Overcoming Transmission Constraints: Energy Storage and Wyoming Wind Power

DOE Energy Storage Systems Research Program
Annual Peer Review

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SAIC, VRB Power Systems, and PacifiCorp

Presented by Tim Hennessy

Examining the Need for Energy Storage

- Wyoming is a significant electricity exporter to western States
- Constraints along PacifiCorp transmission corridors have resulted in wind energy curtailments
- Additional wind projects were under construction
- Tariffs in Wyoming do not encourage wind generation (no capacity charge or time-of-day energy charge)
- Renewable Portfolio Standards in other states encourage Wyoming wind energy exports
- Could energy storage help eliminate wind energy curtailments and reduce transmission congestion?

A Unique Investigation

- Examined operating data from functioning facilities:
  - Foote Creek Rim I windfarm substation owned and operated by PacifiCorp
  - 69 wind turbines and six meteorological stations owned by PacifiCorp and Eugene Water and Electric Board, and operated by SeaWest
  - VRB vanadium redox flow battery installed at PacifiCorp's Castle Valley substation near Moab, Utah
  - Hourly transmission flow data from PacifiCorp for the TOT 4A and 4B paths
  - A negotiated tariff for a windfarm developer
  - PacifiCorp's firm transmission service tariffs

Project Schedule

- $70,000 Special Energy Project grant
- 20% cost share
- Contract signed October 5, 2004
- Staff changes and state procedures delayed progress

Milestone	Due Date
Task 1. Kick-Off Meeting	October 2004
Task 2. Mid-Project Status Report	January 2005
Task 3. Analysis Graphs and Tables	October 2005
Task 4. Final Report/Technical Paper	December 2006

Project Tasks

Task 1. Kick-Off Meeting

Web-conference to familiarize Team with the first-of-its-kind VRB battery demonstration and wind farm

Task 2. Wind/Battery Data Collection

Gather data on wind power, wind speed, temperature, transmission line availability, and battery operations for a calendar year

Task 3. Analysis and Team Review

Clean and combine data files gathered in a single database to permit creation of a hybrid wind-battery system for analysis

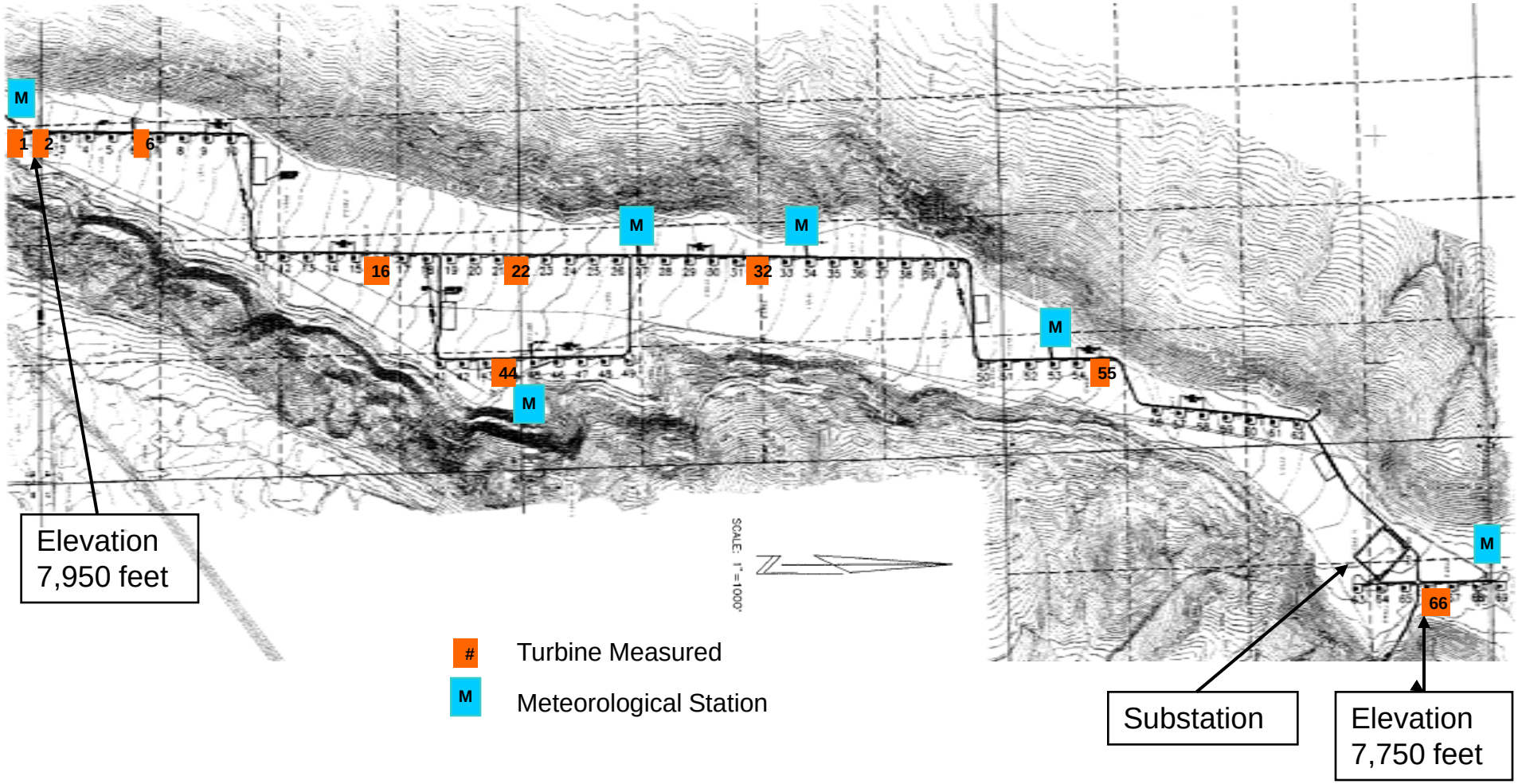
Task 4. Final Report/Technical Paper

Prepare final report that describes wind farm, battery demonstration, analysis performed, and impact of Renewable Portfolio Standards

