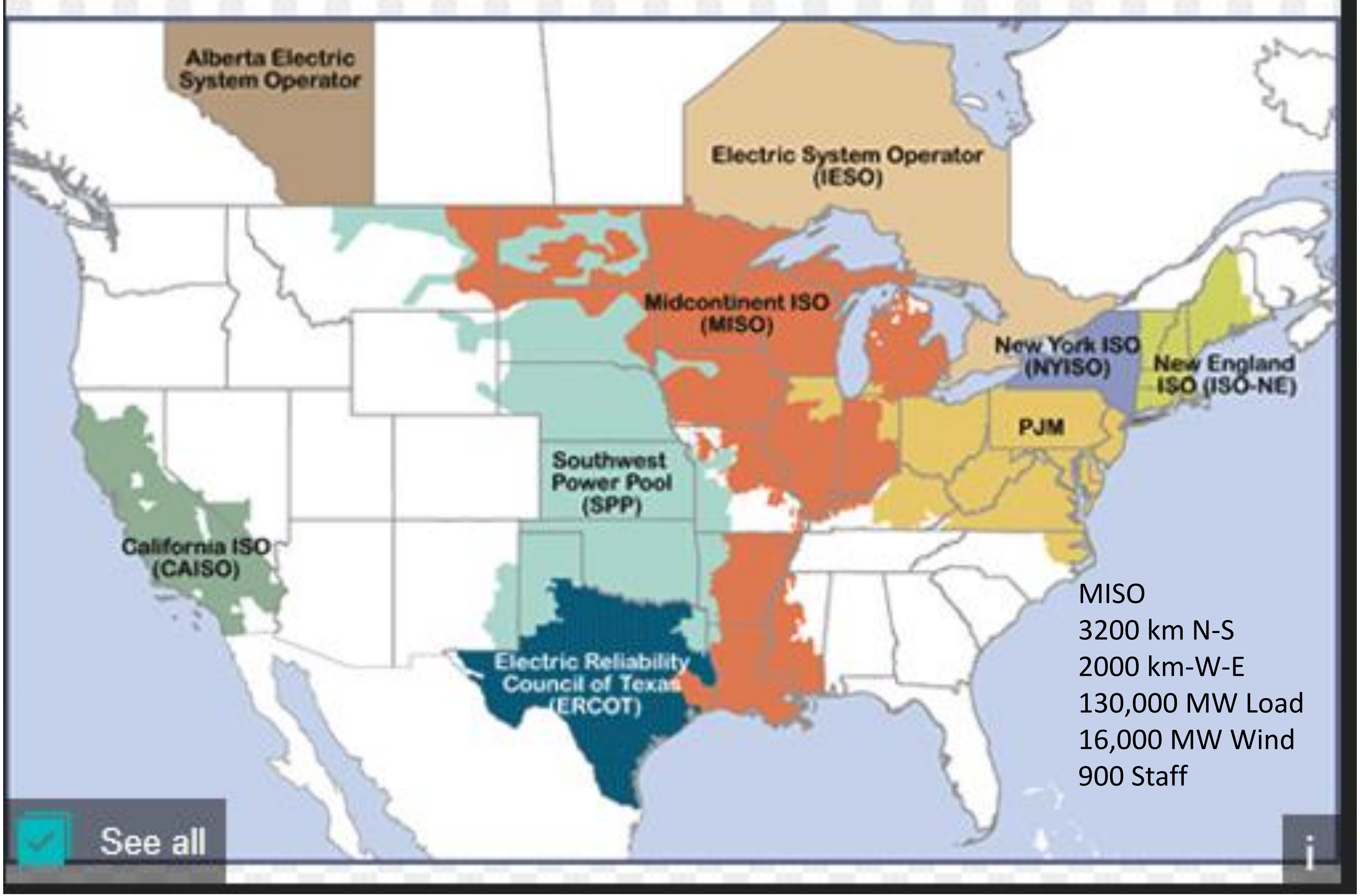
# MISO Transmission Planning Processes

Dale Osborn

April 10.2017




MISO
3200 km N-S
2000 km-W-E
130,000 MW Load
16,000 MW Wind
900 Staff


NERC
National Electric Reliability Corporation
Compliance with Reliabliity Standards are mandatory by law in the U.S. and by agreement in Canada
Rules for operating and planning the transmission system for Reliability, not

# What Is MISO?

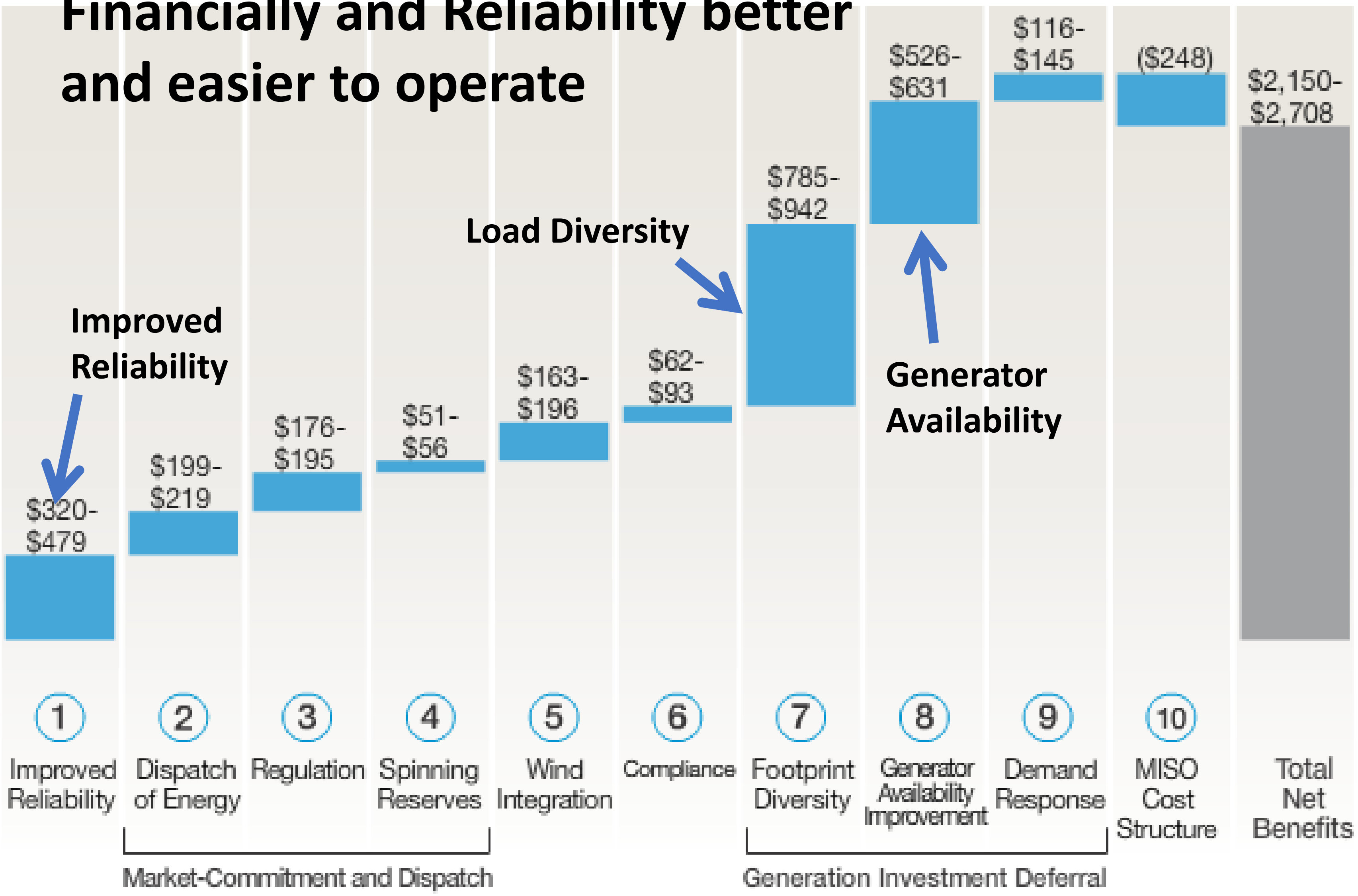
MISO is an essential link in the safe, cost-effective delivery of electric power across much of North America. MISO is committed to reliability, the nondiscriminatory operation of the bulk power transmission system, and to collaborating on creating cost-effective and innovative solutions for our changing industry.

- Regional Transmission Organization that meets FERC specifications- regulated by FERC( Federal Energy Regulation Commission)
  - Independent System Operator
  - Reliably operates the transmission system to comply to NERC and member standards in coordination with neighboring systems
  - Manages the Tariff- processes that are required for operations of the transmission system and markets also provide for the collection of revenue that is distributed to the generators and transmission owners.
  - Operates with the market
  - Plans the expansion of the transmission system in coordination with neighboring systems
  - Independent source of information for MISO state regulators, state legislators and the federal congress and federal agencies
  - Open planning processes through stakeholder governance committees

# What MISO IS NOT?

- Does not own transmission
- Does not physically switch substations
- Does not own generation or control the type of generation built or the location
- Not for profit

