Wind Integration Costs

Integrated Resource Plan Technical Workshop

November 19, 2002

PACIFICORP

Background

- Some wind resource costs are well known.
  - Capital
  - Operation and Maintenance
- Some wind resource costs have significant uncertainty
  - Transmission
  - Green tag credits
  - Tax credits
- Integration costs are least understood.
  - What do they comprise?
  - How are they calculated?

Wind Integration Costs

- Wind resources incur all the integration costs of other resources, but two categories are special to wind:
  - Incremental Reserve Requirements
  - System Imbalance Costs

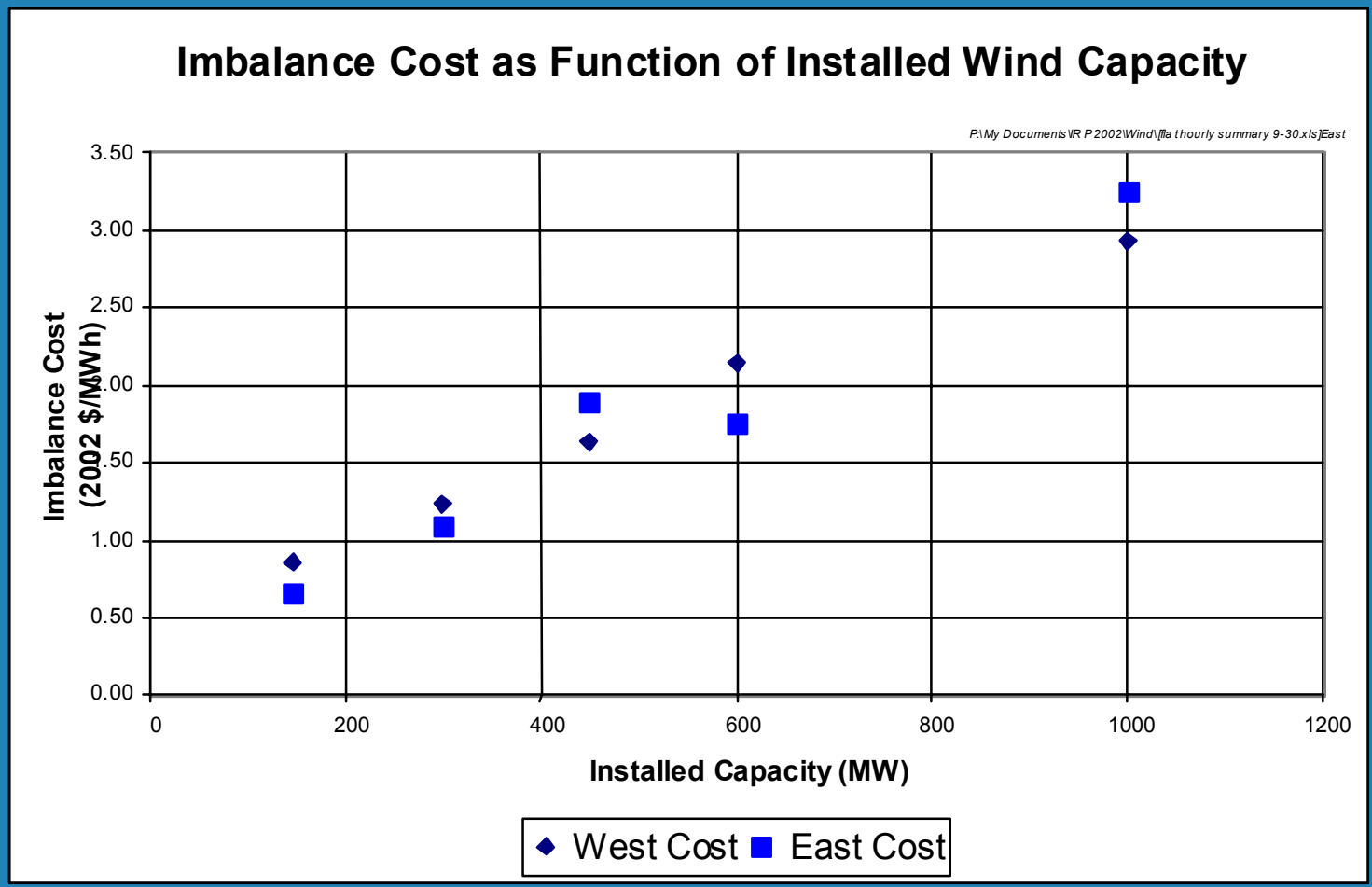
Wind-Specific Integration Costs

