

Wind Integration and Aggregation

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MISO

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California Energy Commission

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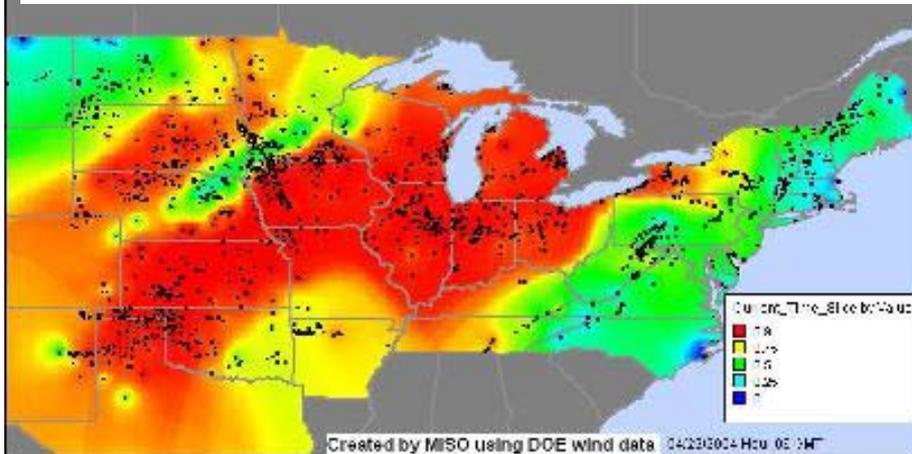
TN 70975

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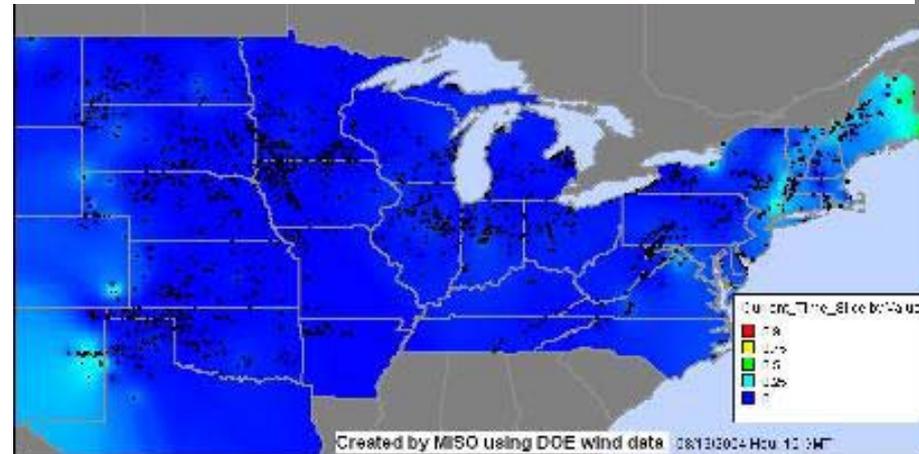
Maximum and Minimum Wind

<http://www.jcspstudy.org/>

Data provided through the DOE Eastern Wind Integration and Transmission Study



Simulated Maximum Power Output on April 29, 0600 GMT for calendar year 2004



Simulated Minimum Power Output on August 13, 1500 GMT for calendar year 2004

	2005		2006		2007		2008	
	MW	% of NP	MW	% of NP	MW	% of NP	MW	% of NP
Nameplate Capacity (NP)	871	///	1,032	///	1,462	///	3,008	///
Actual Metered at Peak	103 ¹	11.8% ¹	686 ²	66.5% ²	24 ³	1.6% ³	351 ⁴	11.7% ⁴

¹ Midwest ISO Peak Hour - August 3, 2005 16:00

² Midwest ISO Peak Hour - July 31, 2006 16:00

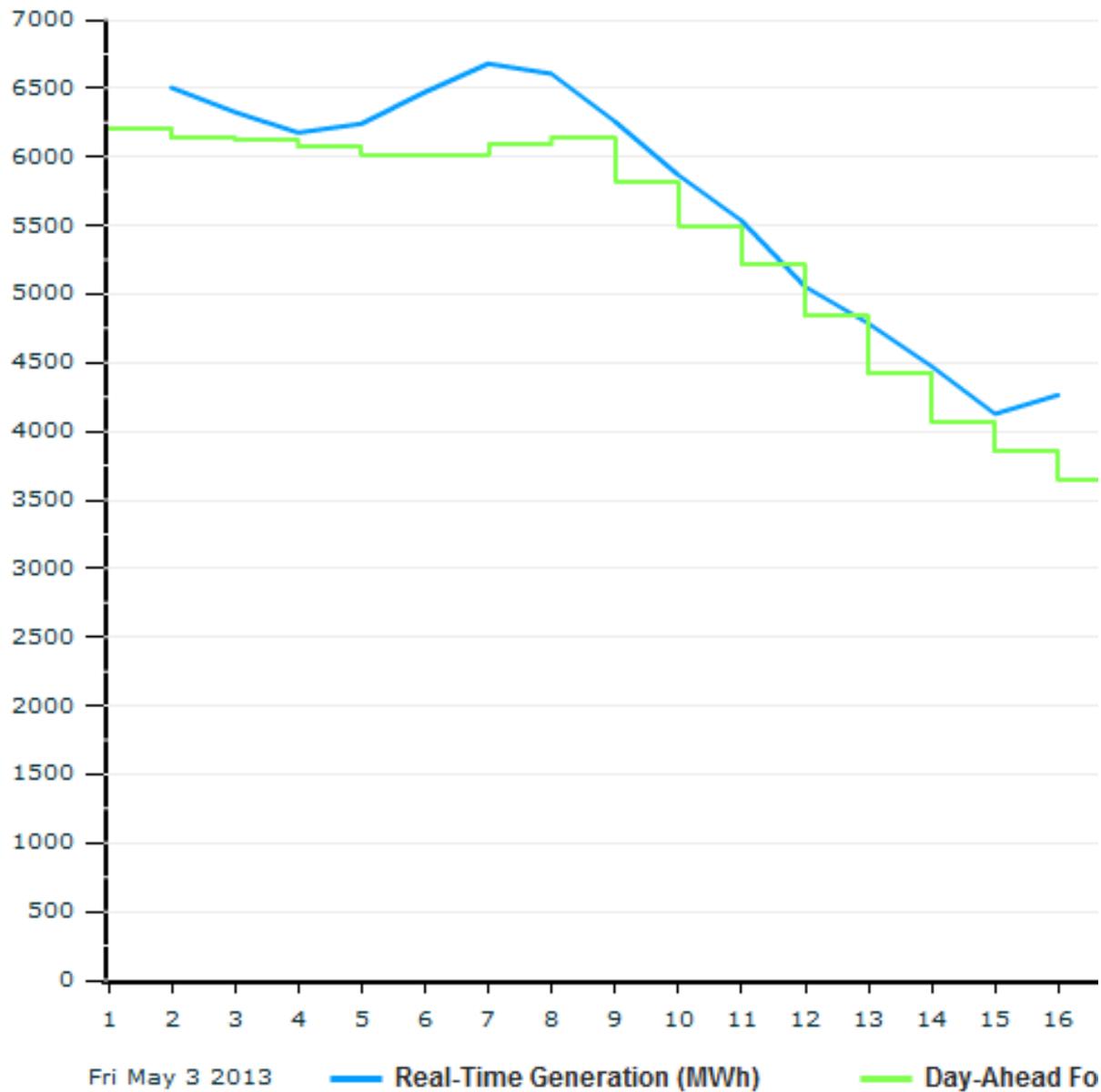
³ Midwest ISO Peak Hour - August 8, 2007 16:00