# Reasons for Being A MISO Member- Financially and Reliability better and easier to operate




7. Need for generation reduced 4% by operating as one Balancing Area instead of 48

8. In a large footprint, there is less variability of Regulation to control frequency and control interchanges.

1. Problems and solutions are often geographically distanced

3. Regulation is plus and minus 600 MW

4. Spinning Reserve is 1500 MW or less

130,000 MW of load and 16,000 MW of wind

Generation Reserve Margins are lower than being alone-12-15%

Energy resources for low water years

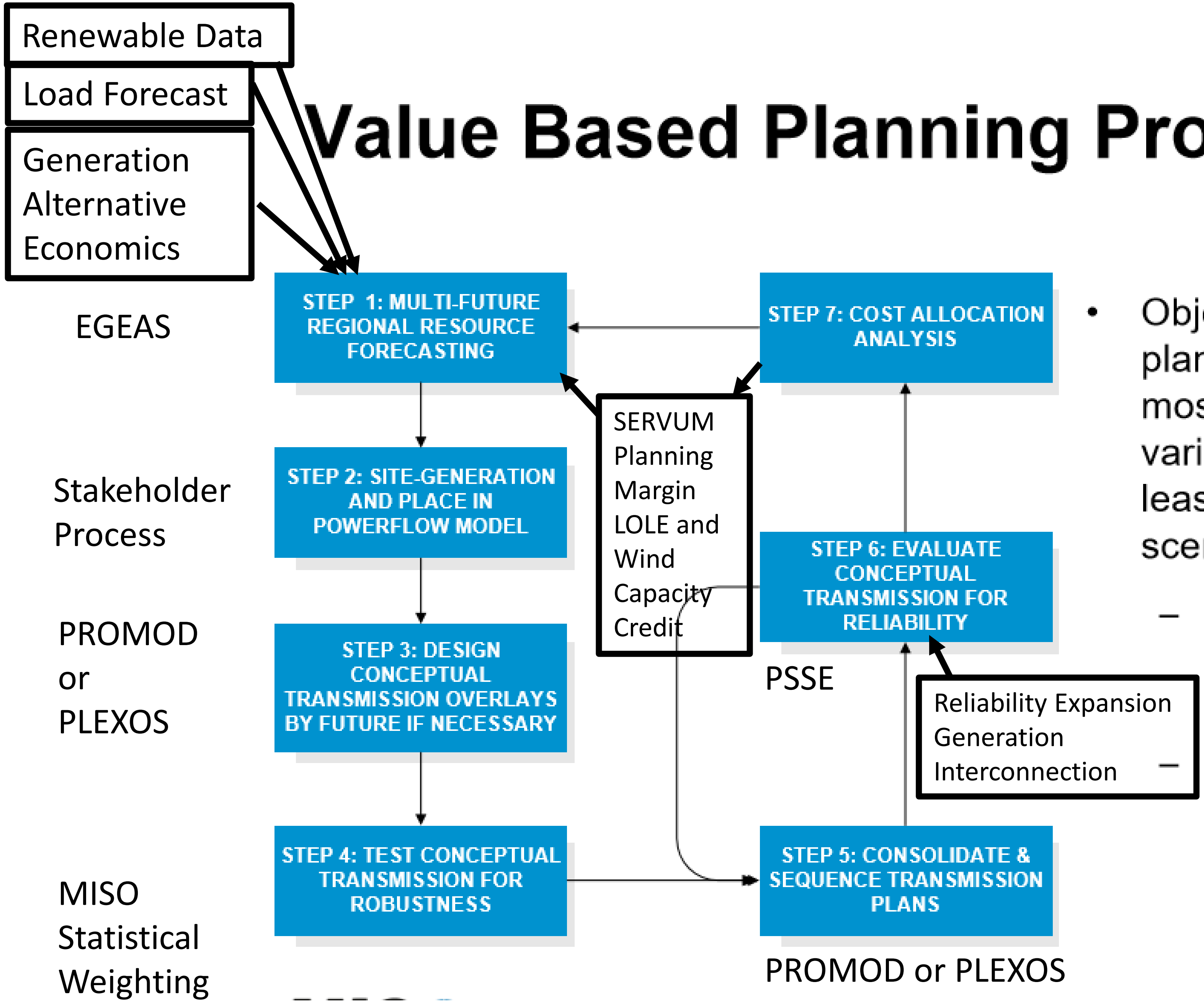
5. Higher capacity credit for wind and higher revenues from a large market access

FERC provides a 1% ROW

# Value Based Planning Concept

- Identify the Maximum Potential Benefit
- Capture as much of the Maximum Potential Benefit
  - Energy arbitrage benefits tend to limit to about 70% of the Maximum Potential Benefit
  - Higher benefit/cost ratios lower the benefit capture percentage
  - The maximum AC capture rate was 78% for the Multi Value Projects
    - 35,000 person-hours of MISO staff time
    - $5.2B for the cost of 17 projects, 1/3 the book value of MISO transmission
    - Benefit/cost ratio of 1.8:1, no project would pass the benefit to cost criteria on its own
    - One time benefit from capturing the inefficiency of MISO being made of 26 Balancing Areas that were not designed to operate as a single market and delivering 21,000 MW(determined by state policy and laws) of low cost wind energy efficiently over the MISO footprint
  - The Value Based Planning Process tools were used to refine the design

# Value Based Planning Process




- Objective of value based planning is to develop the most robust plan under a variety of scenarios – not the least-cost plan under a single scenario
  - The "best" transmission plan may be different in each policy-based future scenario
  - The transmission plan that is the best-fit (most robust) against all these scenarios should offer the most future value in supporting the future resource mix

# Step 3- Transmission Design-one per future

- Take the difference of a Constrained an  Unconstrained production cost simulation with the generation forecast in place
  - Constrained may be the existing transmission initially
  - Unconstrained has all the transmission ratings increased to maximum with no impedance
    - Budgetary transmission is about 70% (experience)of the Adjusted Production Cost ( sales and purchases adjusted)
    - Sources( red) are where increased generation would occur if it could be delivered
    - Sinks (blue) are where energy would flow and generation decreased if imported energy were available at lower prices
    - Interfaces are where the sources and sinks meet
    - Summation of the hourly flows across an interface sorted from high to low produce  a energy duration curve
    - At about 80% of the energy below a horizontal line on the energy duration curve provides and estimate of the power transfer rating of transmission
    - Using the concepts of AC and HVDC transmission design and engineering judgement an economical solution that is estimated to be reliable is designed and added to the base case and run to be the Change case.
    - The difference between the Constrained case and the Change case is the benefit captured. The benefit to cost ratio usually has to be of 1:1 for a Multi Value Project or 1.25:1 for a Market Efficiency project. Stakeholder committees set the criteria in the tariff.
    - The difference between the Change case and the Unconstrained case is the uncaptured Potential Benefit.  New sources and sink diagrams allow the transmission to be redesigned and tested again.  About three or four iterations are needed to reach a final design where the increase in captured benefit to the increase in cost allows the benefit/cost ration of the criteria to be met.