Profile of Foote Creek Rim I Wind Farm

- Remote, treeless plateau between Laramie and Rawlins in southeastern Wyoming
- One of windiest places in the U.S., with average wind speeds of 25 mph
- Some of most extreme temperatures, as low as -30 F
- 69 600-kW Mitsubishi wind turbines started April 1999
- 41.4 MW co-owned by PacifiCorp and Eugene Water & Electric Board
- Built, operated, and maintained by SeaWest
- Turbines can generate power at 8-65 mph wind speeds

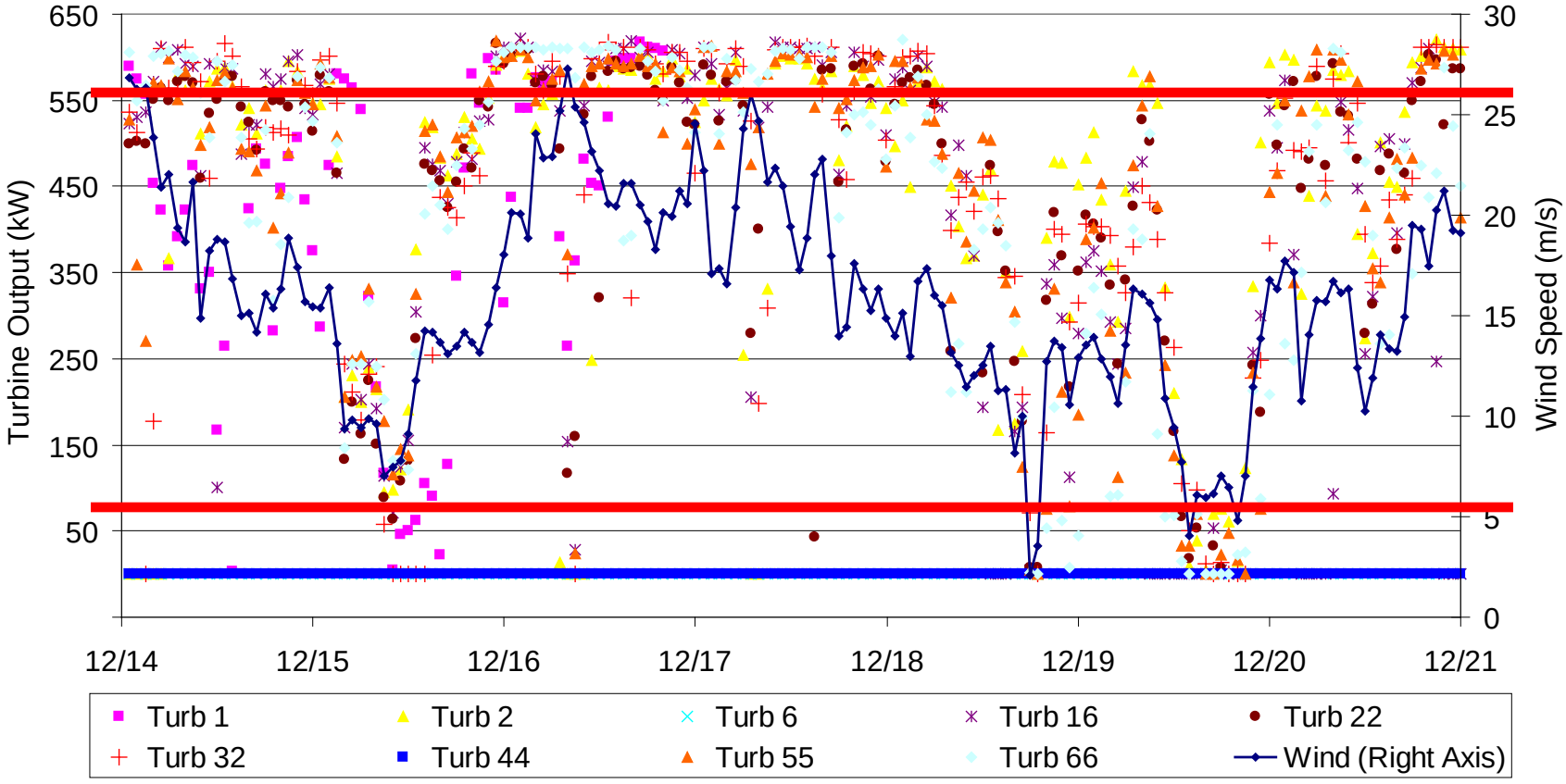
Foote Creek Rim I Layout



Source: SeaWest, December 2004.