⁴ Midwest ISO Peak Hour - July 29, 2008 16:00

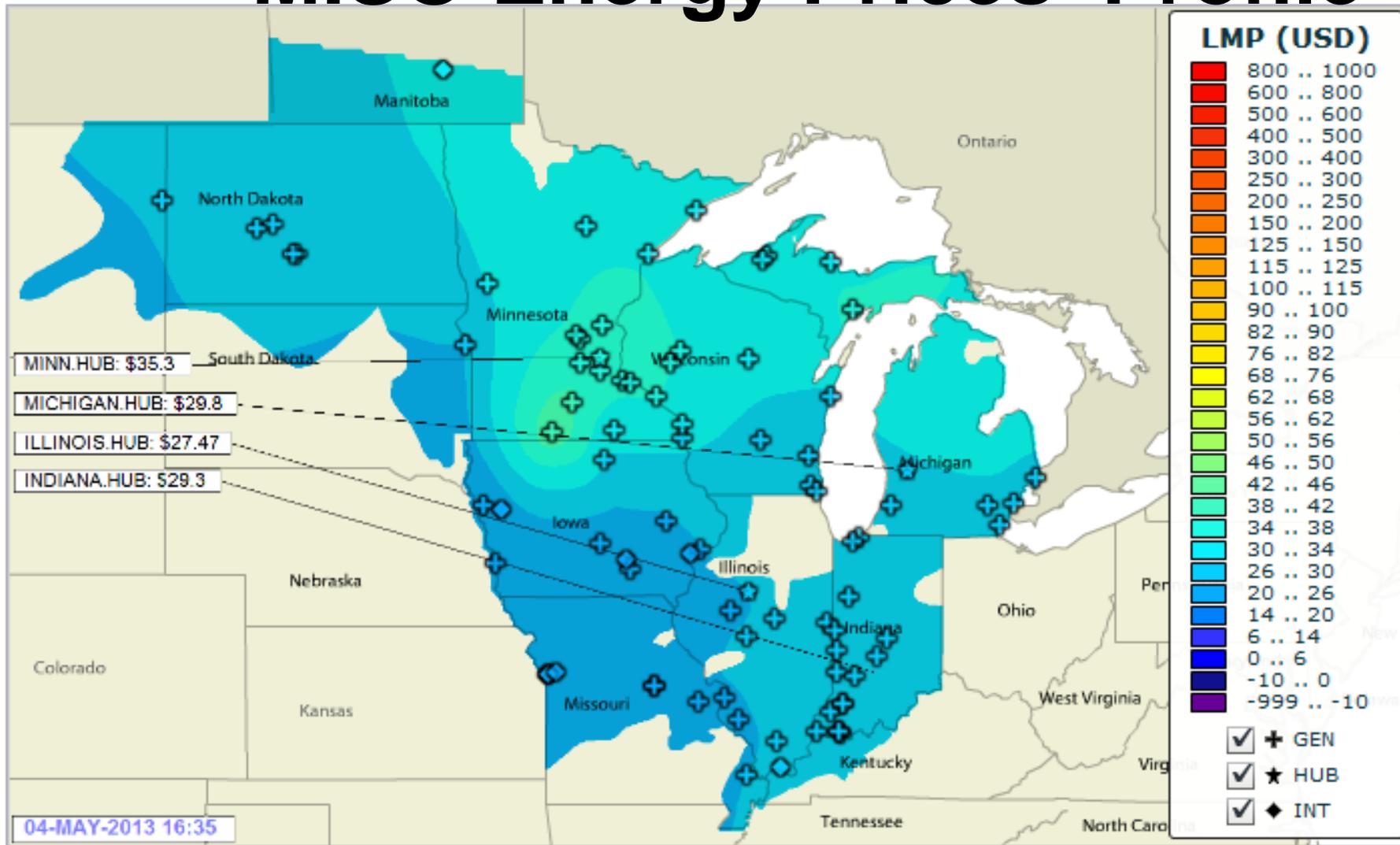
Integration of Wind

- **Regional aggregation- large area, large load**
- **5 minute dispatch compared to 60 minutes**
- **Forecasting-minutes to days ahead**
- **Day ahead bidding of wind generators**
- **Ramping-arranging capacity to follow wind and load variations**
- **Geographic diversity of locations**
- **Transmission to deliver it**
 - Generation Interconnections
 - \$5B Multi Value Projects- transmission to deliver 20,000 MW of wind from state Renewable Portfolio Standards across MISO
 - Pays for itself
 - Cost allocation and Revenue Recovery mechanisms
- **Storage- mitigates curtailments on light load high wind conditions**
- **Gas generation- more flexible than coal**