Price and Quantity of Sources and Sinks Determine Transmission Requirements

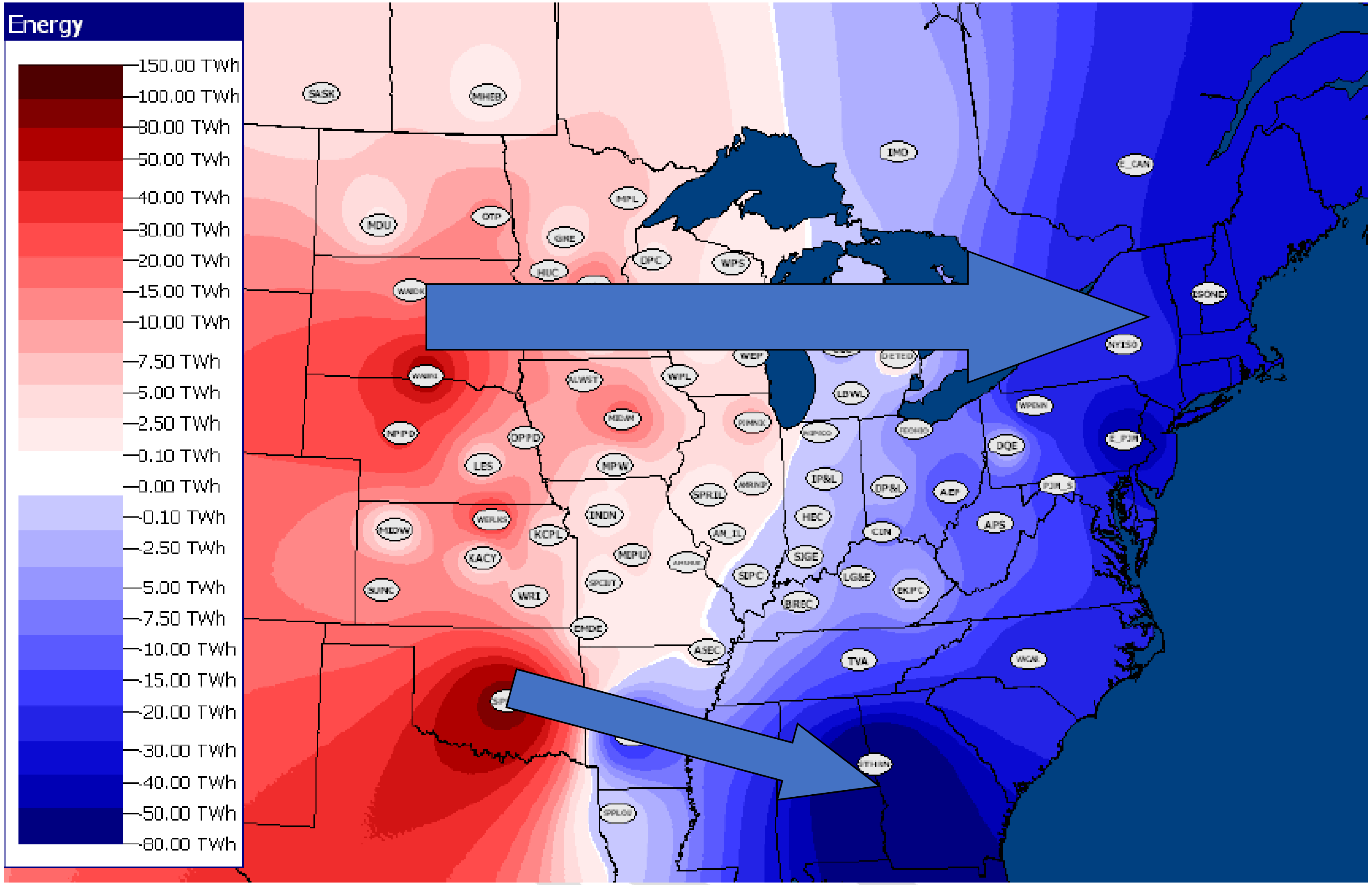
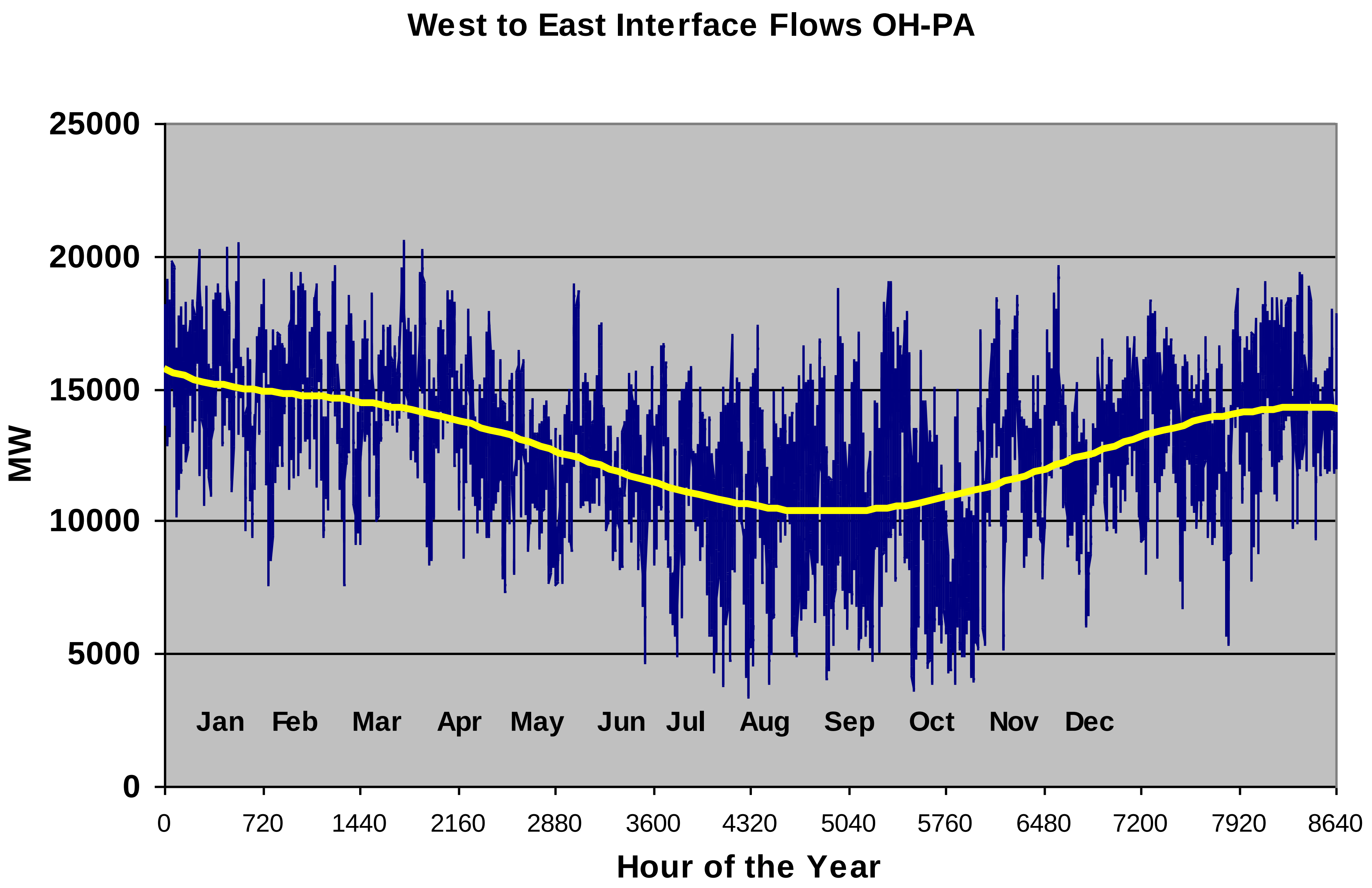
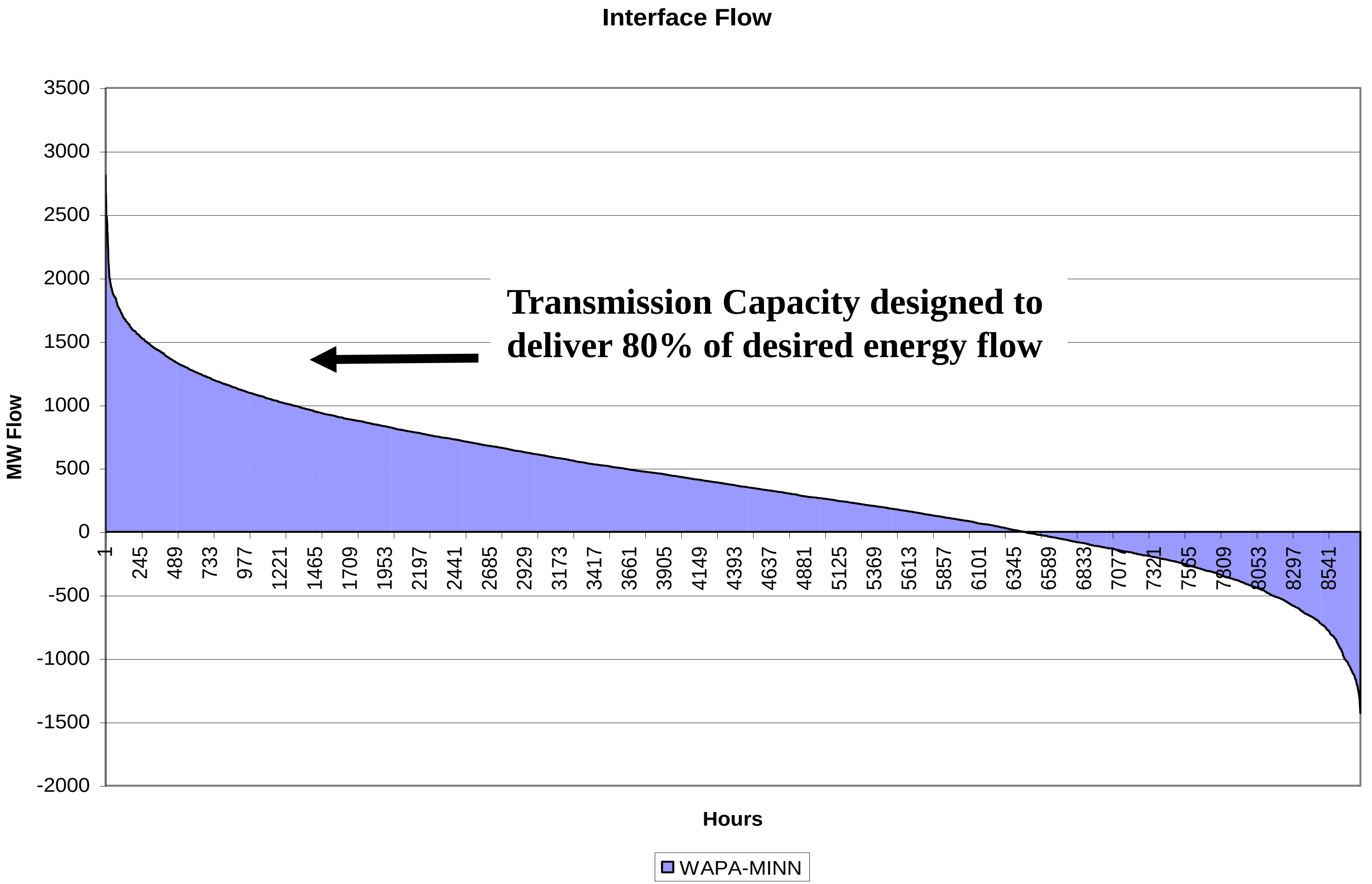


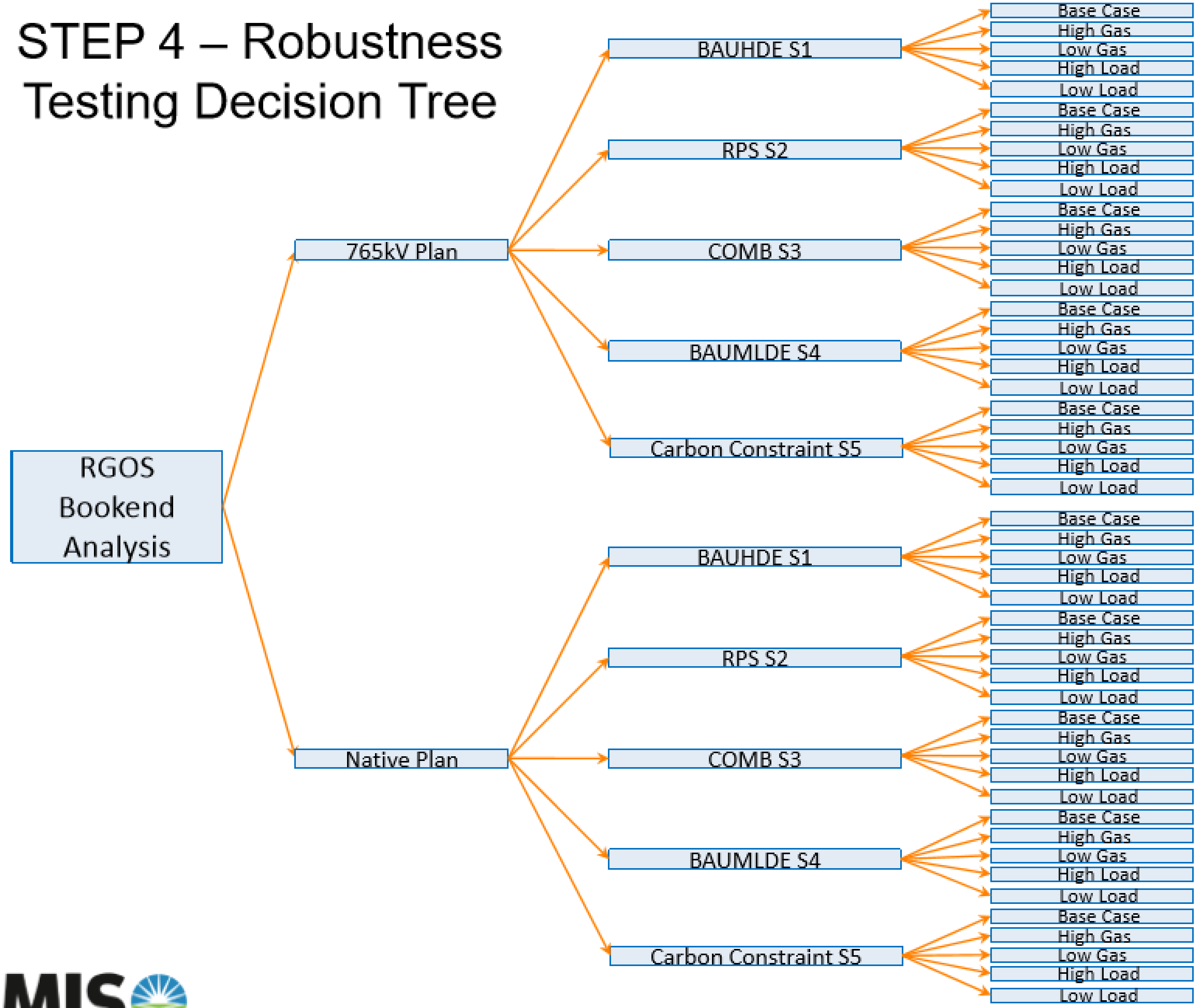

Figure 23: Scenario 2 Generation Difference between Unconstrained Case and Constrained Case


