

Nebraska Power Association
Statewide Wind Integration Study
January, 2010





Nebraska Power Association NPA

- Voluntary Membership
- All Nebraska Electric Utilities PPD's –
Munis – Coops
- NE Total Public Power
- Forum to Discuss Common Issues
- Establish Common Positions
- Prepare Reports and Studies

Study Background

- Began October 2008
- Support through contract with DOE/NREL
- Technical Review Committee – Guide study process – provide Input
- Consultants
 - Enernex – Has knowledge of wind data and experience with prior wind integration studies
 - Ventyx – Created and maintains models for large area studies and has experience with production cost models



Technical Review Committee (TRC)

Nebraska Utility Members

Clint Johannes, NEG&T
Dave Rich, NPPD
Dave Ried, OPPD
Jon Iverson, OPPD
Billy Cutsor, NMPP Energy & MEAN

Paul Malone, NPPD
Doug Kallesen, NPPD
Marc Nichols, OPPD
Bruce Merrill, LES
Dave Mazour, Tri-State G&T
Ron Steinbach, Tri-State G&T

Consultants

Bob Zavadil, EnerNex Corp
Tom Mousseau, EnerNex Corp
Brenton Meese, Ventyx Energy, LLC

Jack King, EnerNex Corp
Gary Moland, Ventyx Energy, LLC
Rick Hunt, Ventyx Energy, LLC



Technical Review Committee (TRC) (continued)

Technical Experts & Stakeholders

Michael Milligan, NREL

Ed DeMeo, RECS/NREL

Laverne Kyriss, WAPA

Jay Caspary, SPP

Neil Moseman, NDOE

John Hansen, NWWG

Michael Goggin, AWEA

Matt Schuerger, ESCS/NREL

Charlie Smith, UWIG

Mike Radecki, WAPA

Sohrab Asgarpoor, UNL, EE

Bruce Hauschild, NEO

Tim Texel, NRPB

Steve Eveans, Windrow Energies, LLC

Five tribes were invited and copied on TRC correspondence

Plus 31 observers that also provided guidance and input

NREL Subcontract Officials

Brian Parsons, NREL

Neil Wikstrom , ESCS/NREL



Study Scope

- Identify issues and cost when operating wind energy at 10% or greater penetration
- Identify production cost change when operating existing generating units under several magnitudes of wind penetration
- Identify necessary regulating reserves required
- Identify if federal hydro system may help with cost effective wind integration
- Allow Stakeholders beyond utilities to have input and participate in the study, Technical Review Committee

Key Study Assumptions

- NREL Meso Scale wind data 2004-2005-2006
- NPA Load Patterns 2004-2005-2006
- Study 2018 Loads & Transmission/Generation
- Study area NPA-rest of SPP-much of rest of the Eastern Interconnection (PJM, MISO/MAPP, SERC, TVA)
- Wind penetration levels 10%-20%-40% of energy
- Determine Integration Cost due to wind variability and uncertainty on SPP-wide basis
- Base Case \$25/ton Carbon Dioxide emission cost
- Several Sensitivity Cases