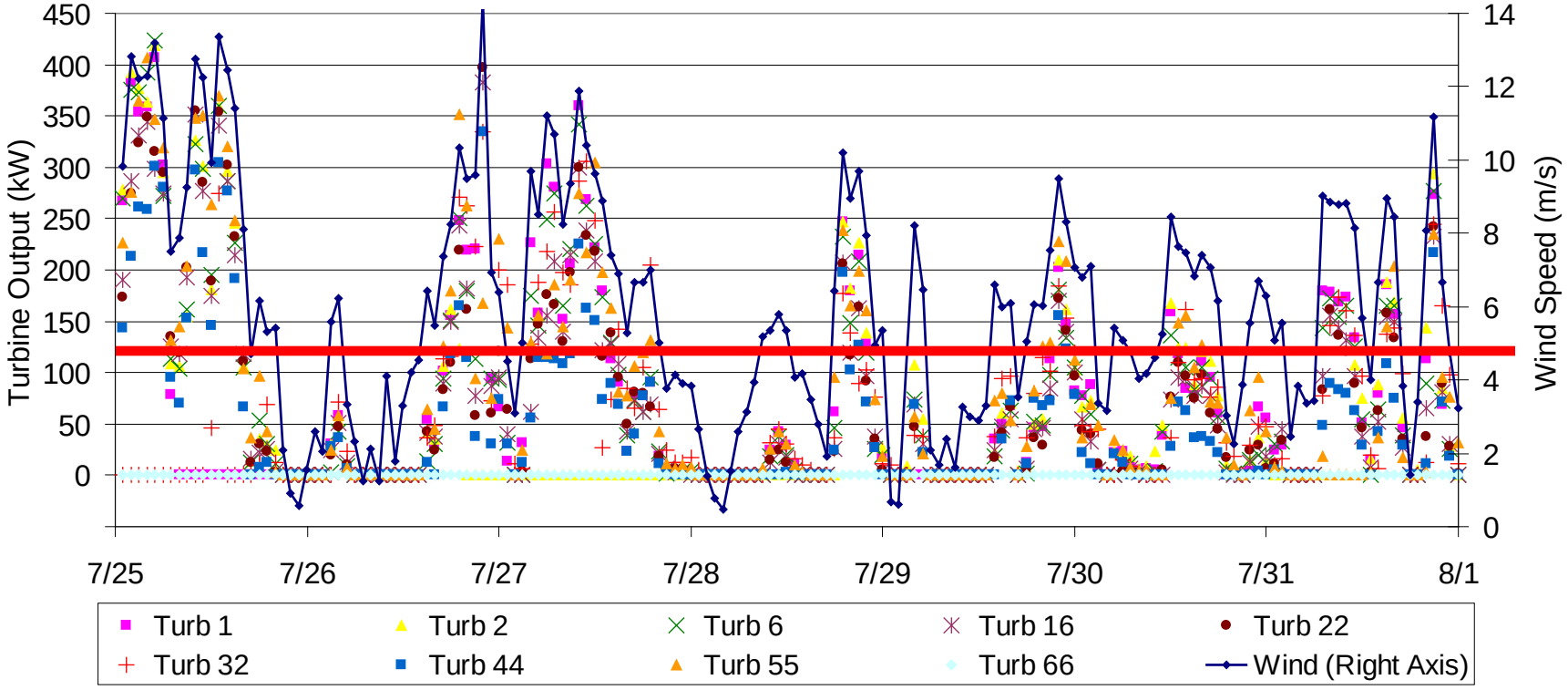
Southern Substation for Foote Creek Rim

Wind Speed and Turbine Output in Winter



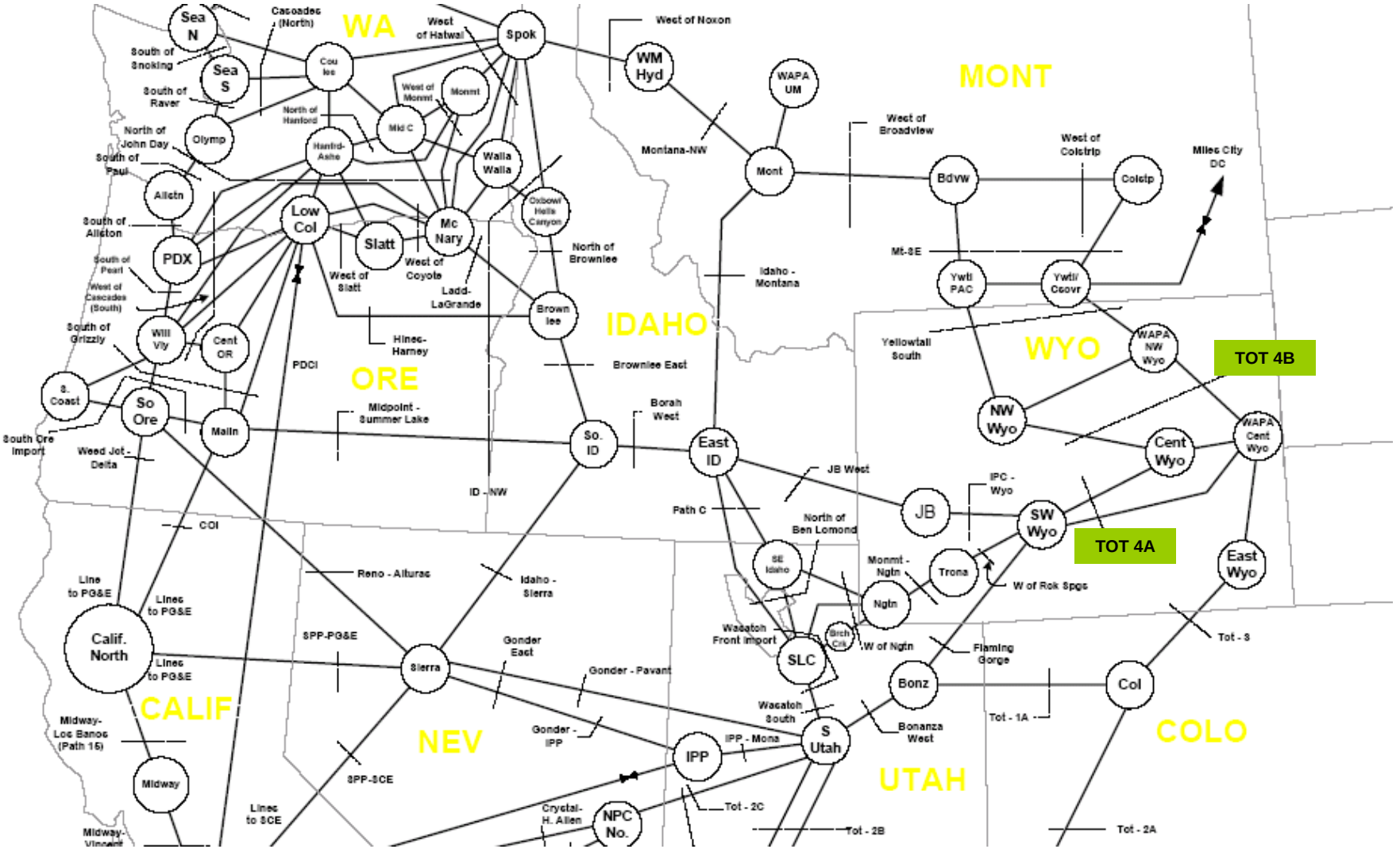
Source: Calculated from SeaWest Data on Wind Speeds at Turbines and Meteorological Stations, December 2004.