West to East Interface Flows OH-PA
25000
20000
15000
10000
5000
0
MW
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0
720
1440
2160
2880
3600
4320
5040
5760
6480
7200
7920
8640
Hour of the Year

# Transmission Overlay Design Workshop
# Example Interface Duration Curve



# STEP 4 – Robustness Testing Decision Tree

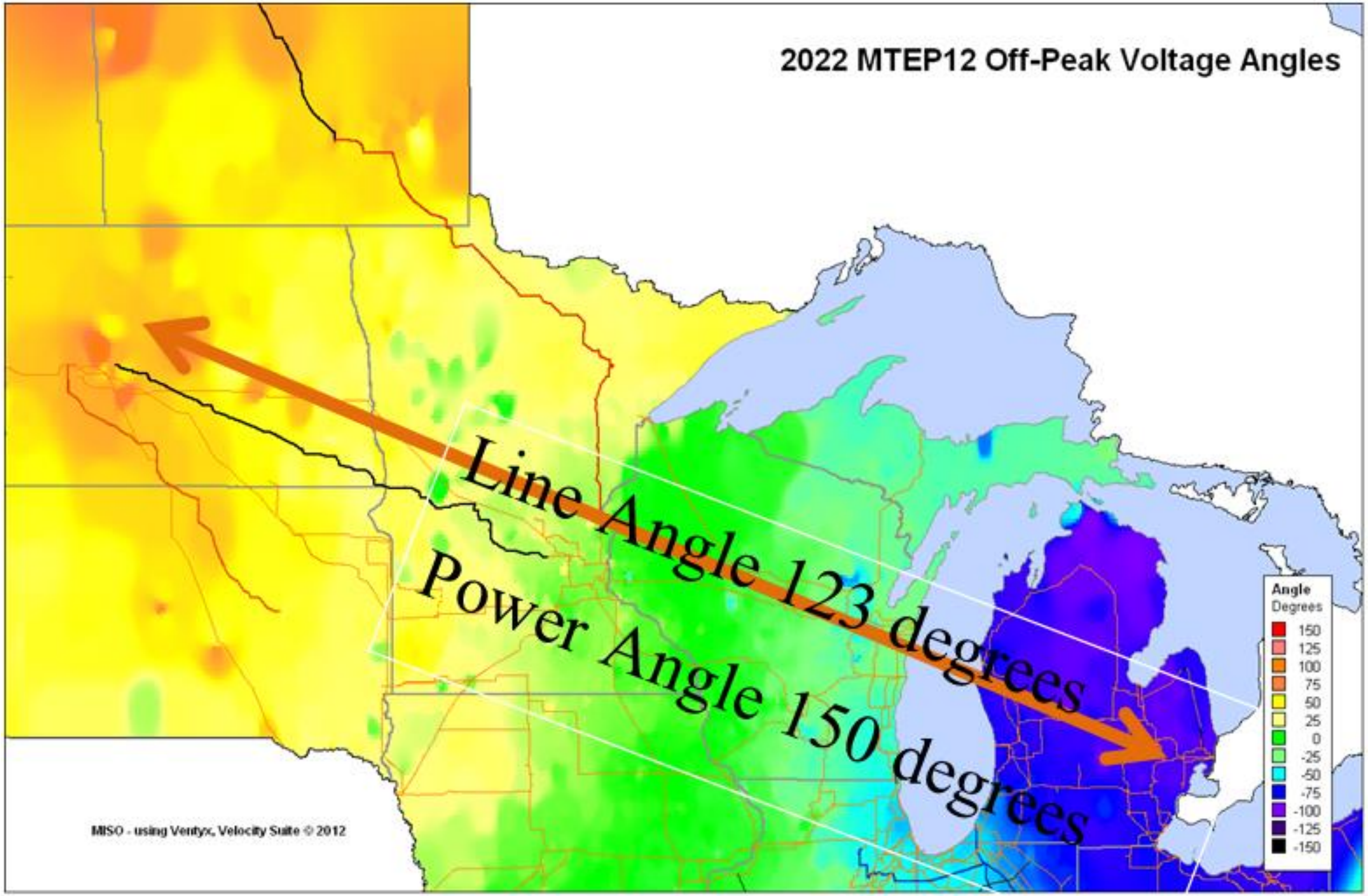


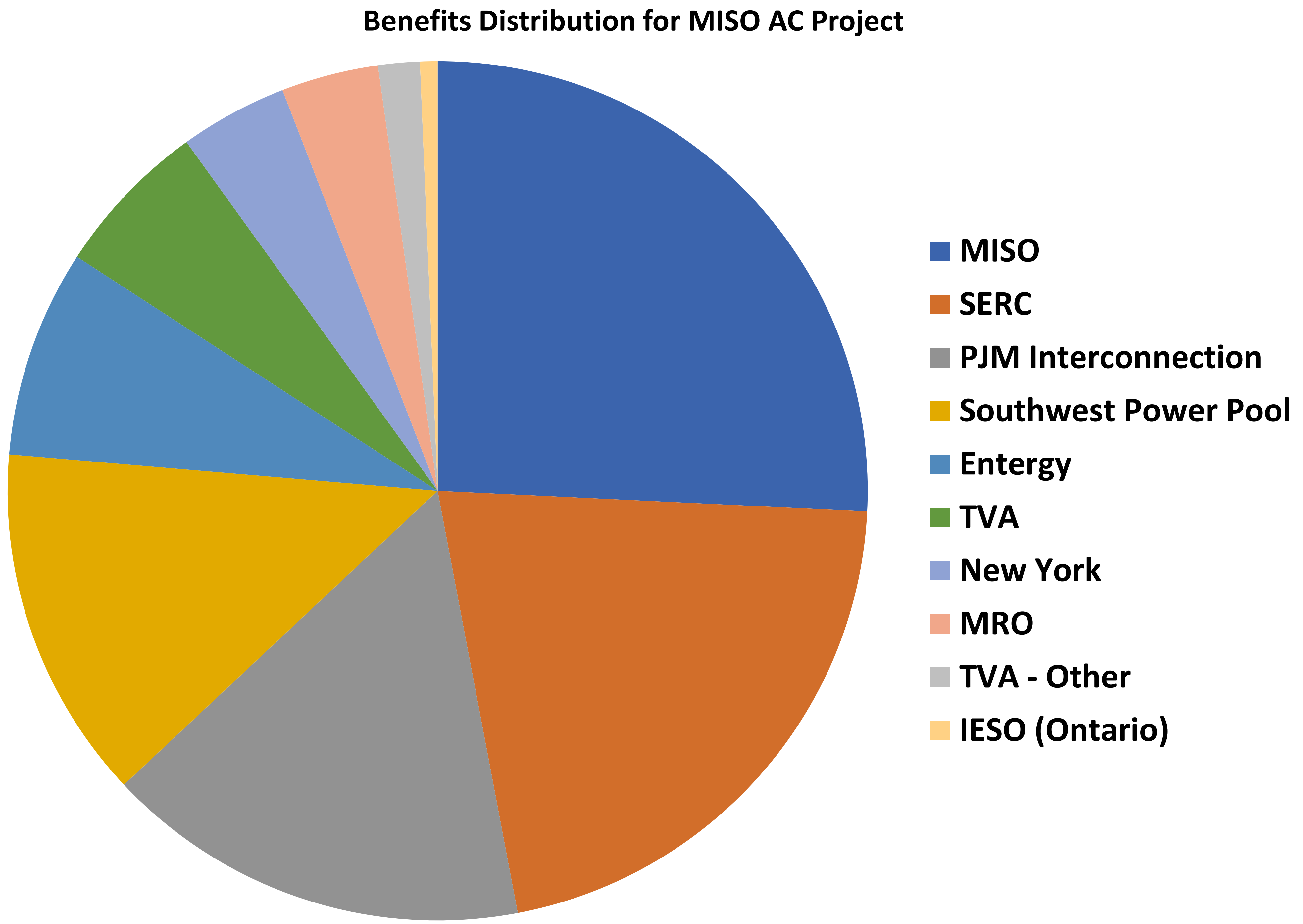

Transmission Overlays → Policy Driven Futures → Bookend Sensitivity Scenarios

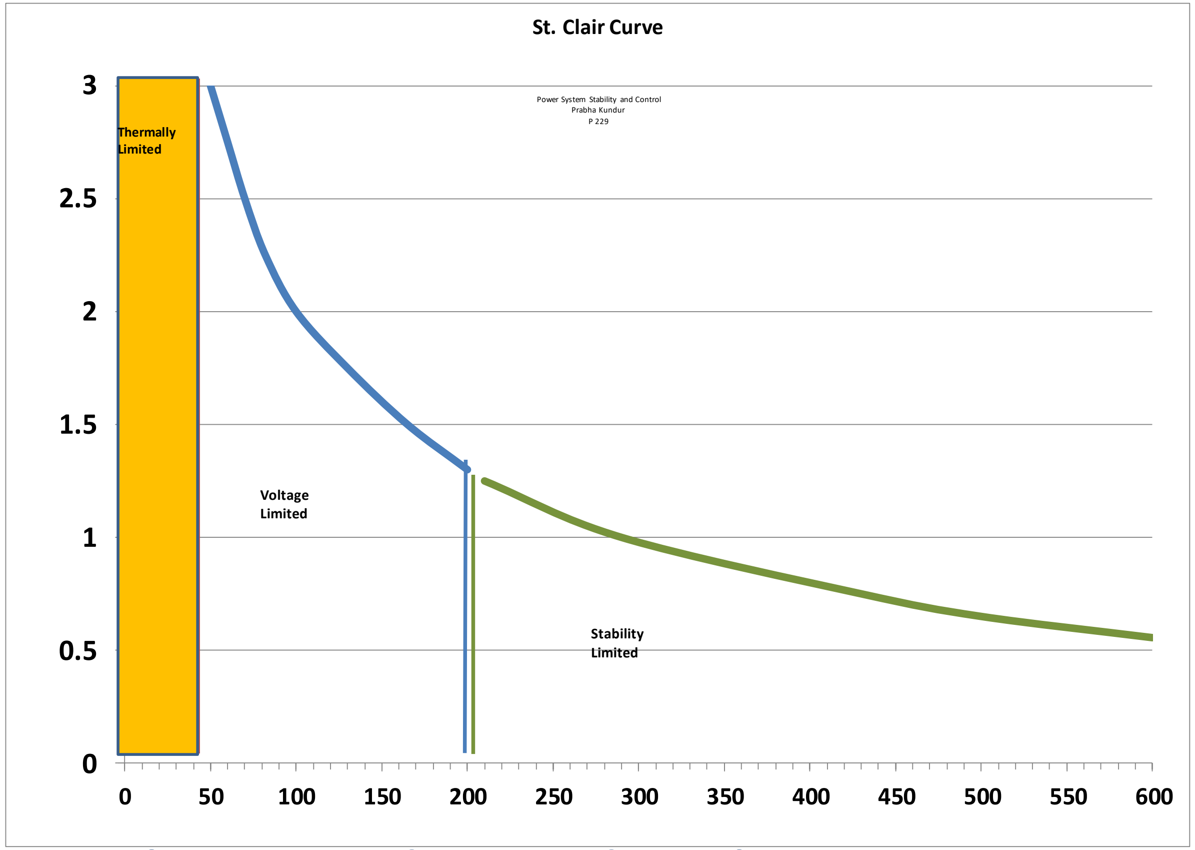
# Transmission Design Concepts

- AC behaves as to the laws of physics
  - Power angles and line angles need to be used for AC design
- HVDC is scheduled by people or programs written by people, HVDC can respond to market signals
  - HVDC lines can be operated to their limits without threat of overload
  - HVDC systems( usually three or more poles or lines)can be designed to have self-contingent power transfer limits higher than the underlying AC system
- AC systems are socialistic and leak benefits to areas that may not pay for the transmission
  - AC systems may have loop flows that impact neighboring systems
  - AC systems are difficult to cost allocate over large distances
- DC systems concentrate benefits at the terminals
  - HVDC flows may pass over a congested area without paying tolls to upgrade the intervening AC system
  - HVDC provides a separate path to a bus with an HVDC terminal that cran relieve operations of managing the congestion on the AC system
  - HVDC is simple to cost allocate –users scheduling power can be identified
- AC systems need reactive power injected along long lines about every 200 miles or less to transfer power
- HVDC can transfer power over long distances without intervening terminals

# Illustration of Power Angle Across a Power System




Benefits Distribution for MISO AC Project
MISO
SERC
PJM Interconnection
Southwest Power Pool
Entergy
TVA
New York
MRO
TVA - Other
IESO (Ontario)



