Status of Regional Wind Integration Studies

Debbie Lew
NREL

WIEB Board Meeting
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Comparison of Cost-Based U.S. Operational Impact Studies

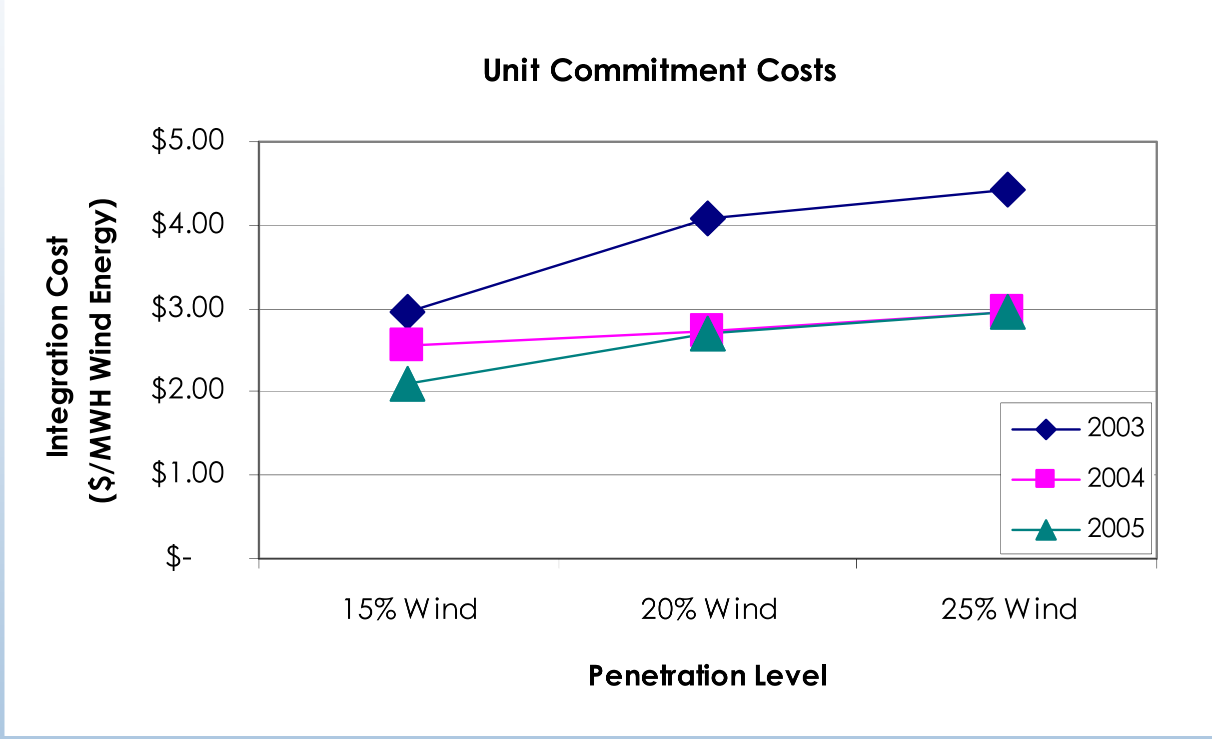
Date	Study	Wind Capacity Penetra-tion (%)	Regula-tion Cost ($/MWh)	Load Following Cost ($/MWh)	Unit Commit-ment Cost ($/MWh)	Gas Supply Cost ($/MWh)	Tot Oper. Cost Impact ($/MWh)
May '03	Xcel-UWIG	3.5	0	0.41	1.44	na	1.85
Sep '04	Xcel-MNDOC	15	0.23	na	4.37	na	4.60
June '06	CA RPS	4	0.45*	trace	na	na	0.45
Feb '07	GE/Pier/CAIAP	20	0-0.69	trace	na***	na	0-0.69***
June '03	We Energies	4	1.12	0.09	0.69	na	1.90
June '03	We Energies	29	1.02	0.15	1.75	na	2.92
2005	PacifiCorp	20	0	1.6	3.0	na	4.60
April '06	Xcel-PSCo	10	0.20	na	2.26	1.26	3.72
April '06	Xcel-PSCo	15	0.20	na	3.32	1.45	4.97
Dec '06	MN 20%	31**					4.41**
Jul '07	APS	14.8	0.37	2.65	1.06	na	4.08

* 3-year average; total is non-market cost

** highest integration cost of 3 years; 30.7% capacity penetration corresponding to 25% energy penetration; 24.7% capacity penetration at 20% energy penetration

*** found $4.37/MWh reduction in UC cost when wind forecasting is used in UC decision

20% Wind Energy Can Be Managed



Unit commitment costs for three penetration levels and pattern years. Cost of incremental operating reserves is embedded.