Wind Speed and Turbine Output in Summer



Source: Calculated from SeaWest Data on Wind Speeds at Turbines and Meteorological Stations, December 2004.

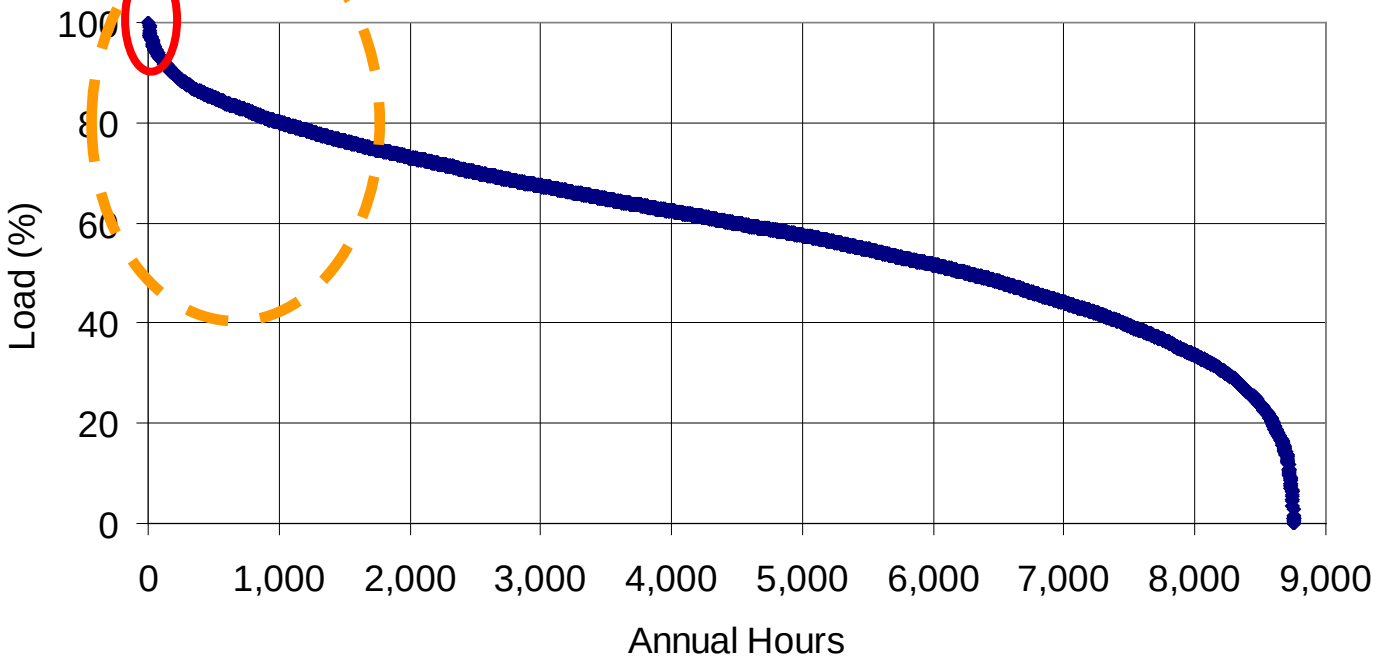
Transmission Paths Impacting the Northwest



Source: PacifiCorp, Conditional Firm Public Stakeholder Meeting, Oct. 23, 2006, http://www.pacificorp.com/File/File69023.ppt

Wyoming TOT4 System Load Duration

In 2003, there were **187** hours spread over 47 days in which load duration exceeded 90% and **1,686** hours spread over 246 days in which load duration exceeded 75%.