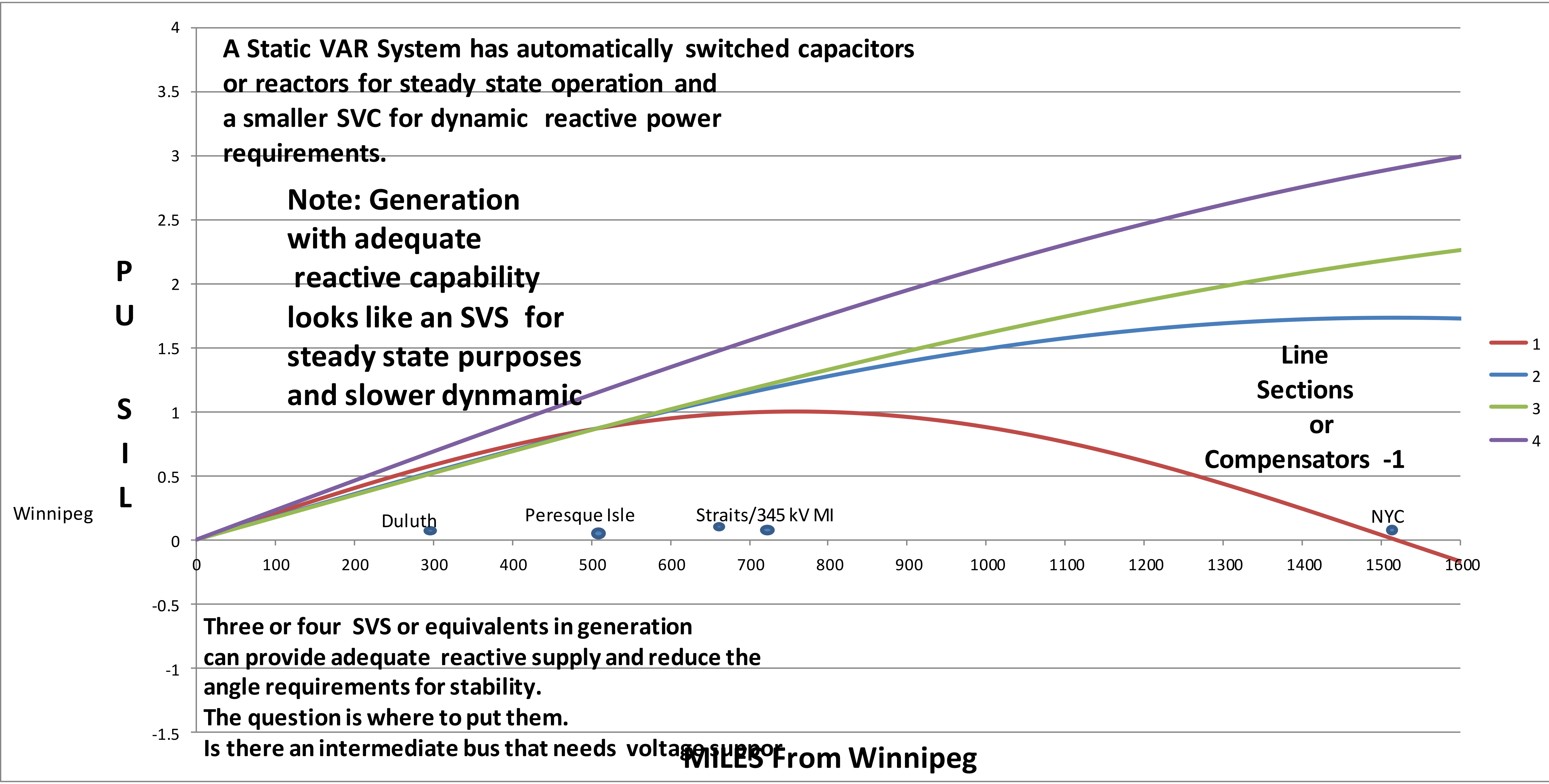

*Typi*cal Surge Impedance Loading values

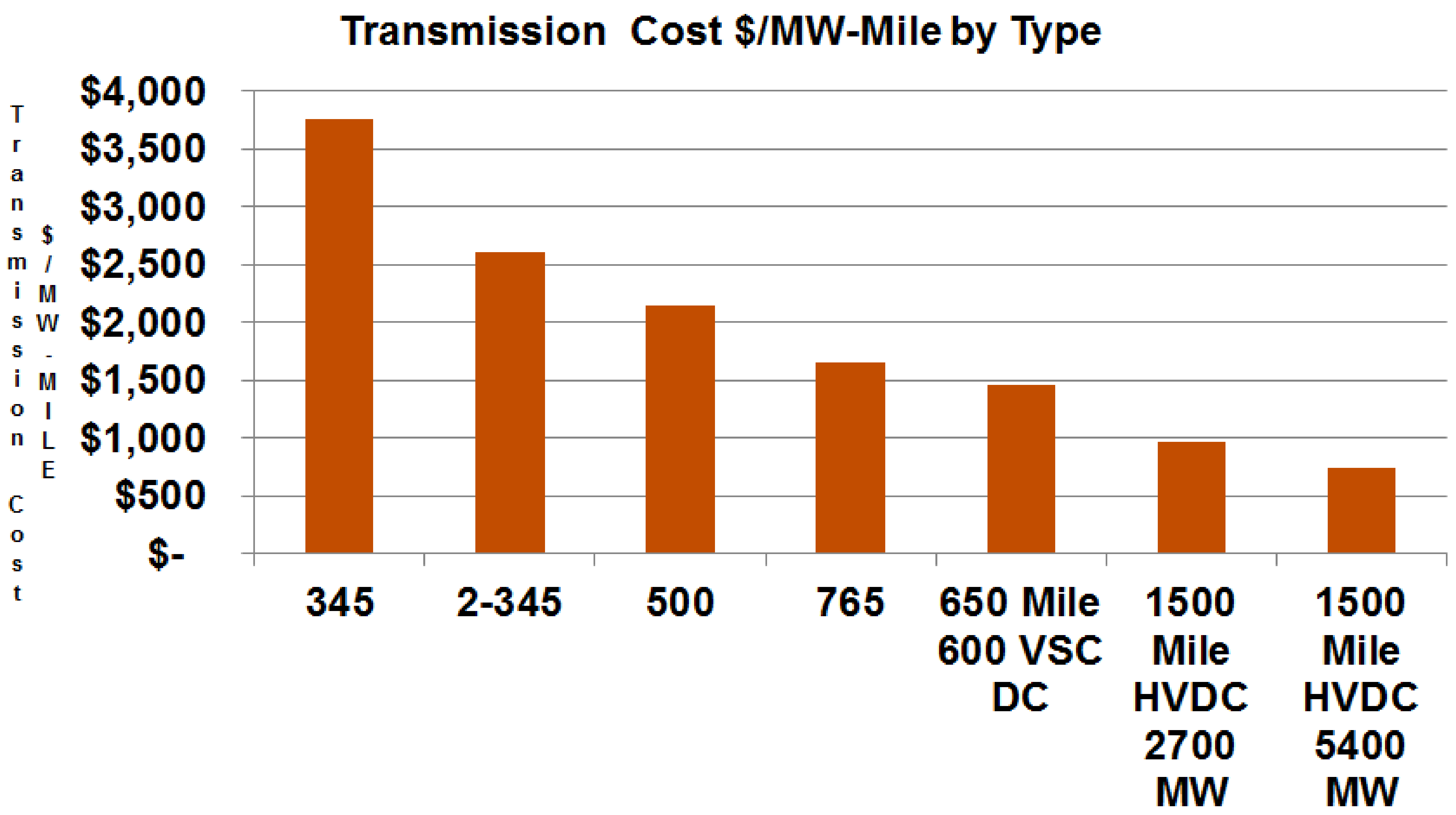
345 kV is about 400 MVA

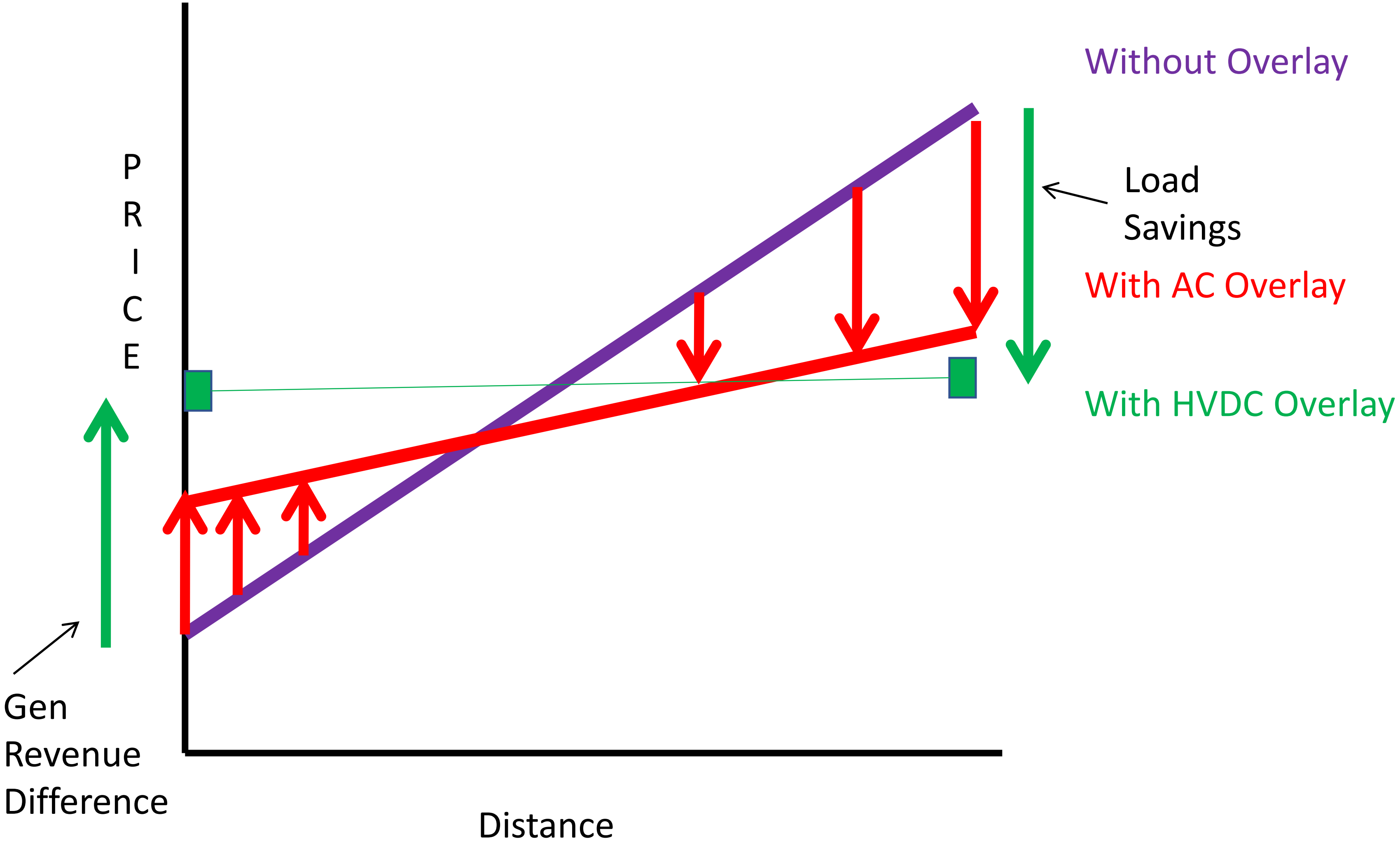
500 kV is about 900 MVA

765 kV is about 2200 MVA

The reactive power created by the capacitance
of a transmission line is equal to the reactive losses at SIL

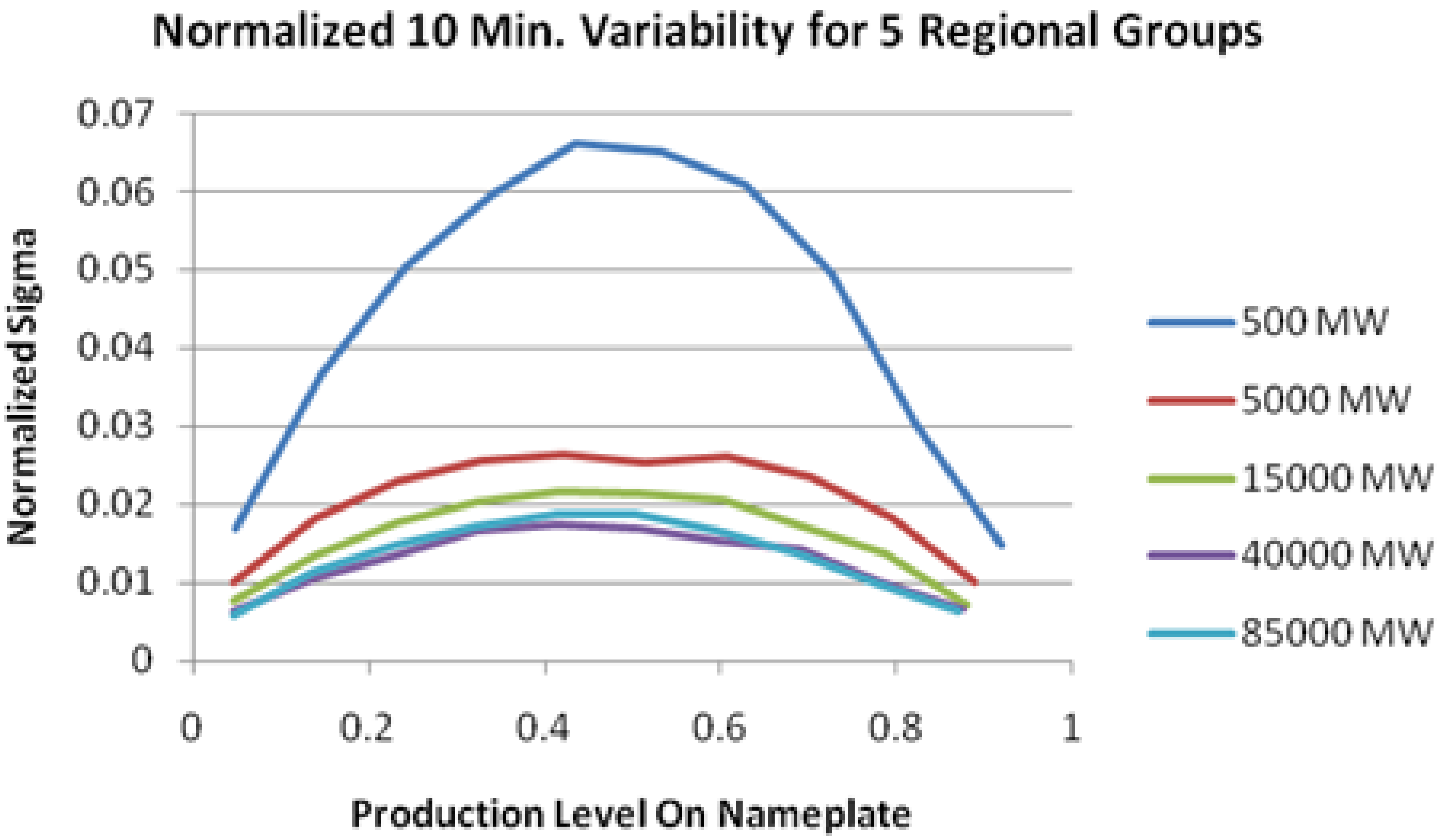

A Static VAR System has automatically switched capacitors
or reactors for steady state operation and
a smaller SVC for dynamic reactive power
requirements.
Note: Generation
with adequate
reactive capability
looks like an SVS for
steady state purposes
and slower dynmamic
Line
Sections
or
Compensators -1
P
U
S
I
L
Winnipeg
Duluth
Peresque Isle
Straits/345 kV MI
NYC
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1
2
3
4
Three or four SVS or equivalents in generation
can provide adequate reactive supply and reduce the
angle requirements for stability.
The question is where to put them.
Is there an intermediate bus that needs voltage suppor
MILES From Winnipeg