- Incremental Reserve Requirement
  - Reserves meet unscheduled fluctuations in expected operations.
- System Imbalance
  - Additional unit start-up costs.
  - Moving to less favorable portions of heat rate curves.
  - Incurring bid-ask spread costs more often.

Imbalance Cost Assessment

- Assessed imbalance costs with PROSYM model.
  - Various levels of wind capacity were tested in three future years.
  - Incremental production costs between wind and equivalent amount of flat energy to meet loads.
  - Difference in costs ascribed to variability of wind output.

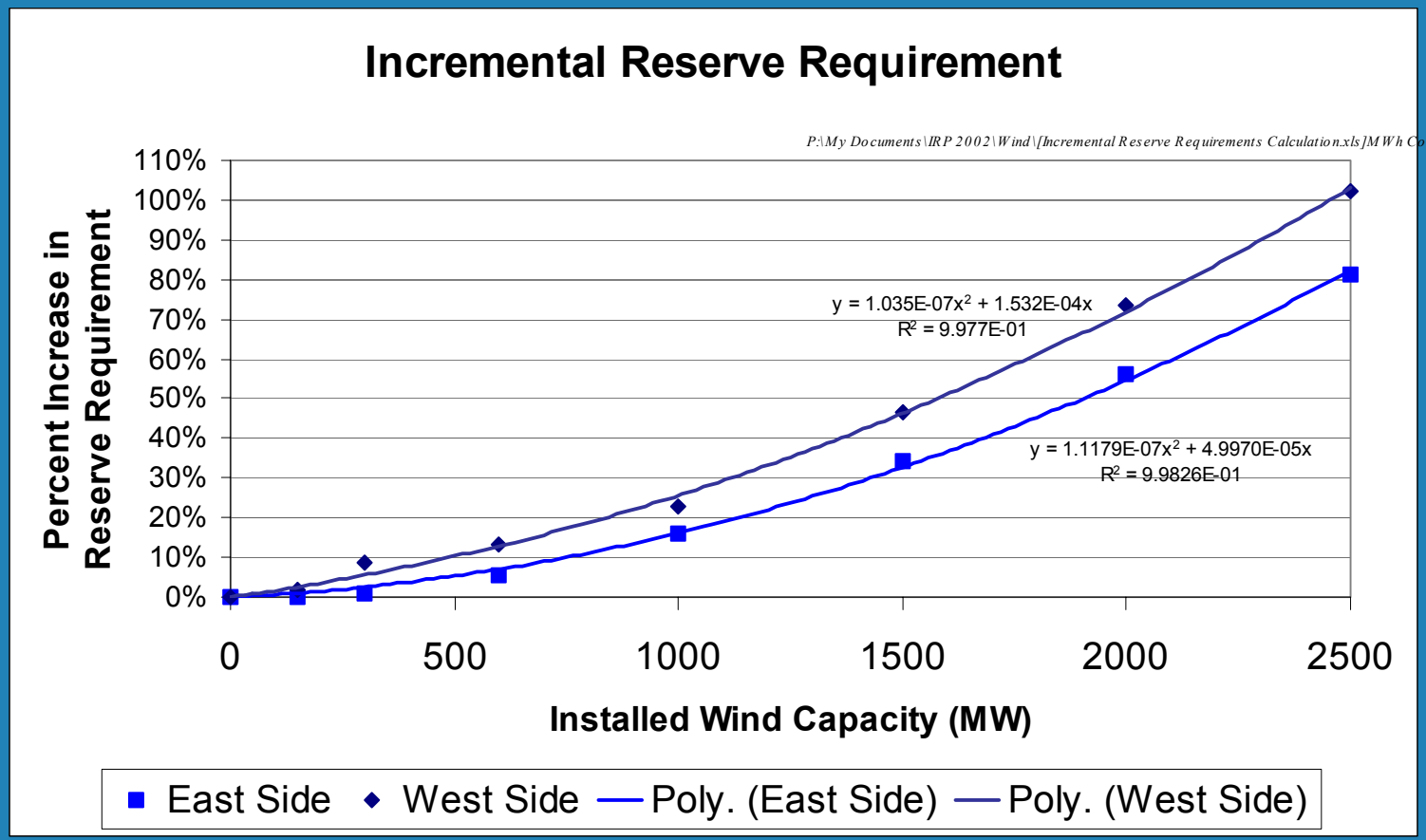
Imbalance Cost Increases with Installed Wind Capacity