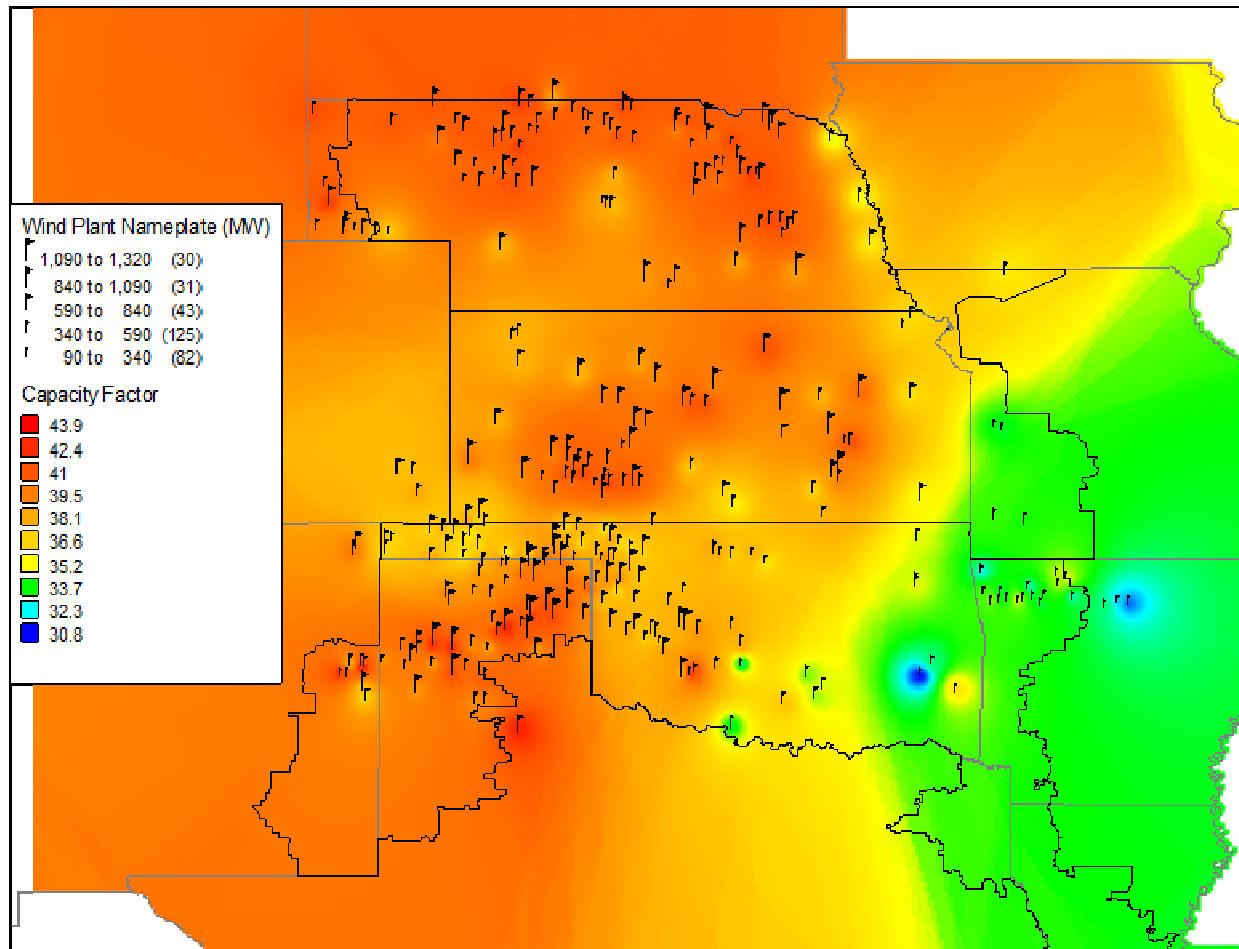


Wind Scenarios

- TRC discussions lead to the following four base cases:
 - 10% NPA wind, 10% SPP wind, without SPP EHV Overlay (**Scenario 1**)
 - 20% NPA wind, 20% SPP wind, without SPP EHV Overlay (**Scenario 2**)
 - 20% NPA wind, 20% SPP wind, SPP EHV Overlay (**Scenario 3**)
 - 40% NPA wind, 40% SPP wind, SPP EHV Overlay (**Scenario 4**)
- NPA amounts are approximately 1.2 GW, 2.5 GW, and 4.7 GW
- Rest of SPP amounts are approximately 6.3 GW, 12.6 GW, and 25.4 GW
- As perspective, the 40% case (30.1GW) represents 59 wind farms in Nebraska and 318 in the rest of SPP (assuming they are sized like Nebraska's largest wind farm today of 80MW).
- Wind Capacity for "Rest of Eastern Interconnection" that was modeled
 - per EWITS (MISO/JCSP) reference case
 - Approximately 50 GW about 6% penetration for all scenarios



NREL Meso-scale Data Overview



NREL data, developed by AWS TrueWind.