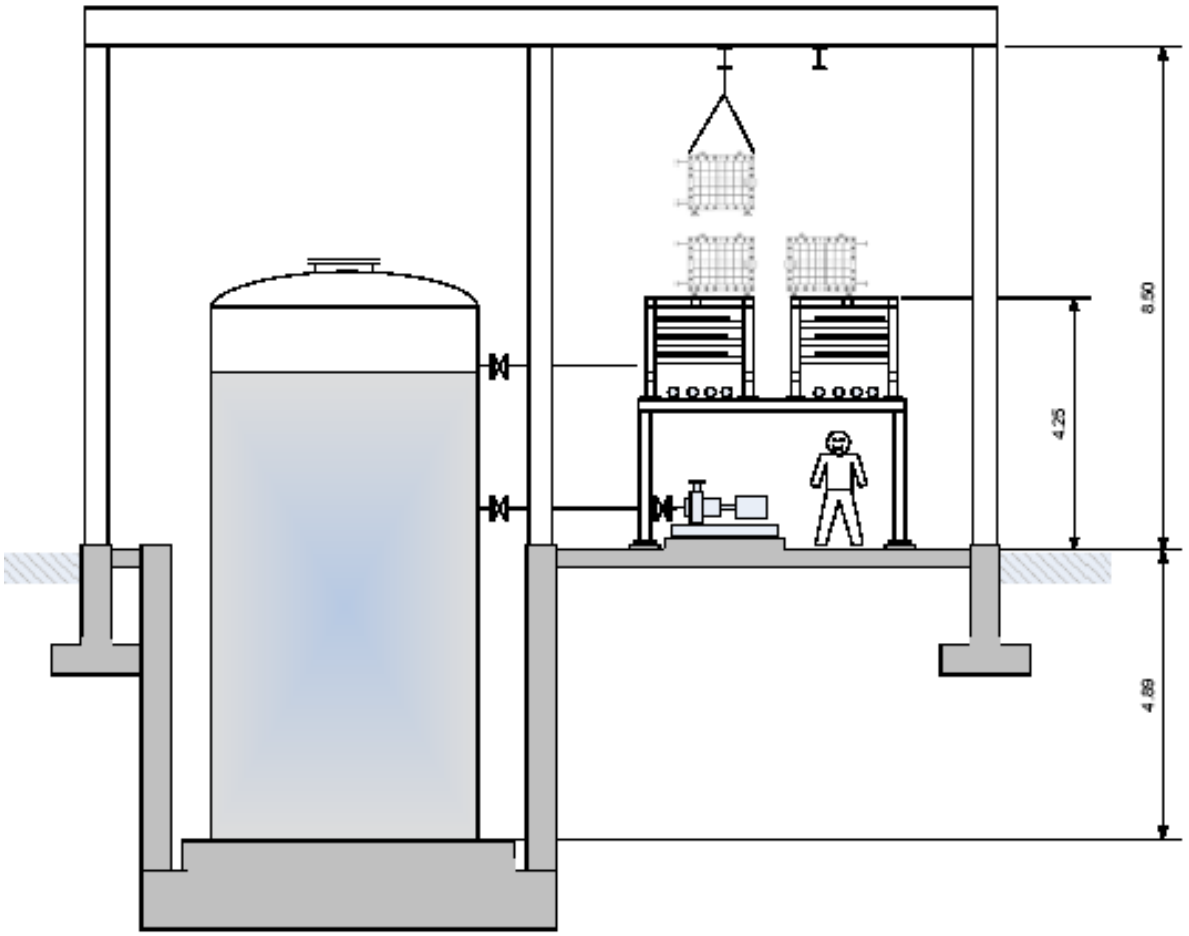


Source: Calculated from PacifiCorp's End-of-Hour TOT 4A and 4B Load Data in Wyoming.