Source: MN DOC

Additional reserves may need to be committed

Reserve Category	Base		15% Wind		20% Wind		25% Wind	
	MW	%	MW	%	MW	%	MW	%
Regulating	137	0.65%	149	0.71%	153	0.73%	157	0.75%
Spinning	330	1.57%	330	1.57%	330	1.57%	330	1.57%
Non-Spin	330	1.57%	330	1.57%	330	1.57%	330	1.57%
Load Following	100	0.48%	110	0.52%	114	0.54%	124	0.59%
Operating Reserve Margin	152	0.73%	310	1.48%	408	1.94%	538	2.56%
Total Operating Reserves	**1049**	**5.00 %**	**1229**	**5.86%**	**1335**	**6.36%**	**1479**	**7.05%**

Estimated Operating Reserve Requirement for MN BAs – 2020 Load

Source: MN DOC

Comparison of Regulating Reserves

Balancing Authority	*Peak Load*	*Regulating Requirement (from chart)*	*Regulating Requirement (% of peak)*
GRE	3443 MW	56 MW	1.617%
MP	2564 MW	48 MW	1.874%
NSP	12091 MW	104 MW	0.863%
OTP	2886 MW	51 MW	1.766%
Sum of Regulating Capacity		**259 MW**	
Combined	20984 MW	**137 MW**	**0.655%**