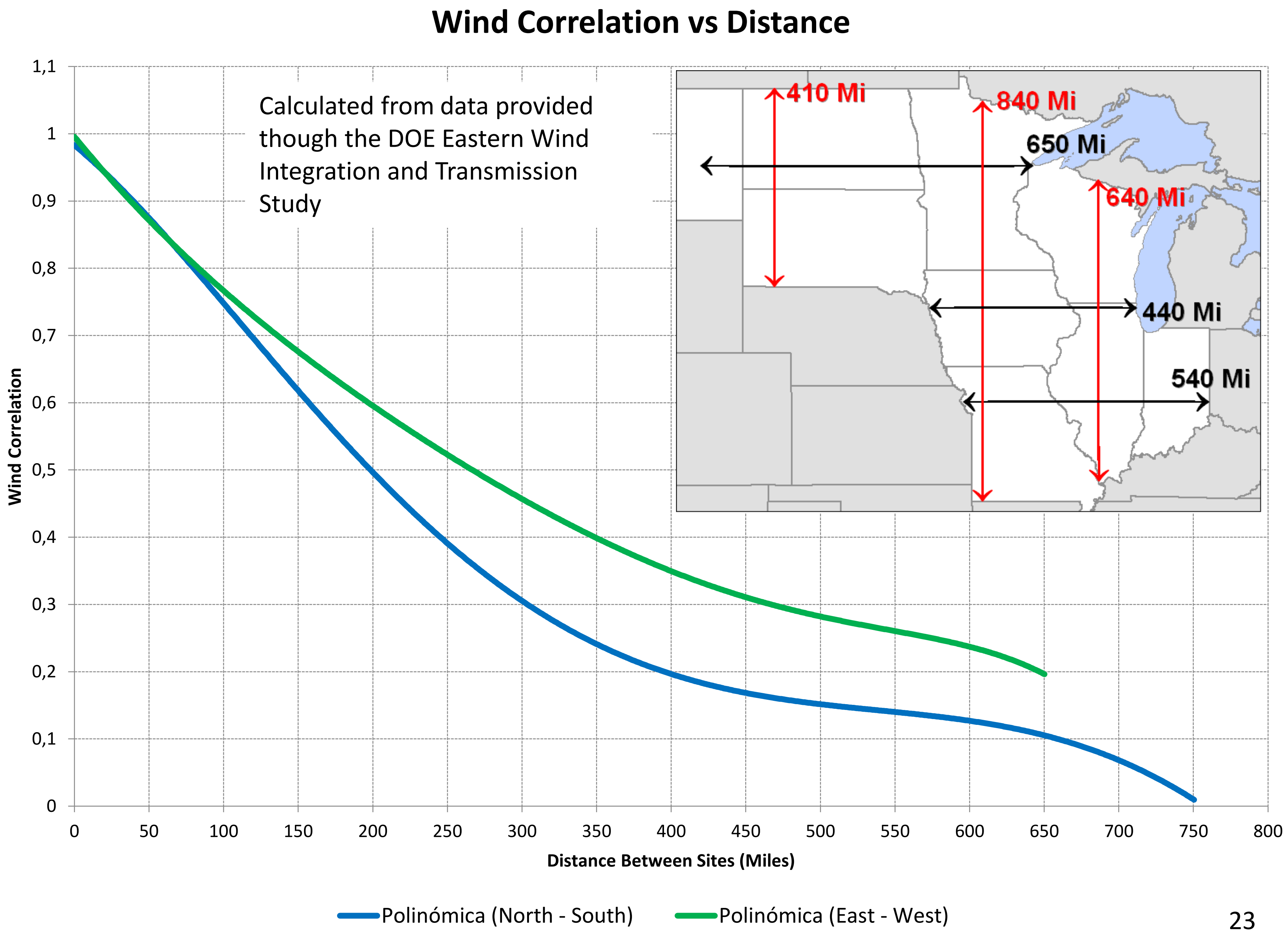

Transmission Cost $/MW-Mile by Type
Transmission Cost
$/MW-MILE
$4,000
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$-
345
2-345
500
765
650 Mile 600 VSC DC
1500 Mile HVDC 2700 MW
1500 Mile HVDC 5400 MW


Without Overlay
Load
Savings
With AC Overlay
With HVDC Overlay
P
R
I
C
E
Gen
Revenue
Difference
Distance

# Information Learned about Wind Generation

- With wind generation distributed over a wide geographic footprint, the aggregate variability of wind tends to change slowly after 5,000 MW of installed capacity. MISO operates with the same Spinning Reserve with 16,000 MW of wind and 130,000 MW of load as predecessor pools did with 0 wind and 43,000 MW of load in the past.
- Wind generation capacity credits in MISO at 16,000 MW of wind is about 15% of turbine rating. Studies indicate that the capacity credit could reach 28% using limited data.
- Aggregating MISO, WECC and ERCOT wind with a HVDC transmission network would reduce the ramp rates for wind generation in WECC and ERCOT by 50%
- For a limited data base, wind and solar revenues may stabilize around an average revenue if the renewable resources are aggregated with large amounts of renewable energy

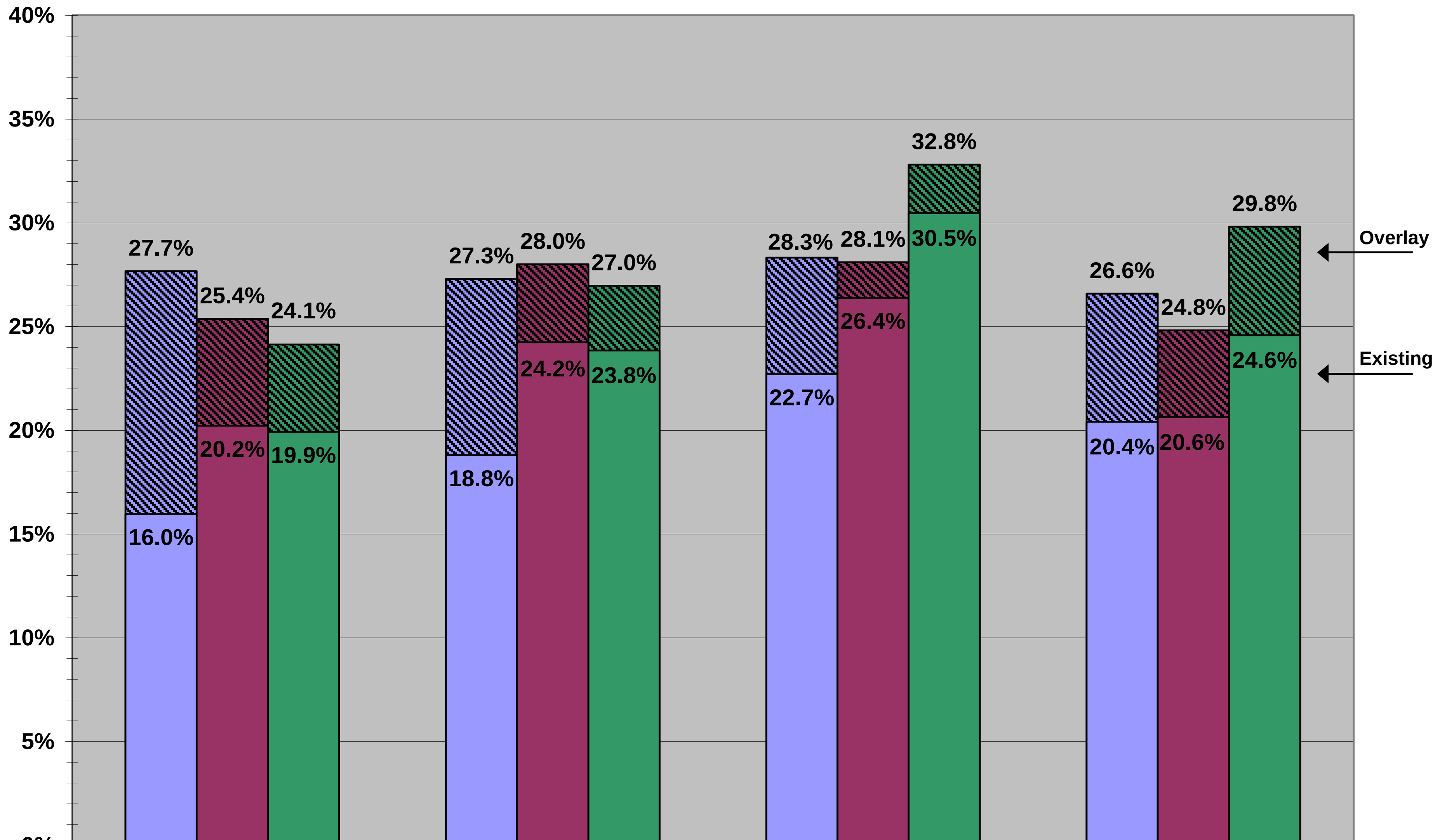

Normalized 10 Min. Variability for 5 Regional Groups
Normalized Sigma
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.2
0.4
0.6
0.8
1
Production Level On Nameplate
500 MW
5000 MW
15000 MW
40000 MW
85000 MW



Wind Correlation vs Distance
Calculated from data provided though the DOE Eastern Wind Integration and Transmission Study
410 Mi
840 Mi
650 Mi
640 Mi
440 Mi
540 Mi
Wind Correlation
1,1
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
Distance Between Sites (Miles)
Polinómica (North - South)
Polinómica (East - West)

# **Study System ELCC** Scenarios (1 - 4)

**Existing & Overlay Transmission Tie Limits - ELCC** (%) {Shaded Area shows Increased ELCC of Overlay}



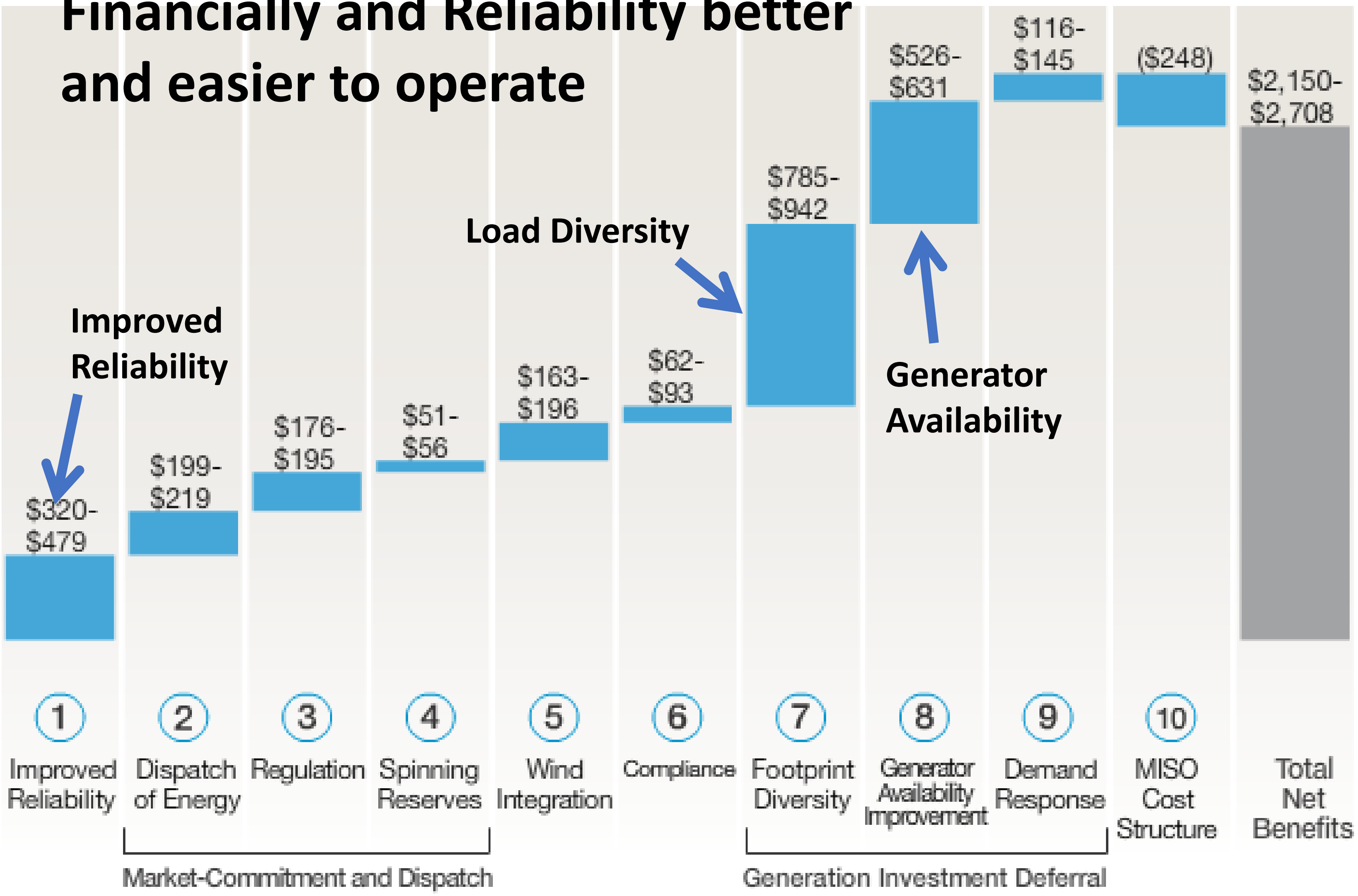

Scenario 3 is a Geographically Diverse Wind Resource Across the Eastern Interconnection

For the 3 years studied capacity credit is 28% with transmission. The transmission would more than pay for itself in benefits.