May. 04, 2013 - Interval 14:59 EST

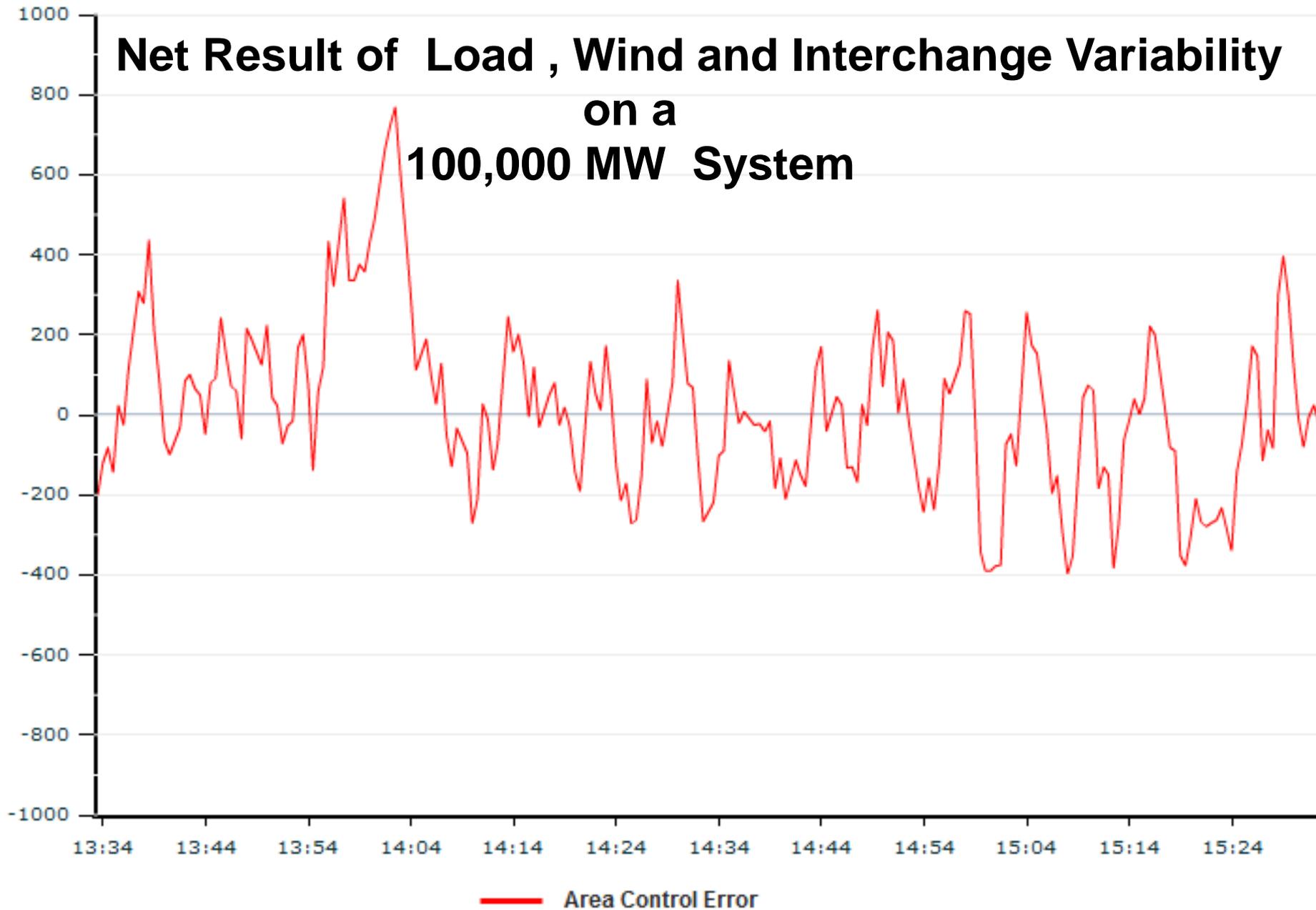


MISO Energy Prices Profile



May. 4, 2013 - Interval 16:32:30 EST

Net Result of Load , Wind and Interchange Variability on a 100,000 MW System



Value Based System Planning

- **A robust transmission system is designed based on economics of the operation of the system over multiple years with a Benefit/Cost Ratio being the decision criteria**
- **Verified to be Reliable**
- **Stakeholder, including regulators, driven processes**
- **Differs from other methods which chose the least cost project**

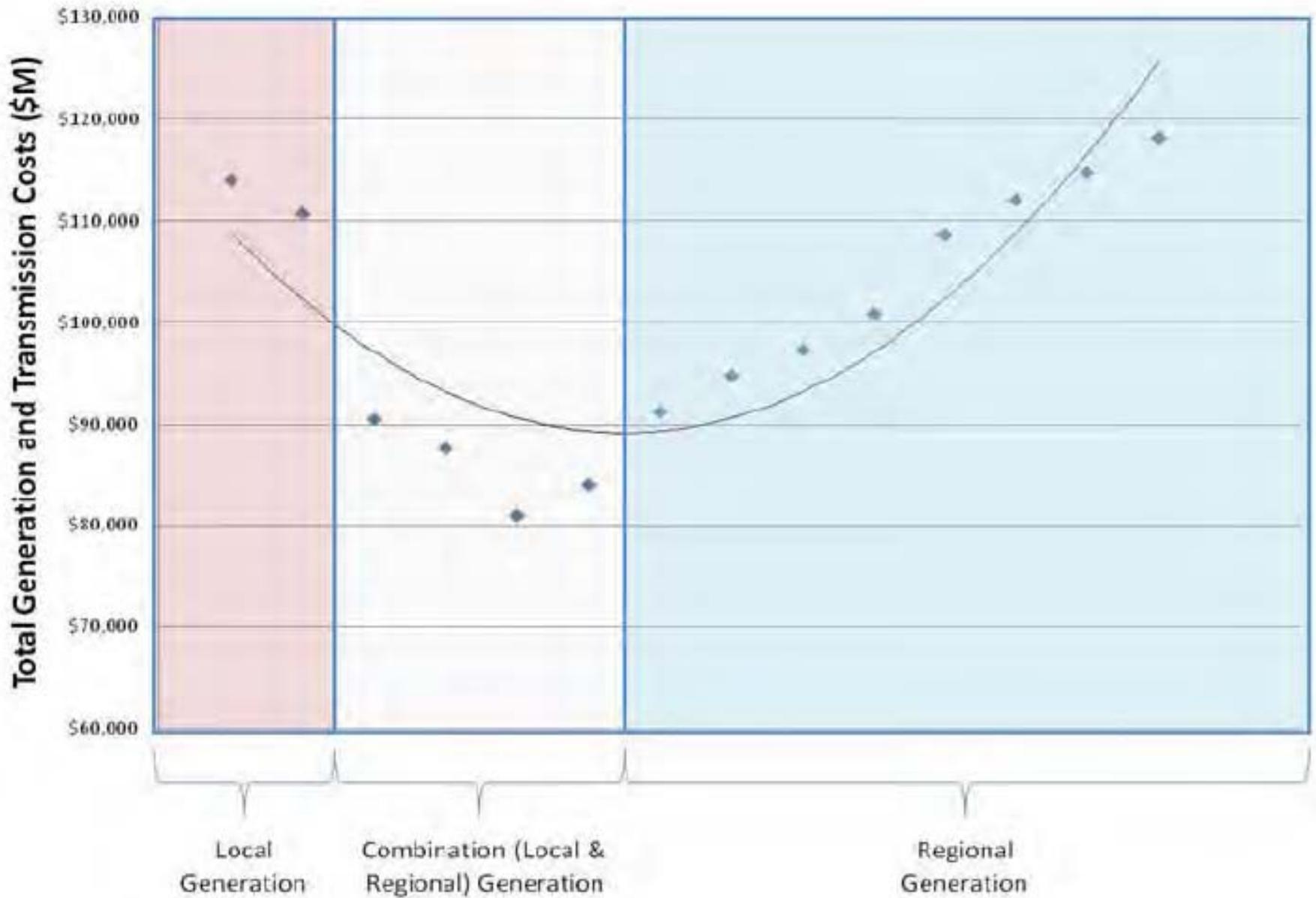
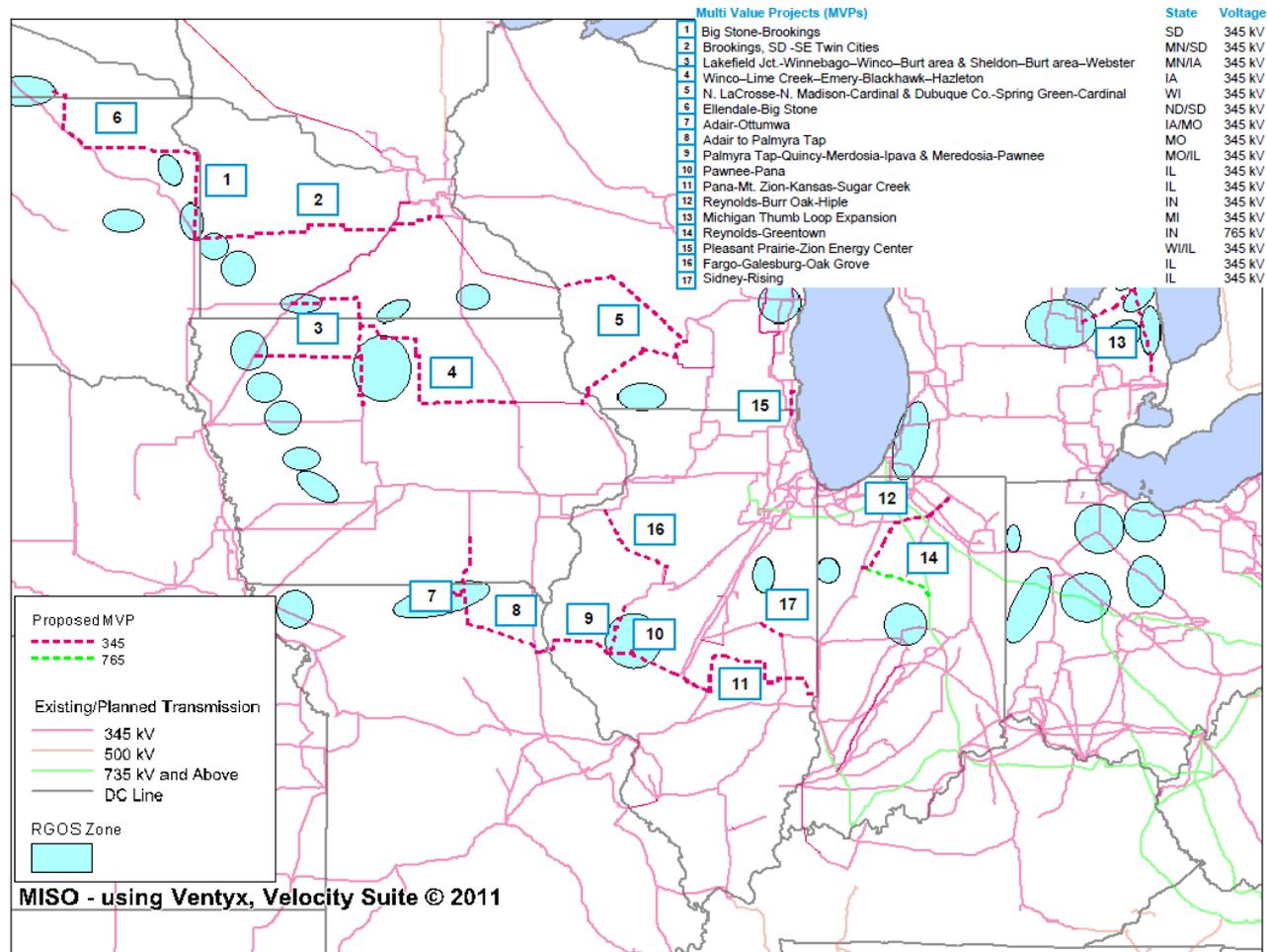