Incremental Reserves Cost Assessment

- Power systems cope with variable, unpredictable, and uncontrollable changes in loads and resources.
- Current operating margins developed over time and experience-- not calculated analytically.
- Change in standard deviation of loads net of wind generation was used as proxy for increased need for reserve margins.
  - Reserve margin costs were grossed up by percent increase in standard deviation.

Reserve Requirements Increase with Wind Capacity



Reserve Requirement Cost Formula

$$C_w = A\frac{P_w}{f} + B/f$$

Cw = Reserve requirement cost ($/MWh)

Pw = Installed wind capacity

f = Wind capacity factor

A, B = constants (B/f~ $1/MWh)

Formula assumes cost of reserves increases linearly with reserve requirement.

Wind-Specific Integration Cost Calculation Examples

System	Capacity	Factor	Imbalance	Reserve	Total
East	500 MW	35%	**$1.75**	**$1.51**	**$3.26**
West	**500 MW**	**35%**	**$2.10**	**$1.39**	**$3.49**
East	**1,000 MW**	**30%**	**$3.25**	**$2.72**	**$5.97**
West	**1,000 MW**	**30%**	**$2.95**	**$2.04**	**$4.99**

Analysis Assumptions

- Dispatch model accurately reflects imbalance costs.
  - Model does not fully account for hydro flexibility.
  - Model has perfect wind resource forecast.
    - under-estimates start up costs.
- Operating reserve requirements are proportional to hourly load volatility net of wind generation.
  - Did not include variability caused by thermal forced outages.
  - Reserve margins may not be sufficient coping mechanism.
    - May need additional ability to drop load.

Analysis Assumptions (continued)

- Cost of reserves remains relatively constant relative to market prices.
  - Analysis is something of a snapshot and not indexed to market prices or fuel costs.
- Sufficient transmission to fully integrate wind resources with the system.
  - Resource often located in isolated parts of control areas.
- Intra-hour variability is not significant.
  - Has not been an issue to date.

Total Wind Costs

	2002 $/MWh (levelized) Low	High
Capital and O&M (20yr life)	$40.00	$50.00
Transmission	$ 2.00	$ 6.00
Imbalance and Incremental Reserves	$ 5.00	$ 6.00
Production Tax Credit ($18.00 1st 10 years)	-$ 12.00	$ 0.00
Renewable Energy Credits ($5.00 1st 5 yrs)	-$ 2.00	$ 0.00
Total	$33.00	$62.00

Average $47.50

Conclusions

- Strong evidence that wind integration issues and costs are manageable for fairly significant amounts of wind on the system.
- Wind-specific integration costs on PacifiCorp's system for wind, up to about 20% (wind capacity to peak load), appear to be around $5-6/MWh.
- FINDINGS ARE PRELIMINARY!
  - Operating experience will build confidence and understanding.

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