Wind generation data for 80-meter heights: “**Actual**” at 10-minute intervals and hourly.

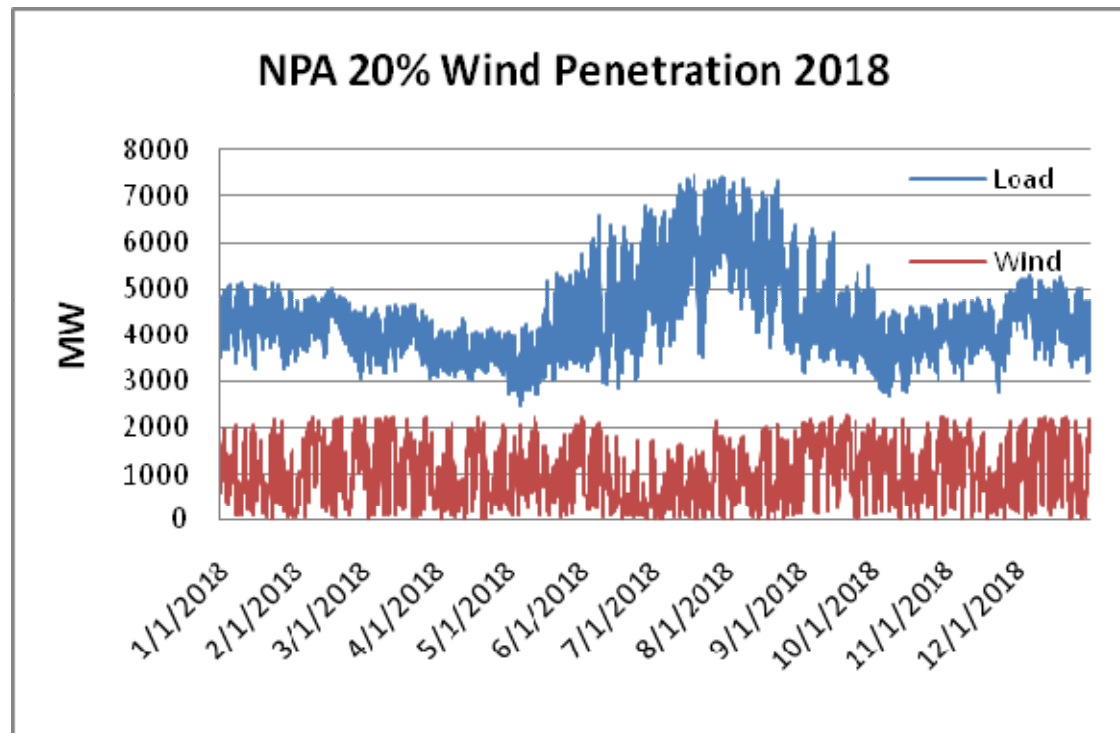
“**Forecasts**” of hourly with lead times of day-ahead, 6 hours and 4 hours (only forecast used was day-ahead).

Years involved 2004-2006.

Spatial resolution was 2 kilometers between “sample” points.

Wind and load data drive analysis

- High resolution data scenarios were created from the NREL data
- Variations and correlation between wind and load are represented



Wind Generation Penetration

Region	10% Penetration			20% Penetration			40% Penetration		
	Name Plate	CF	GWh Ref Energy	Name Plate	CF	GWh Ref Energy	Name Plate	CF	GWh Ref Energy
NPA	1,249	41%	4,523	2,488	41%	8,855	4,727	41%	16,831
SPP w/o NPA	6,256	42%	22,901	12,596	41%	45,807	25,431	41%	91,548
PJM	25,807	36%	81,460	Same as for 10% Penetration					
MISO/ MAPP	19,547	36%	61,700	Same as for 10% Penetration					
SERC	3,615	36%	11,410	Same as for 10% Penetration					
TVA	1,397	36%	4,410	Same as for 10% Penetration					
Total	57,871	37%	186,405	65,450	37%	213,642	80,524	38%	267,359