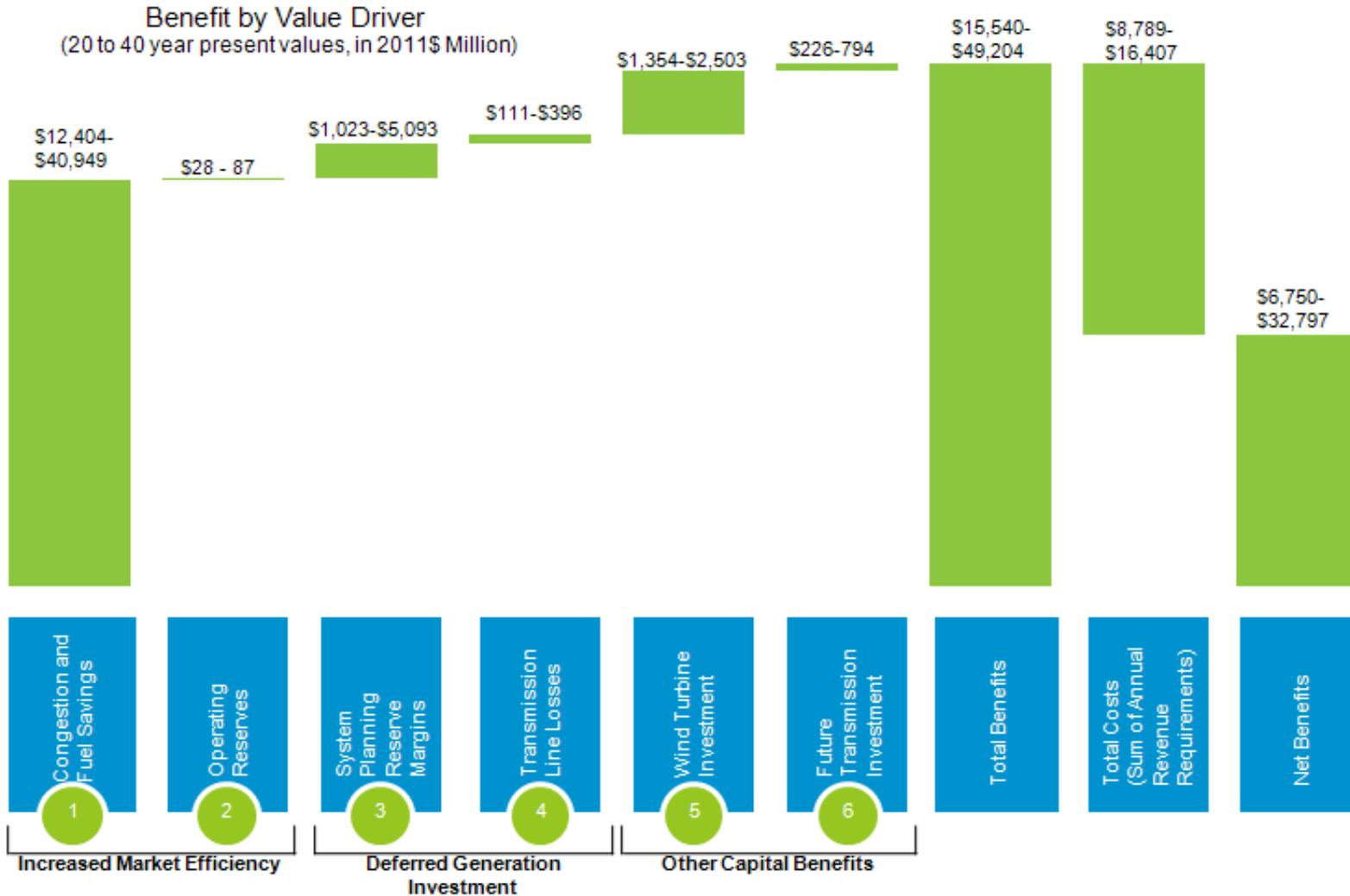
Figure 1.2-1: Wind Generation Siting Cost Comparison