Estimated Regulating Requirements for MN BAs - 2020

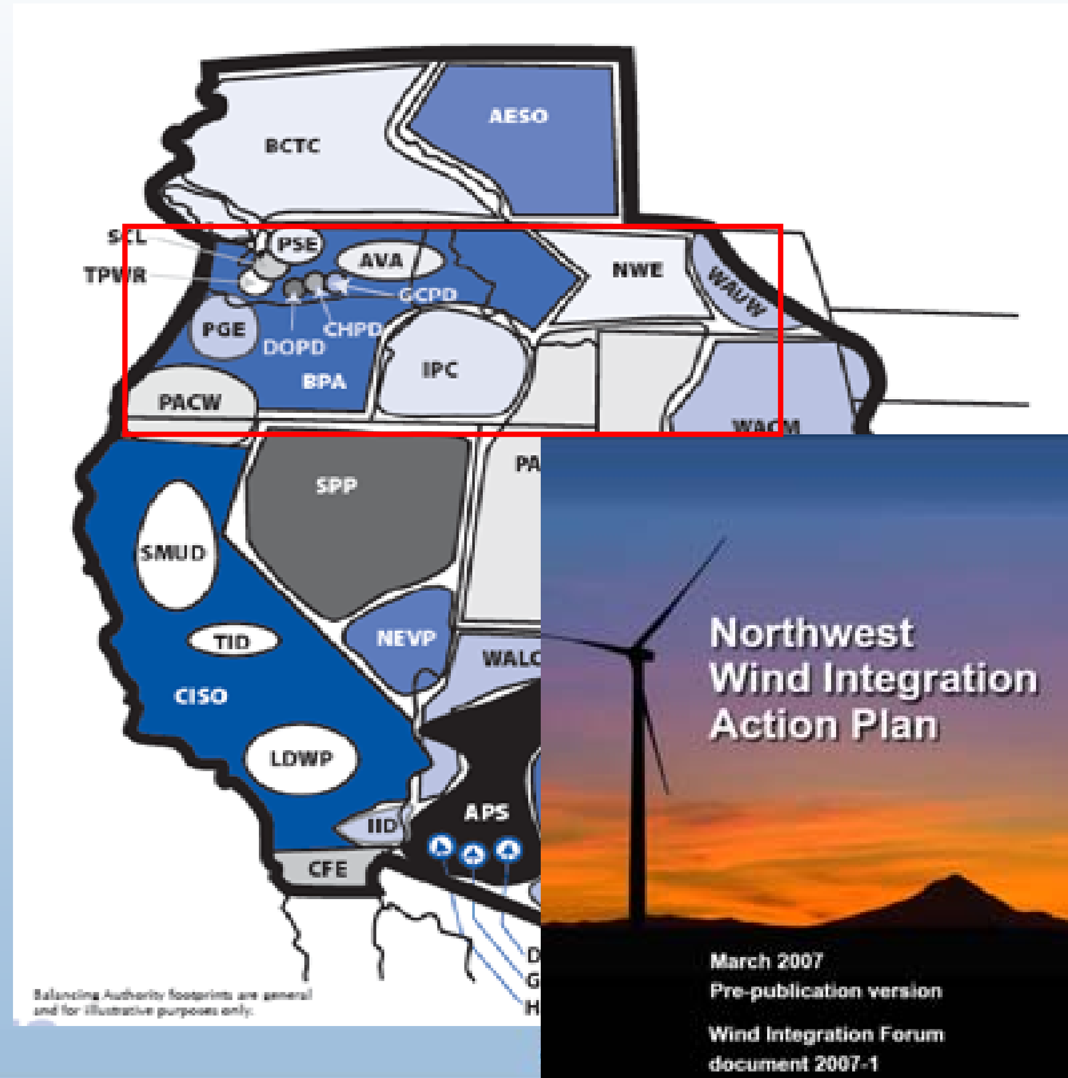
Source: MN DOC

Northwest

- Northwest Integration Action Plan / Northwest Integration Forum
- Avista wind integration study
- Idaho Power wind integration study
- BPA

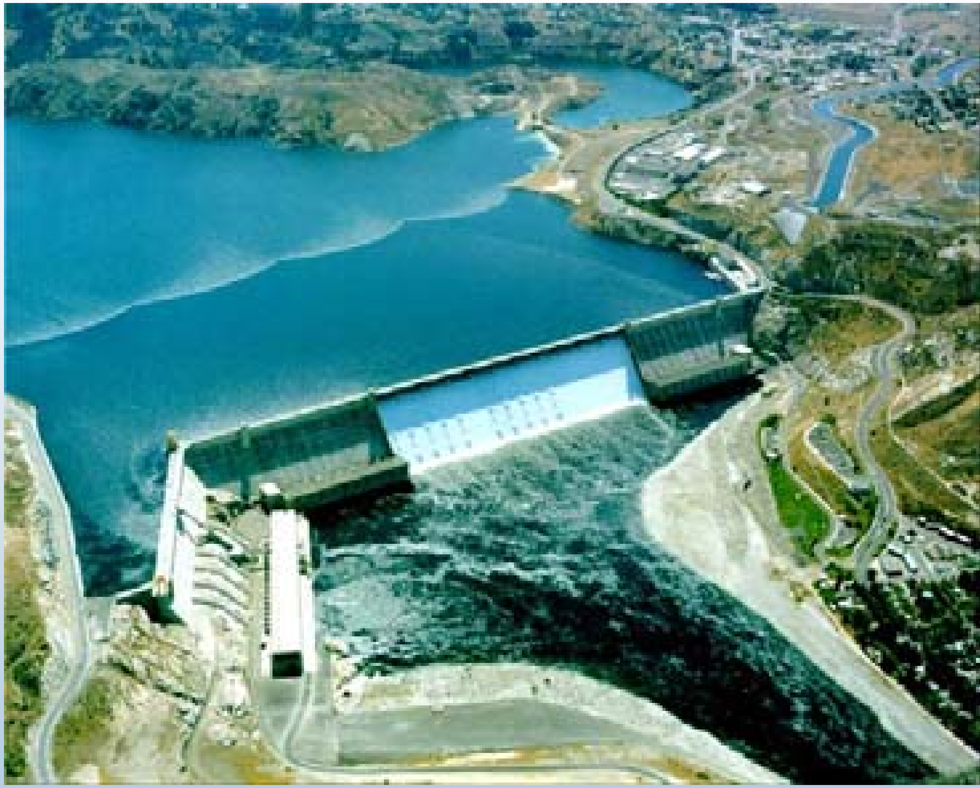
Pacific Northwest Initiated Wind Integration Action Plan

- Large stakeholder effort to examine wind; action items developed
- Wind mesomodel dataset completed
- ACE diversity
- Dynamic load following service
- BPA wind integration rate