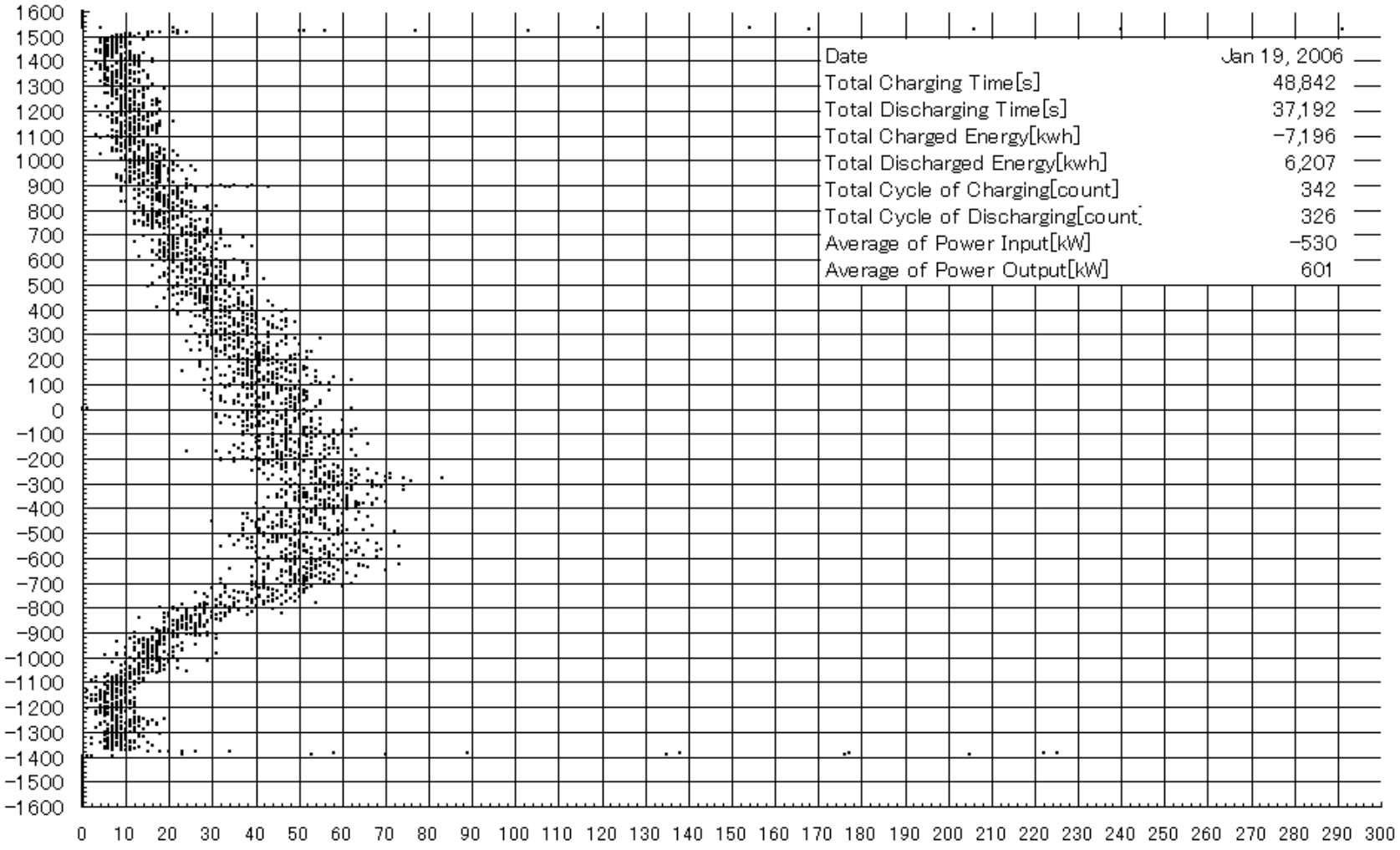
Short-Term Transmission Products

- PacifiCorp is working with Bonneville Power Administration to develop a Conditional Firm product to be implemented by year-end 2008
- Many transmission paths are scheduled near capacity (75-90%) a high percentage of time
- Wind energy and other resources are curtailed because of transmission congestion
- PacifiCorp is holding public stakeholder meetings to review Conditional Firm products that can:
  - Optimize use of existing transmission system
  - Increase product flexibility for customers