Multi Value Transmission Linking Renewable Energy Zones

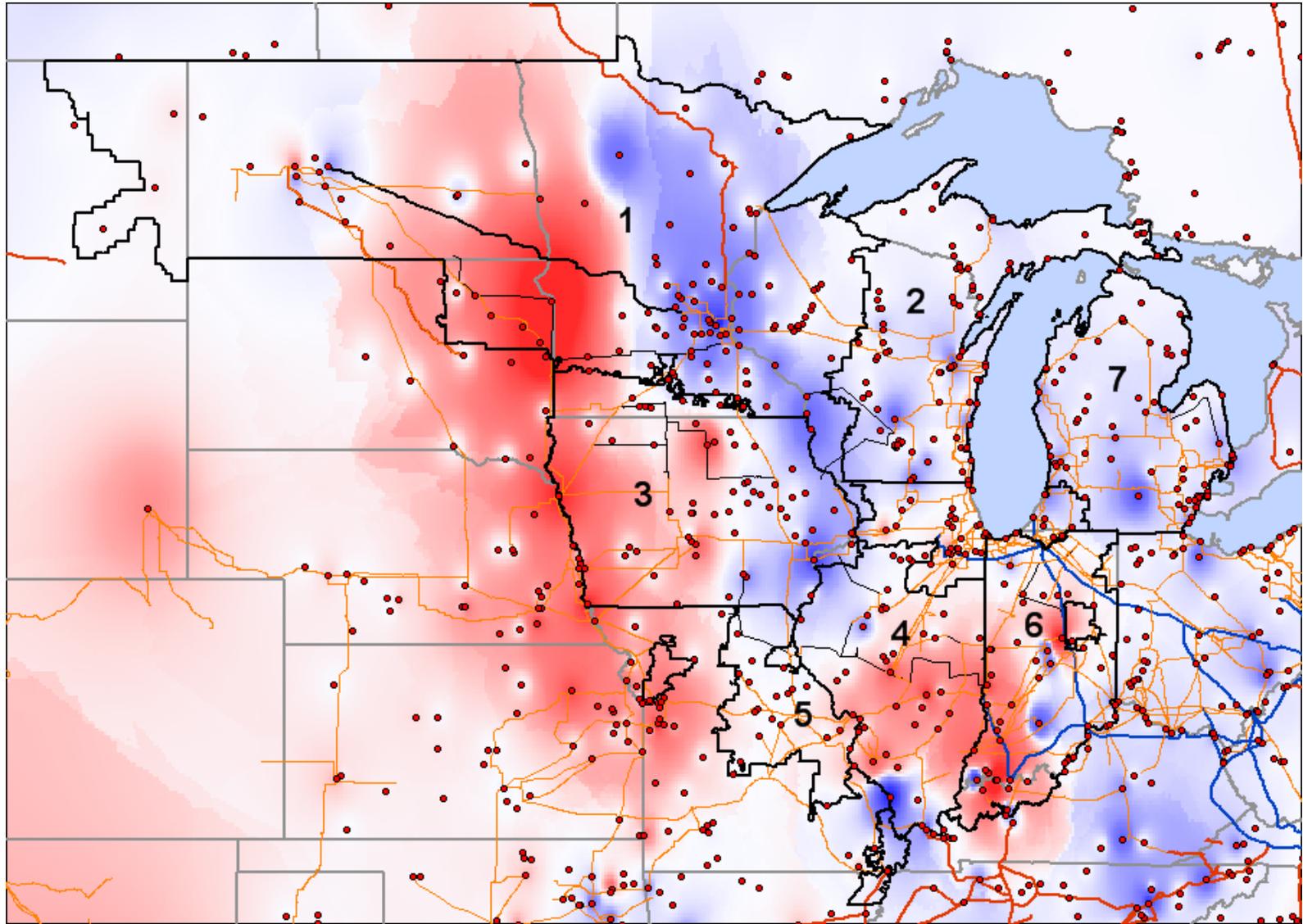


Multi Value Projects Benefit Components and Costs

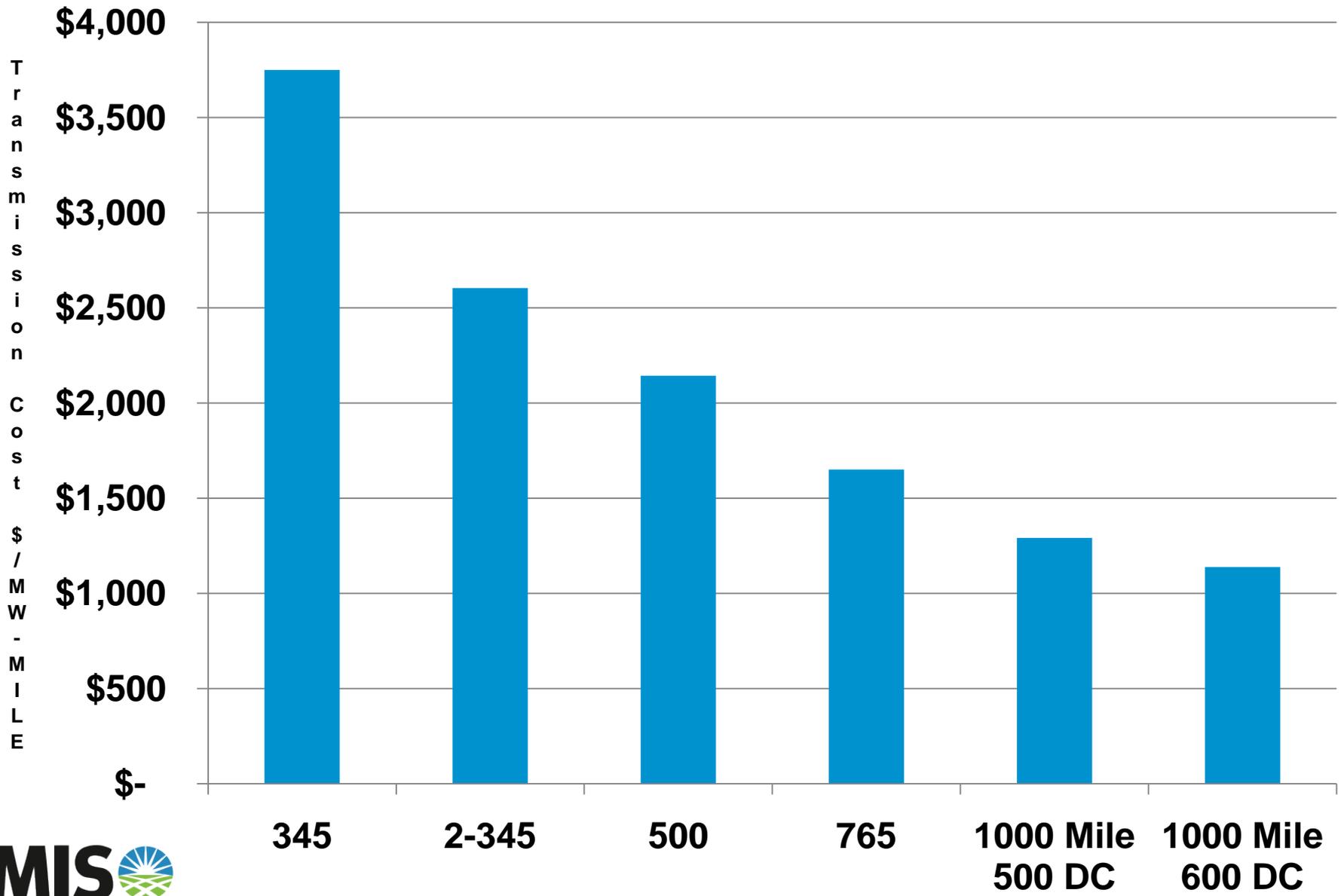
Benefit by Value Driver
(20 to 40 year present values, in 2011\$ Million)