Studies in the Northwest

- Studies were not subject to rigorous peer review and may still contain errors
- Avista Utilities: Up to 30% wind penetration (peak)
- Idaho Power: Up to about 30% wind penetration (peak)
- Idaho PUC considering settlement agreement
- BPA: analytical work in progress; integration cost is consistent with others
- Northwest Wind Integration Action Plan: http://www.nwcouncil.org/energy/Wind/Default.asp



California

- CEC Intermittent Analysis Project
- CAISO Renewable Integration Study
- Transmission planning (CEC Regional Integration of Renewables and Renewable Energy Transmission Initiative)

Four Scenarios - Overview

	2006	2010T	2010X	2020
Peak California Load, MW	58,670	64,336	64,336	80,742
Peak CA ISO Load, MW	48,466	53,147	53,147	66,700
Total Geothermal, MW	2,400	4,100	3,700	5,100
Total Biomass, MW	760	1,200	1,000	2,000
Total Solar, MW	330	1,900	2,600	6,000
Total Wind, MW	2,100	7,500	12,500	12,700
Wind at Tehachapi, MW	760	4,200	5,800	5,800
CA Wind+Solar Capacity Penetration	4%	15%	23%	23%
CA ISO Wind+Solar Capacity Penetration	5%	17%	26%	25%
CA Wind+Solar Energy Penetration	2%	8%	13%	12%
CA ISO Wind+Solar Energy Penetration	2%	9%	15%	14%

Source: CEC/GE

Conclusions

- 2010X Scenario includes 12,500 MW wind and 2,600 MW solar with projected load and generation mix for year 2010
- These renewables can be integrated into the California grid provided appropriate infrastructure, technologies, and policies are in place
  - Investment in transmission, generation and operations infrastructure to support the renewable additions,
  - Appropriate changes in operations practice, policy and market structure,
  - Cooperation among all participants, e.g., CAISO, investor owned utilities, renewable generation developers and owners, non-FERC jurisdictional power suppliers, and regulatory bodies.

Source: CEC/GE

CAISO Renewable Integration Study

- Operational study
  - Examine ramps in detail
  - Determine ramping requirements due to load following and regulation
  - Examine over-generation issues
- Conclusions - 20% RPS is manageable
  - New market design mitigates current challenges
    - Important to integrate improved wind forecasting with dispatch procedures
  - Operational implications significant but manageable

Southwest and Mountain region

Arizona Public Service Study
Acker et. al Sep 2007

Wind Energy Penetration	1%	4%	7%	10%
Within-hour Regulating	$0.40	$0.41	$0.31	$0.37
Hour-ahead Uncertainty	$0.11	$1.88	$2.32	$2.65
Day-ahead Uncertainty	$0.39	$0.95	$0.93	$1.06

Figure ES 4 – Sensitivity of integration cost to percent penetration of wind energy, under base case assumptions.

APS Wind Integration Cost Impact Study

Table ES 3 – Matrix of wind integration scenarios considered with the associated integration costs listed in $/MWh.

Integration Cost Summary ($/MWh)

Wind Scenarios		Geographic Diversity		
Energy Penetration	Penetration by Capacity	High	Med	Low
1%	1.5%		0.91	
4%	5.9%	2.60	**3.25**	3.30
7%	10.4%		3.57	
10%	14.8%		4.08	