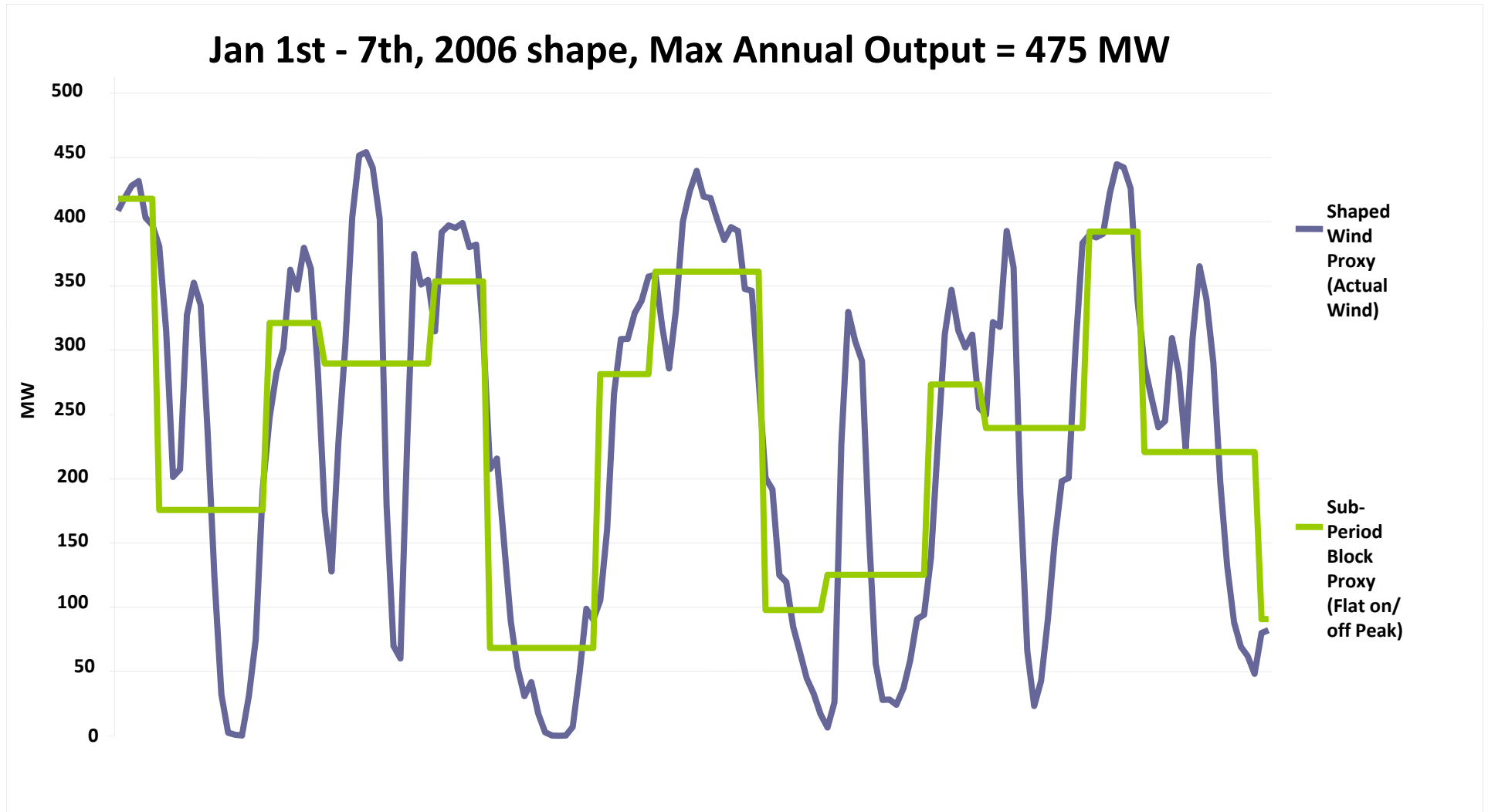


Wind Integration Cost

- Basically, added production costs to operate dispatchable generating units with wind added (variable and not 100% predictable) along with load also not 100% predictable
- Determined by making 2 different production cost studies
 - One simulation uses “actual” wind (not predictable) → higher cost
 - Other simulation uses a wind proxy with same amount of “ideal” wind generation (which is perfectly forecasted and potentially has a better “shape”) → lower cost (several proxies were tested)
 - Difference in production costs divided by total wind generation results in \$ per MWh wind integration cost
- The cost of increased reserve requirements to manage the wind variability and uncertainty are part of the cost difference between the simulations for “actual” and “ideal” wind
- Integration Cost as used does not include: 1) capital and operating cost of wind, 2) cost of transmission, and 3) other potential cost impacts on generating units