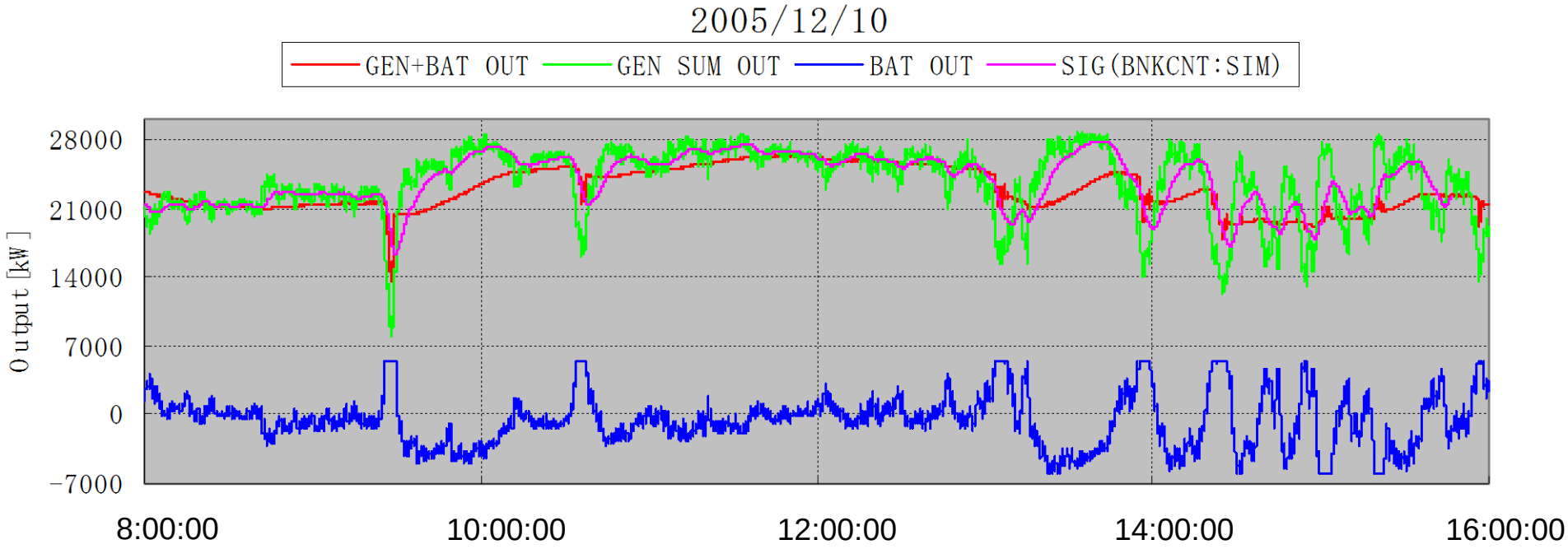
Conceptual Plan for Multi-MWh VRB Plant



VRB Battery Cycling at a Large Windfarm in Japan



Daily Wind Output Smoothing at J-Power



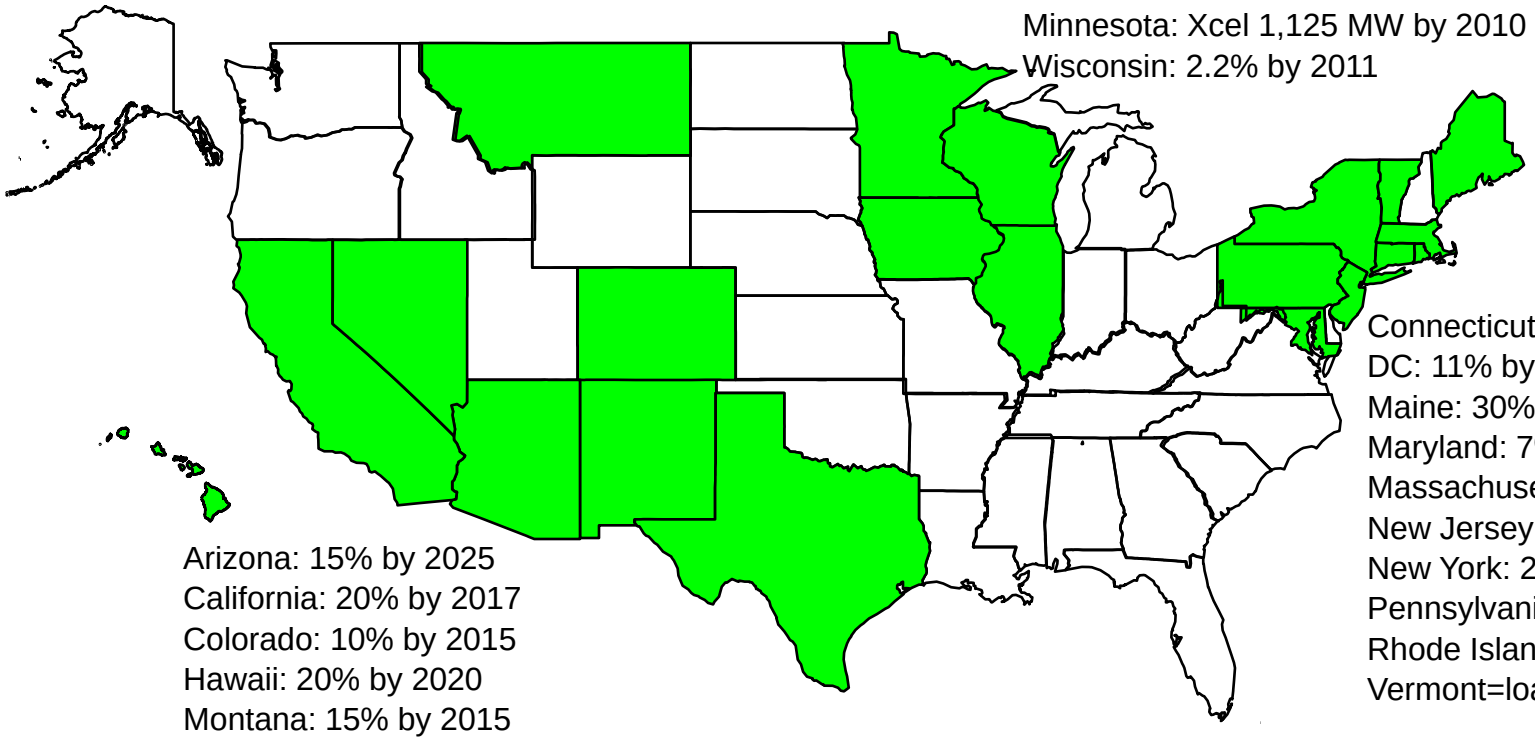
- The VRB-ESS (blue line) runs continuously to smooth wind farm production (green line)
- At only 20% of the wind-farm's nameplate capacity, the VRB ESS has a significant smoothing effect to total wind-farm + battery output (red line)
- The VRB-ESS intelligently recharges throughout the day so that it maintains 50% SOC

Modeling Efforts

- Built and tested Excel model to calculate battery cycling based on actual transmission congestion, wind turbine output, tariff, and potential output without congestion

Battery Capacity Charge Duration Discharge Duration Round-trip Efficiency Losses Minimum Discharge Level	Battery Capital and O&M Costs Interest Rate Battery Expected Life Span Battery Salvage Value Conditional Firm Incentives
Tariff - Energy Charge Tariff - Capacity Charge - Up to 5 different rate classes - Up to 2 seasons (Summer/Winter) Base Cost of Energy	Charging/Discharging Schedule - Up to 2 seasons (Summer/Winter) - Weekday/Weekend - Up to 2 cycles/day - Start/Finish at end of hour

Aggressive Renewable Portfolio Standards



Illinois: 8% by 2013
Iowa: 105 MW
Minnesota: Xcel 1,125 MW by 2010
Wisconsin: 2.2% by 2011

Connecticut: 10% by 2010
DC: 11% by 2022
Maine: 30% by 2000
Maryland: 7% by 2008
Massachusetts: 4% new by 2009
New Jersey: 6.5% by 2008
New York: 25% by 2013
Pennsylvania: 18% by 2020
Rhode Island: 16% by 2009
Vermont=load growth 2005-2012

Arizona: 15% by 2025
California: 20% by 2017
Colorado: 10% by 2015
Hawaii: 20% by 2020
Montana: 15% by 2015
Nevada: 20% by 2015
New Mexico: 10% by 2011
Texas: 10,000 MW by 2025

Source: Modified from Pew Center on Global Climate Change, www.pewclimate.org/what_s_being_done/in_the_states/prs.cfm.

Model Sensitivity Runs – Time of Day Profiles

Aligning the battery charge/discharge profile with tariff time-of-use factors increased the MWh discharged and the revenue from capacity charges.