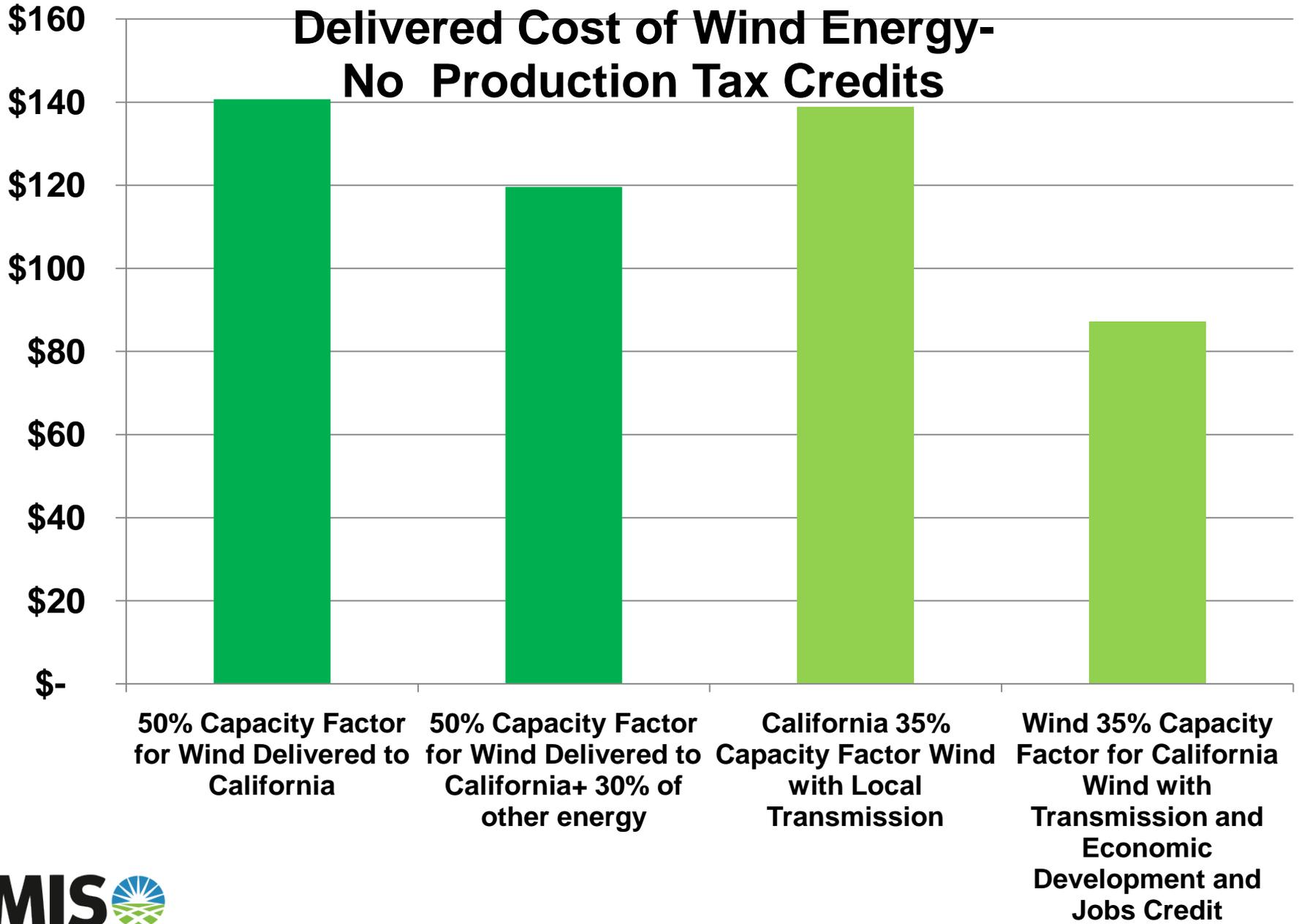
Sources, Sinks, Congestion Location Planning Information