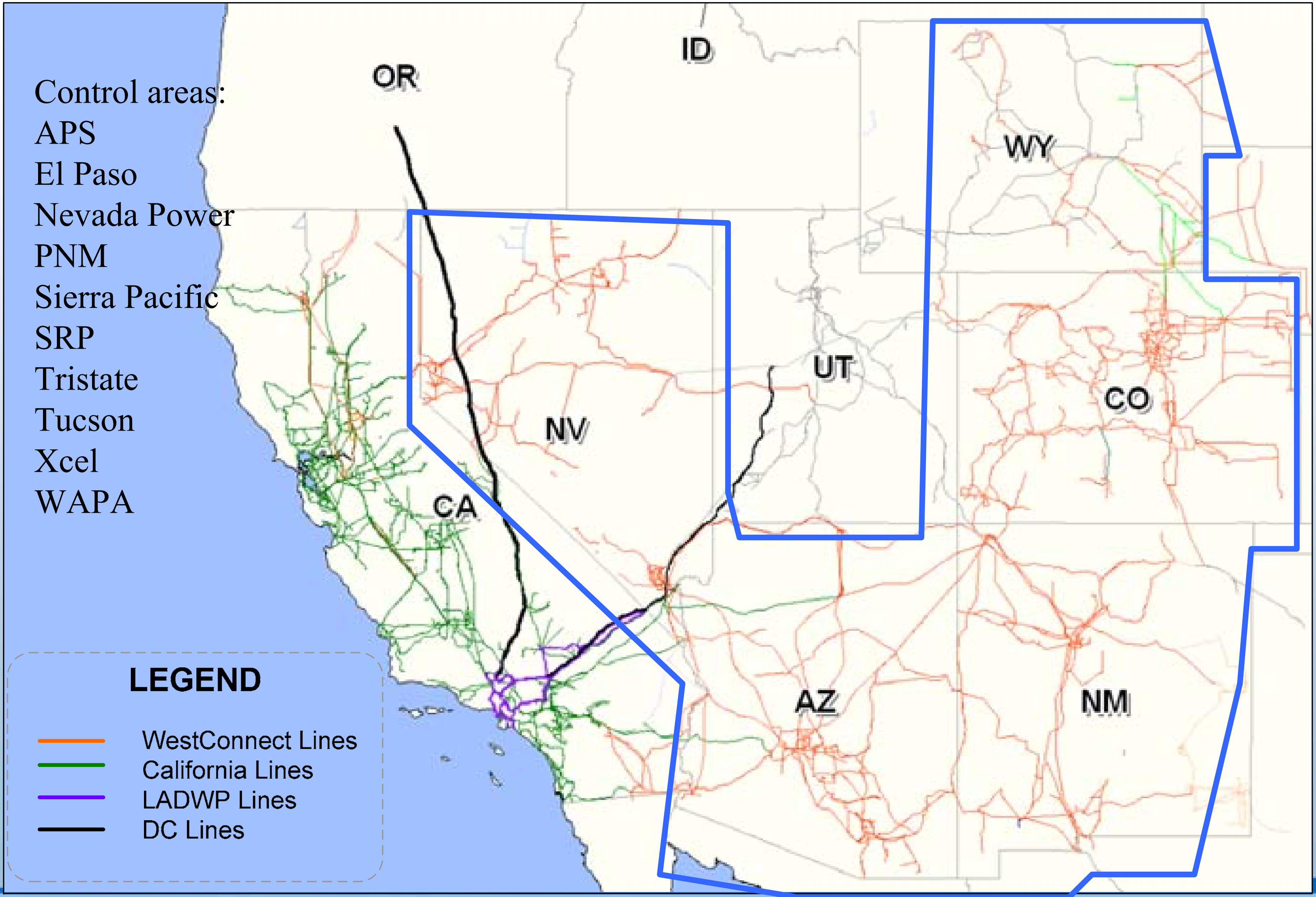
Gray Shading = Cases run **Bold** = Base Case

Western Wind and Solar Integration Study - WestConnect

To understand the operating and cost impacts due to the variability and uncertainty of wind and solar power on the grid

- How can utilities manage the incremental variability and uncertainty of wind and solar?
- Do geographically diverse wind/solar resources reduce variability and increase transmission utilization?
- How do local wind/solar resources compare to out-of-state resources in terms of load correlation or cost?
- How can hydro help with wind/solar integration?
- The role and value of wind forecasting
- Can balancing area cooperation help manage the variability?
- How do wind and solar contribute to reliability and capacity value?

Revised Study Footprint



Schedule

Kickoff Stakeholder Meeting	5/23/07
Data Collection	Jun-Dec '07
Wind/solar mesoscale modeling	Oct '07-May '08
Preliminary Analysis	Feb-Jun '08
Prelim. results stakeholder mtg	Jul '08
Production Cost Modeling	Jul '08-Jan '09
Interim Technical Results mtg	Dec '09
Draft report	Feb '09
Draft results Stakeholder mtg	Mar '09
Final Report	Apr '09

For more information

- Debbie Lew
- NREL
- 303-384-7037
- debra_lew@nrel.gov

- http://westconnect.com/init_wwis.php