Restrictive tariff with low winter rates and efficiency losses worked against incremental revenue.

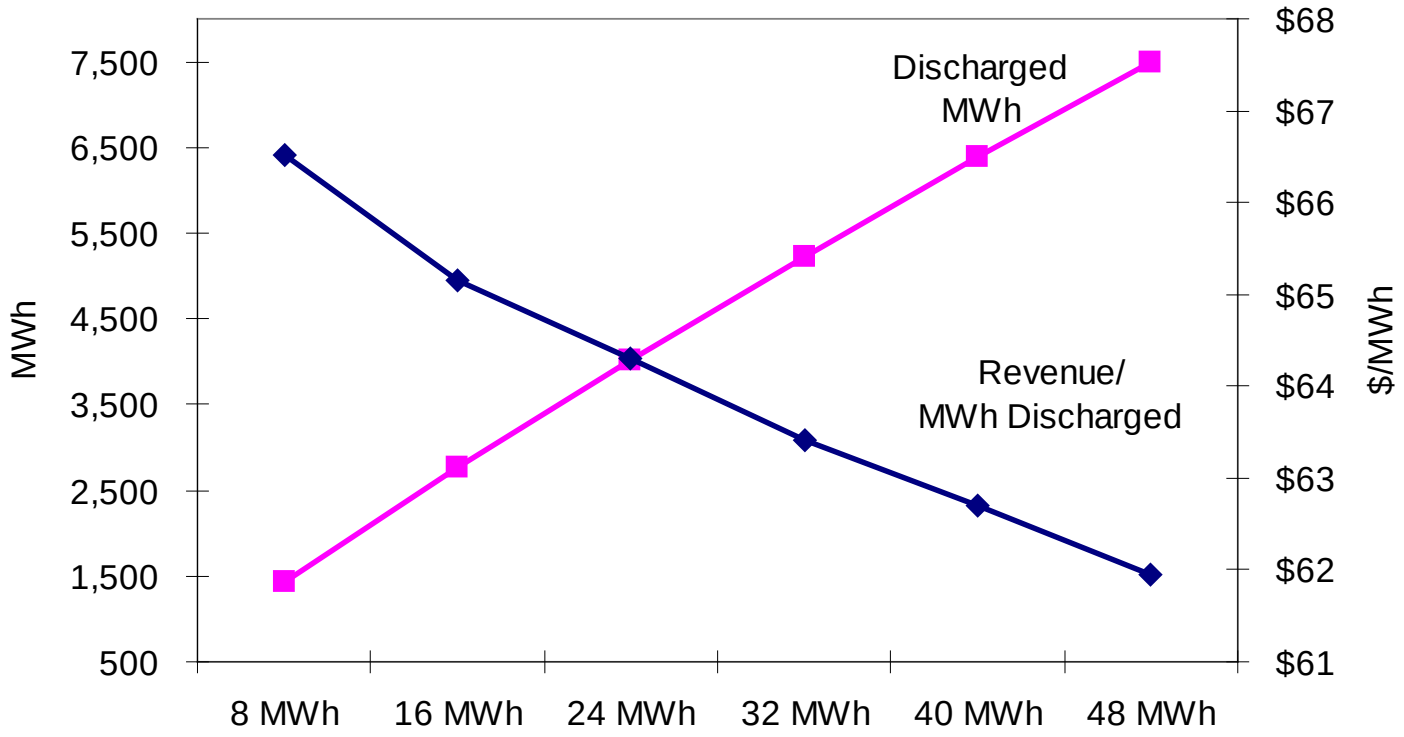
Variables	Once a Day	Twice a Day
Summer Charge	0:00 - 10:00	24:00 - 9:00; 19:00 – 21:00
Summer Discharge	12:00 - 20:00	11:00 – 19:00; 21:00 – 24:00
Winter Charge	0:00 - 10:00	0:00 - 10:00; 15:00 – 20:00
Winter Discharge	13:00 - 21:00	10:00 - 15:00; 20:00 – 24:00

Discharged MWh	4,020	6,083

Model Sensitivity Runs - Capacity

Altering battery capacity from 8 MWh to 48 MWh while holding a once a day 10-hour charge and 8-hour discharge.

24 MWh is the optimal size. Energy discharged and revenue per MWh discharged are optimized: 4,020 MWh at $64/MWh.



Model Sensitivity Runs – Salvage Values

- VRB battery has two electrolyte storage tanks of active vanadium-sulfuric acid solutions
- Vanadium can be recovered from the electrolyte at the end of battery life
- VRB estimates this value at $76/kWh of energy storage capacity
  - Compared a range of salvage values to examine the contribution to cost reduction

Salvage Value	Reduction
$50/kWh	13%
$76/kWh	19%
$100/kWh	25%

Summary/Conclusions

- Energy storage can help windfarm operators cope with transmission congestion and forced curtailments
- Novel firm transmission products can improve project economics
- The model is robust; it can provide reliable analysis of wind speeds and turbine outputs in other transmission-constrained markets.
- Less restrictive tariffs with capacity charges improve project economics
- Easier access to data can greatly improve analysis
- Thank you to DOE Energy Storage Program, Sandia National Laboratories, Wyoming Business Council, PacifiCorp, and VRB

Future Work

- No future work is anticipated through the grant with the State of Wyoming
- Approach PacifiCorp to consider integrating a flow battery with a windfarm in Wyoming and examine flow battery value under conditional firm transmission
- Track Conditional Firm and other novel transmission products
- Monitor future integrated wind-storage projects in the U.S. and abroad