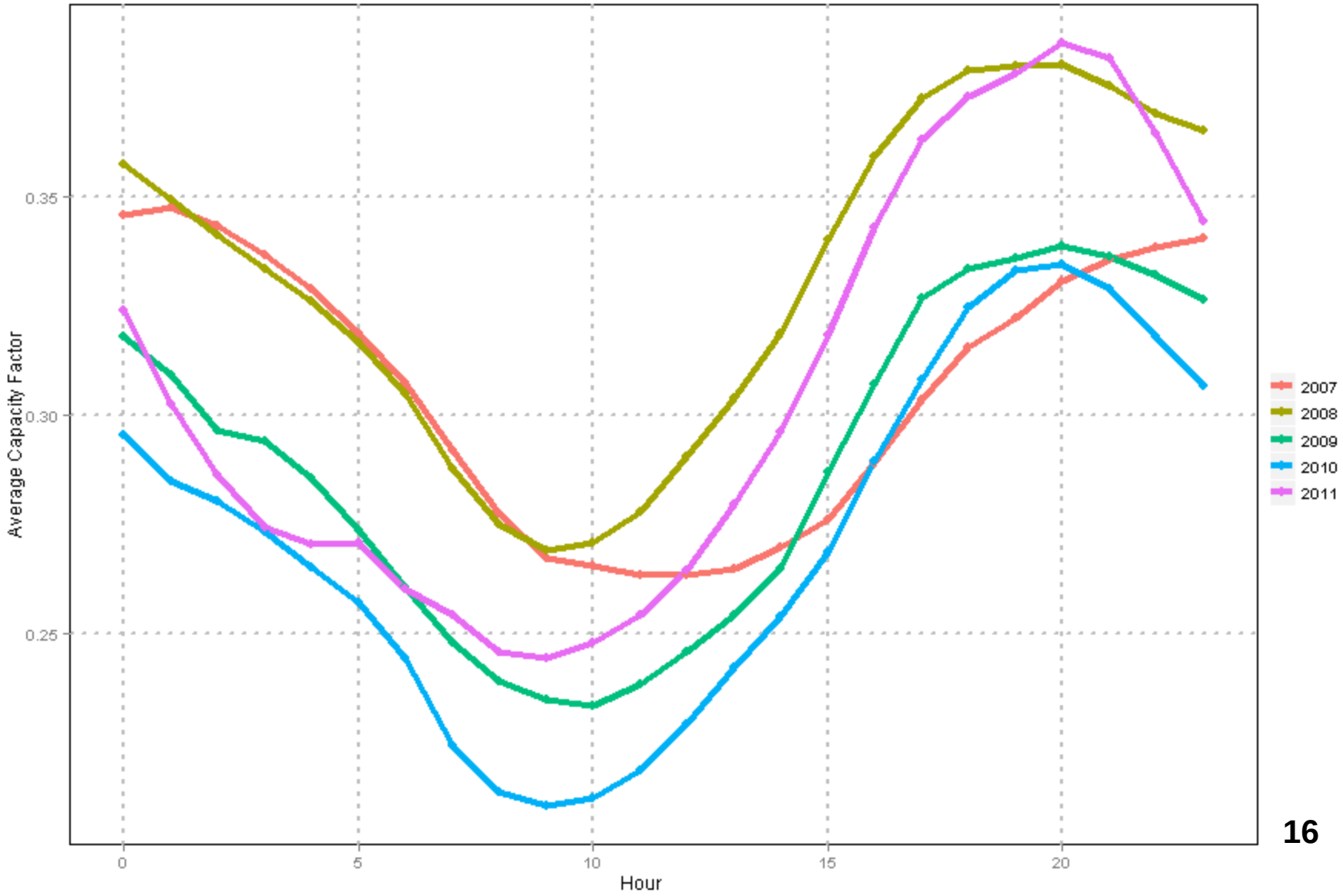
Seasonal Uncertainty



Ramping Capability



Load Coincidence



Planning Challenges

- Monthly and Annual Energy Variability
- Capacity Value of Wind
- System Flexibility

Lessons Learned

- When planning for wind
  - Verify if each hour has the same expectation
  - Verify if each season or month has the same expectation
  - Beware of independence
  - Model the underlying system flexibility needs for ramping and reserves

Public Data

- BPA Wind Fleet Forecast and Actual
- BPA and OSU Anemometer Data
- BPA Control Area Load Actual
- Regional Load
- Intertie Transmission Ratings and Usage

For More Information

- BPA wind initiatives
  - http://www.bpa.gov/Projects/Initiatives/Wind/Pages/default.aspx
- Northwest Power and Conservation Council Wind Integration Forum
  - http://www.nwcouncil.org/energy/Wind/Default.asp

Thank you for your attention.

bkkujala@bpa.gov (prior to Feb 22nd) OR

BKujala@NWCouncil.org (after Feb 22nd)

http://www.linkedin.com/in/kujala

Appendix

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Reserves and Wind Power

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System Flexibility

- Metrics
  - E. Lannoye, D. Flynn, and M. O'Malley, "Evaluation of Power System Flexibility," *Power Systems, IEEE Transactions on*, vol. 27, no. 2, pp. 922 –931, May 2012.