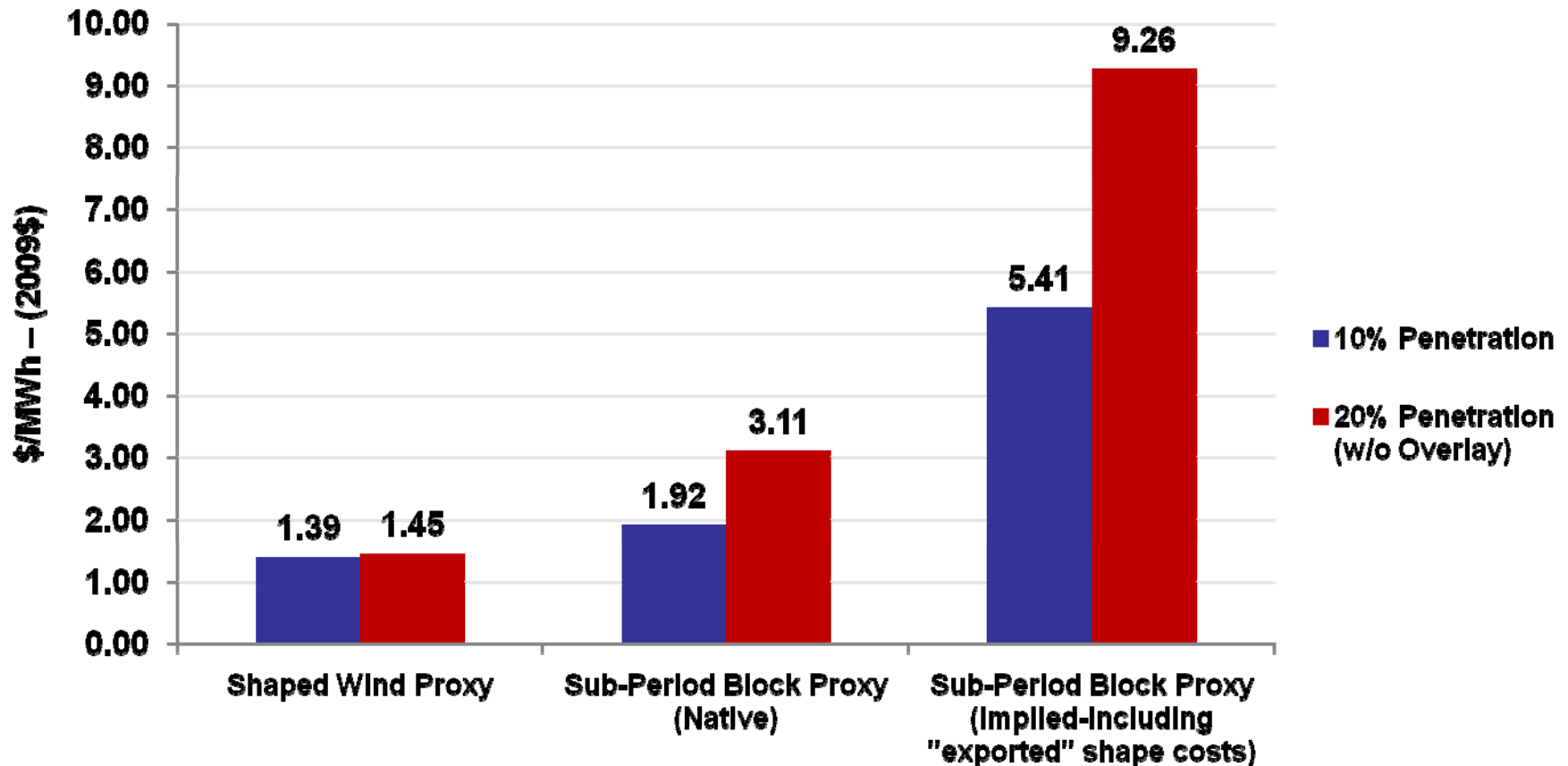


Shaped and Sub-period Block Proxy Samples



NPA Wind Study – Findings & Conclusions

SPP Integration Costs – Proxy Resource Comparison – 2009\$



Note: Cost using Shaped Proxy includes increased regulating reserve requirements and wind forecast error. Cost using Sub-Period Block Proxy also includes shape costs (from wind's variable nature vs. a flat profile for period). "Native" costs include all integration costs found in the SPP area. "Implied" costs include all integration costs including those "exported" out of SPP (external areas had constant wind penetration while SPP penetration varied, creating exports).

NPA Wind Study - Findings and Conclusions

Annual Capacity Credit by Wind Farm

(Using SPP Rules* in % of Wind Plant Nameplate)