Transmission Cost \$/MW-Mile by Type



Delivered Cost of Wind Energy- No Production Tax Credits



**Aggregation of Wind
Requires
Cooperation and Coordination
Plus Transmission**

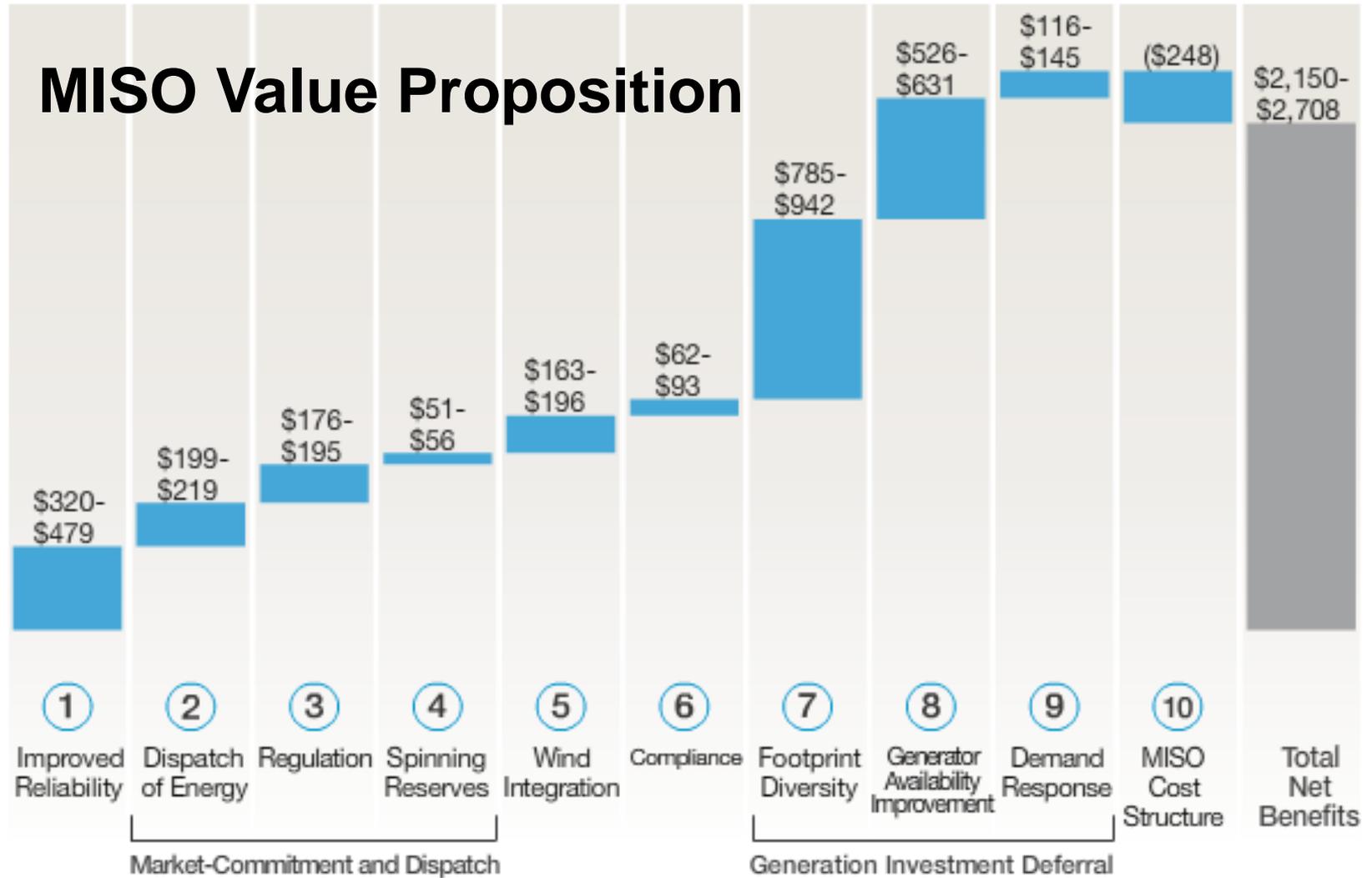
Wind Variability Can Be Managed

- **Aggregation of wind energy over large areas with transmission**
 - Increases the Capacity Credit of wind generation
 - Decreases the need for other generation
 - Do not have to pay for as much other generation
 - Capacity Credits may be 24%
 - Make interconnection and greatly increase the wind pool
 - Decreases the Variability of all the wind energy that is aggregated
 - Need over 600 miles to get maximum results
 - Eastern Interconnection EWITS decreases Variability by a factor of 3
 - Market connections to energy storage may mitigate curtailment during minimum generation events
 - MVP transmission

Aggregation with MISO External Asynchronous Resources

- **EARs are HVDC terminals tied to MISO**
- **Allow the terminal to act as a generator or load in all the markets including Ancillary Services(variability products)**
- **Provides an open competitive price for all market products**
- **Does not require the terminal participant to be in the MISO markets or share transmission costs in MISO**
- **Manitoba participates as an EAR due to Crown Corporation status**

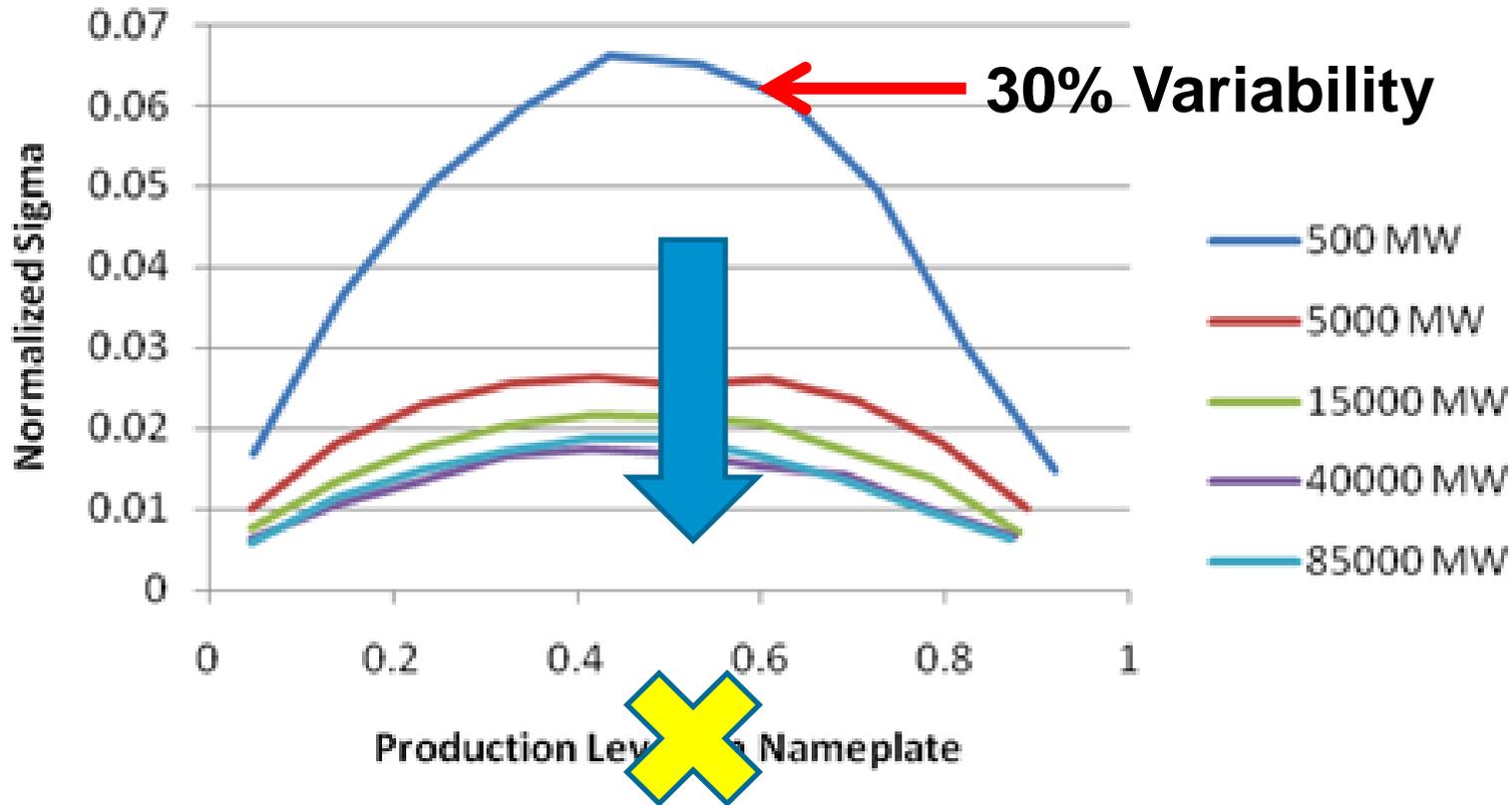
MISO Value Proposition

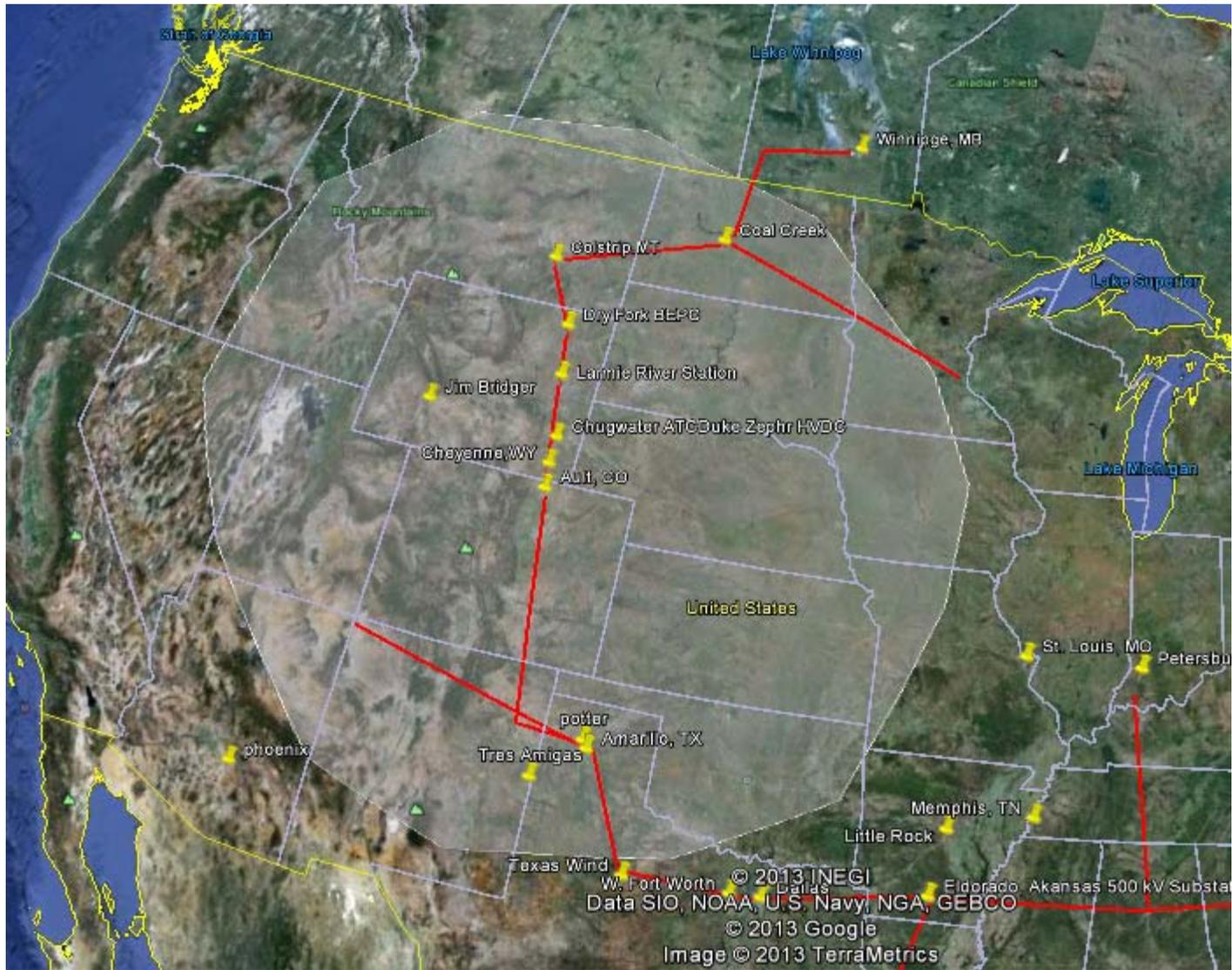


Wind Diversity

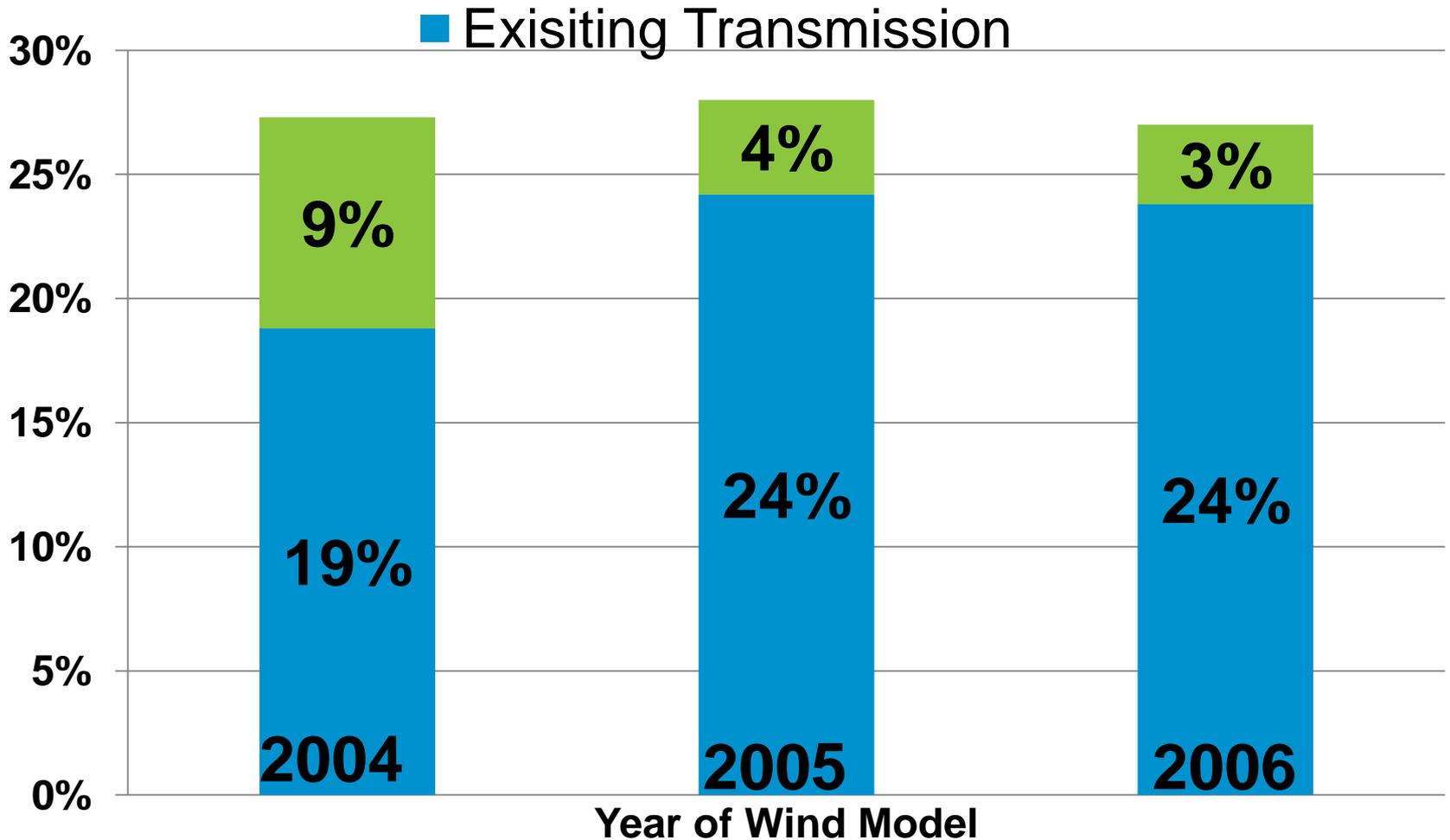
Reduce Variability by 2.5-3 Times

Normalized 10 Min. Variability for 5 Regional Groups





Wind Generation Capacity Credit Aggregated Across the Eastern Interconnection- NREL EWITS 2010



HVDC Can Cherry Pick High Value Variable Capacity Products and May Be Able to More than Pay for Itself

- **Frequency Response**
- **Load Diversity**
- **Capacity Credit**
- **Variability Mitigation**

Questions