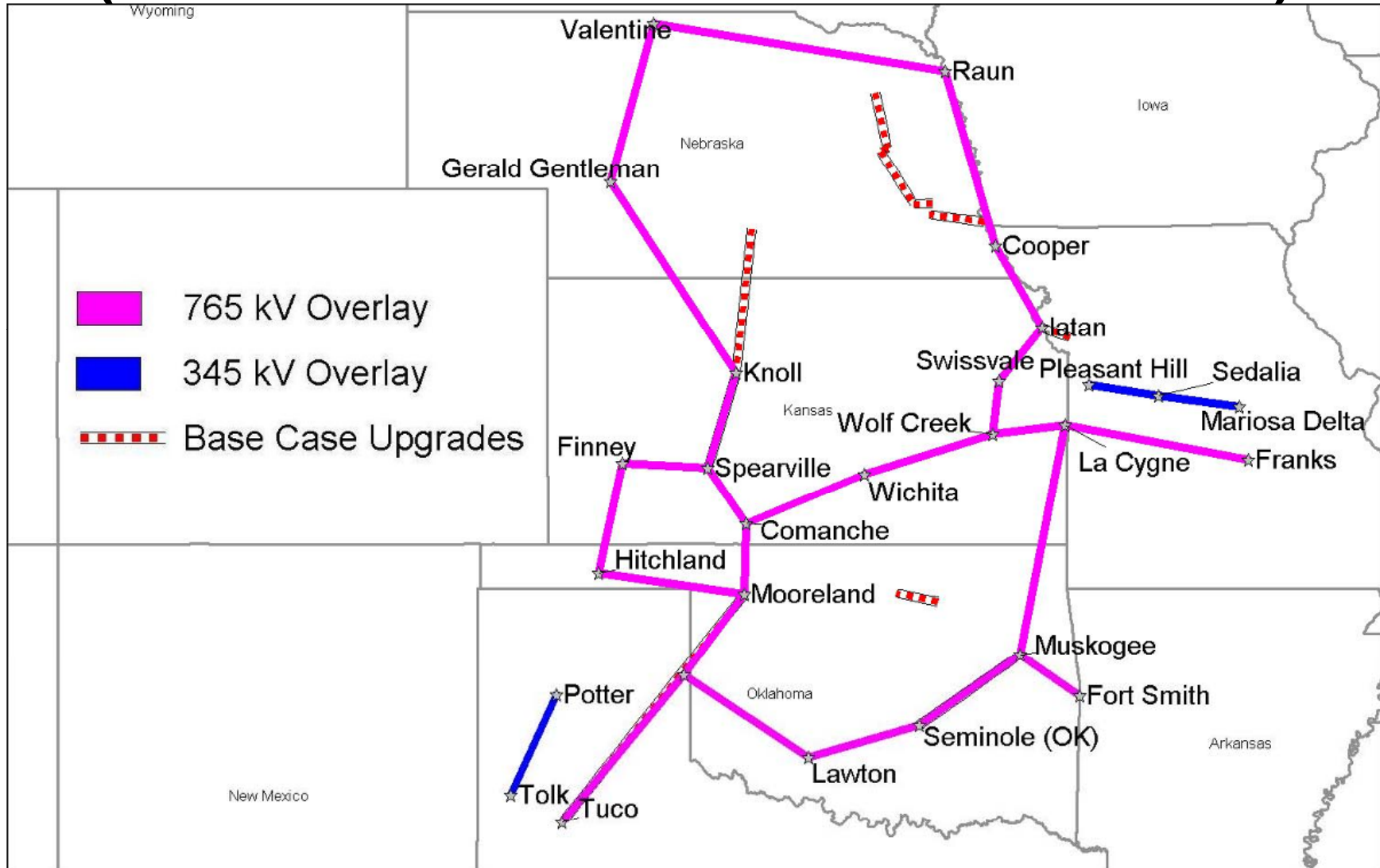
- 0.06% is the minimum summer credit (found at a 235 MW plant in July)
- 2.41% is the maximum summer credit (found at a 660 MW plant in July)

*SPP rules are currently applicable. NERC standards are forthcoming which will likely affect SPP practice.

Transmission Considerations

- This NPA Wind Integration Study is not a transmission planning study
- The Nebraska wind sites used to obtain 10%, 20% and 40% wind penetrations chosen for the NPA Study are samples, not committed sites, but do reflect geographic diversity
- In Nebraska and the rest of the SPP region additional transmission is needed to get wind energy to load at these levels of penetrations. Localized collector systems as well as Inter-RTO ties need to be strengthened
- Uses short term planned Nebraska and SPP transmission additions
- Uses the conceptual SPP 765 kV overlay for 20% and 40% wind penetration
- A sensitivity uses 345 kV in place of the SPP 765 kV in Nebraska

EHV Conceptual Overlay for NPA Study (for reference – used in Scenarios 3 and 4)



NPA Wind Study – Findings and Conclusions

■ Nebraska Transmission System

- New transmission will be required to bring any significant new wind resources online.
- The transmission system will be stressed with increased wind penetration.
- The transmission system expansion must be designed with wind expansion in mind to minimize those stresses.
- Specifically, the transmission system shows increased usage and risk of overloads as wind penetration increases

NPA Wind Study – Findings and Conclusions

- Wind Generation Curtailment in rest of SPP due to transmission constraints (near zero curtailment in Nebraska in all scenarios):
 - 2% at the 10% penetration without the overlay (Scenario 1)
 - 7% at the 20% penetration without the overlay (Scenario 2)
 - 0% at the 20% penetration with the overlay (Scenario 3)
 - 5% at the 40% penetration with the overlay (Scenario 4)
- Incremental* SPP Transmission Cost modeled as part of the Total Cost Calculation (2018\$ basis):

	<u>Annual</u>	<u>Investment</u>
10% w/o overlay	\$ 53,000,000	\$ 0.7 billion
20% w/o overlay	145,000,000	1.8 billion
20% with overlay	947,000,000	11.8 billion
40% with overlay	1,129,000,000	14.0 billion

* These incremental cost estimates do not include future facilities that are already committed to be built (such were included in total cost, however).

Incremental SPP Regulating Reserves due to the wind generation - 2006 wind/load pattern

Pen	Load Only MW		Load and Wind MW		Delta Load and Wind minus Load MW		Wind Name plate MW
	Max	Avg	Max	Avg	Max	Avg	
10%	528	295	1152	794	852	499	7505
20%	528	295	1800	1291	1542	996	15084
40%	528	295	3257	2337	3034	2042	30158

Nebraska Hourly Ramping Results for 20% Wind Penetration in 2018 (2006 pattern)

Time Period	Up Ramps MW per hour		Down Ramps MW per hour	
	Load Max	Load Net Wind Max	Load Max	Load Net Wind Max
Winter	643 (hr 7)	1,113 (hr 8)	-522 (hr 1)	-927 (hr 23)
Spring	592 (hr 7)	728 (hr 9)	-667 (hr 1)	-808 (hr 1)
Summer	632 (hr 7)	941 (hr 11)	-620 (hr 24)	-913 (hr 24)
Fall	586 (hr 7)	738 (hr 7)	-718 (hr 1)	-1,008 (hr 23)
Annual	643 (hr 7)	1,113 (hr 8)	-718 (hr 1)	-1,008 (hr 23)

NPA Wind Study – Findings and Conclusions

■ Wind Energy Usage

- Consistently as wind penetration increased, the study results had SPP (including Nebraska) increasing exports by half of the amount of the wind generation increases.
- Wind penetration in external systems was held constant as SPP penetrations increased.

NPA Wind Study – Findings and Conclusions

■ CO2 Emissions

- Increased wind penetrations result in lower CO2 emissions.
- A pure price penalty on CO2 is not very effective at reducing CO2 emissions in Nebraska (given a constant expansion fleet and export market) until the penalty gets very large.
- Increased penalties on CO2 result in decreased wind integration costs as more gas resources are committed due to CO2 penalties in both the ideal and actual cases diminishing the cost difference between coal and gas.
- Significant carbon reductions from large CO2 penalties result in huge increases in the use of natural gas for electricity.



NPA Wind Study – Findings and Conclusions

■ Cooperation with WAPA

- Scheduling WAPA firm power to Nebraska utilities proportional to load-net-wind vs. proportional to load may save Nebraska on the order of \$1 million per year (2018\$) subject to Missouri River Basin management priorities.
- Because of modeling Nebraska separate from SPP a substantial portion of these benefits are likely returned through participation in SPP.



NPA Wind Study – Findings and Conclusions

■ Additional Considerations

- There may be some additional costs associated with managing wind generation not captured in these production simulations:
 - Additional maintenance and forced outages and derates
 - Degradation of heat rate from ramping, cycling and range of operation
 - Increase in emission rate per MWh production

NPA Wind Study - Summary of Results

Wind Integration Costs 2009 \$/MWh

	<u>10%</u>	<u>20%</u>
Shaped proxy (added reserves and wind error only)	1.39	1.45
Sub-period block proxy (native, w/o exported cost)	1.92	3.11
Sub-period block proxy (including exported cost)	5.41*	9.26

*Total of \$5.41/MWh at 10% penetration is an approximately 10% additional cost associated with the cost of wind generation and transmission additions.

	<u>10%</u>	<u>20%</u>
<u>Incremental Transmission Investment Cost</u>	\$0.7 billion	\$11.8 billion

modeled in SPP (not including future facilities that are already committed to be built) --- 2018\$

<u>Nebraska Wind Capacity Credit in SPP</u>	0.06 – 2.41% of Nameplate
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For further information go to:

www.nepower.org

Nebraska Power Association website