# Potential Benefits Outside of MISO with Capacity Diversity to justify most of the transmission

- The benefits identified in the MISO Value Proposition plus some others may exist outside of MISO
- HVDC has no limit to who is your neighbor
- Time zone differences and north-south load pattern differences have an estimated $50 B Potential Benefit mainly Capacity Diversity, renewable aggregation and energy arbitrage.
- MISO designed an HVDC network ( Macro Grid) that is estimated to capture $45B in benefits and has a rough estimated cost of $36B, benefit/cost ration of 1.25:1. The footprint covers ¾ of the U.S.
- There is little Reliability reason to build RTO-RTO transmission.  Each RTO is planned to be reliable on its own.  Economic justification is needed to build inter-RTO transmission.  The distances, AC loop flow considerations and cost allocation issues favor HVDC for connecting the asynchronous area of the US together as well as the synchronous area.

# Reasons for Being A MISO Member- Financially and Reliability better and easier to operate

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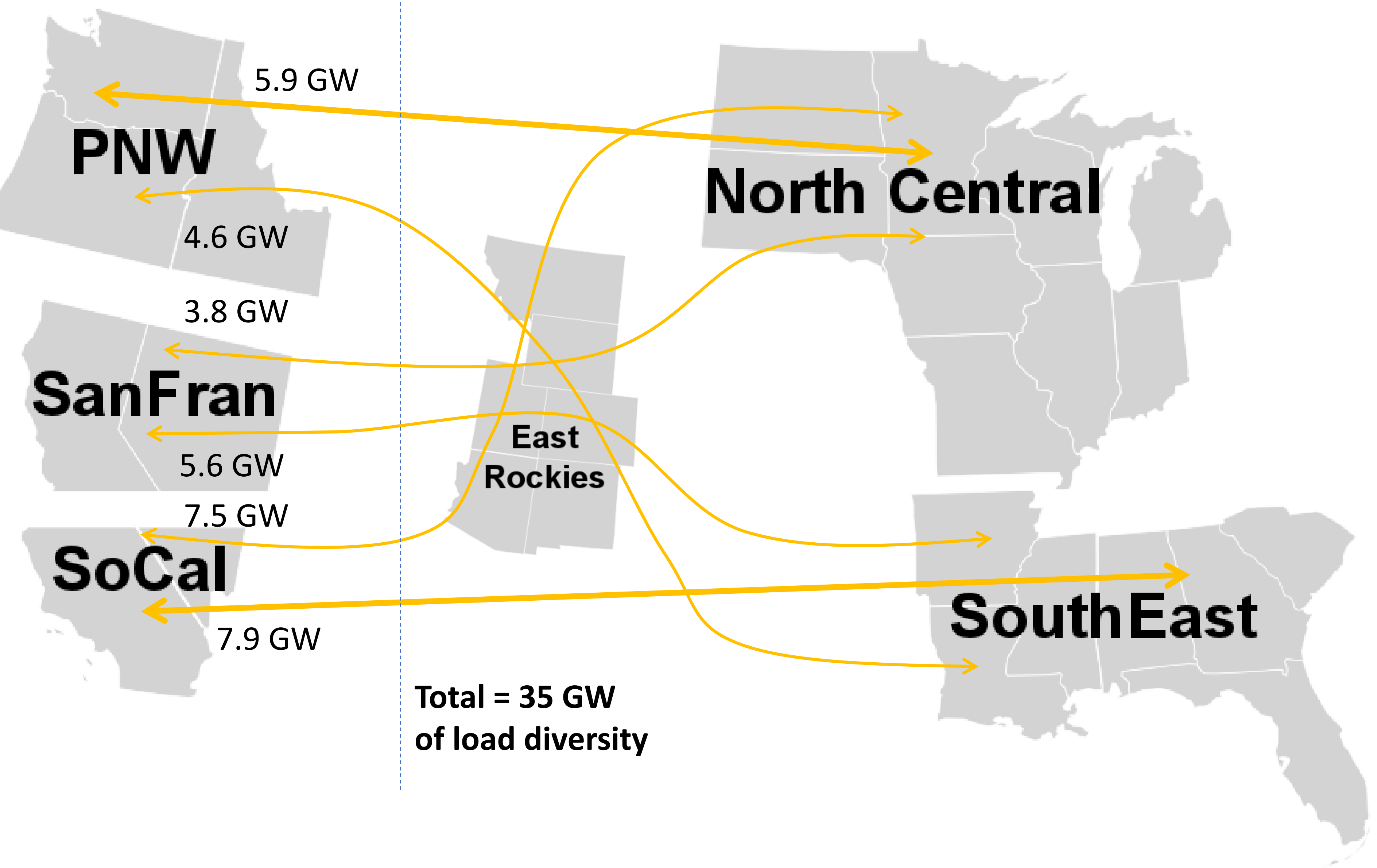
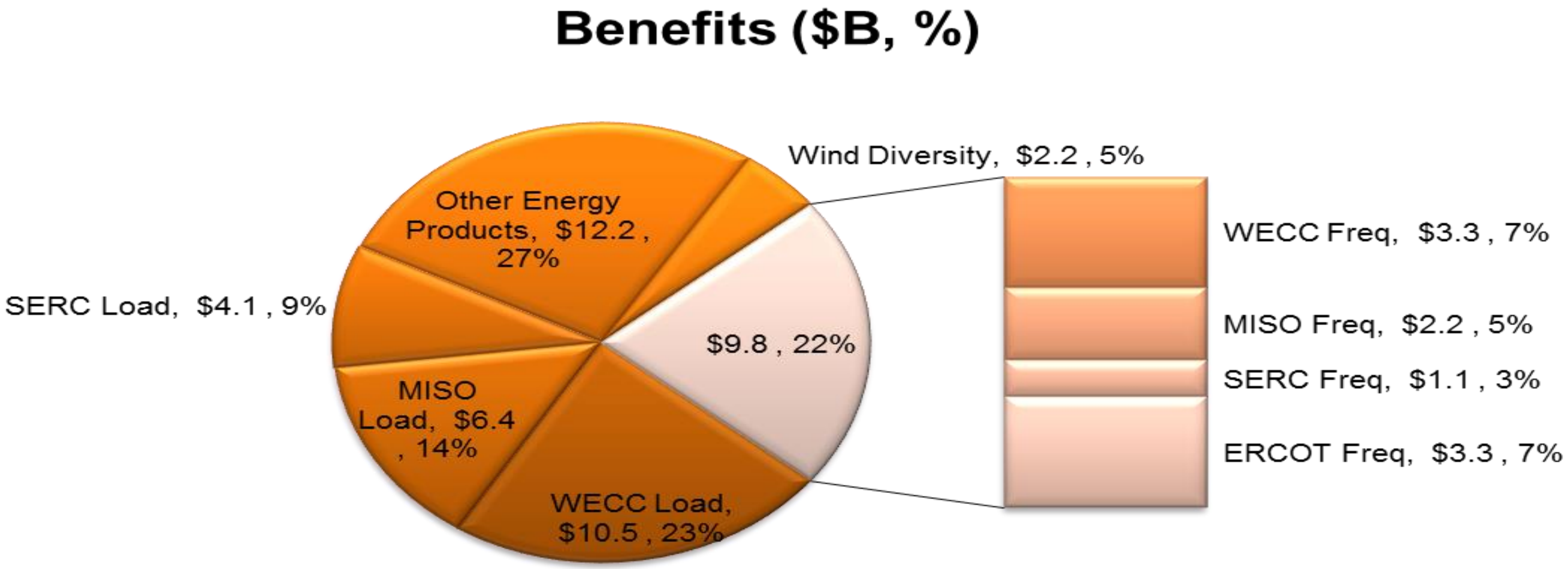
- Load Capacity Diversity



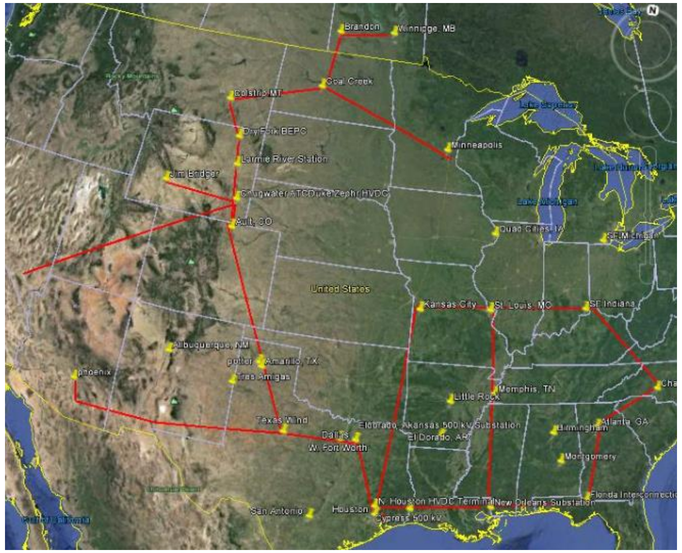
# Simple Distribution of Costs by Benefits



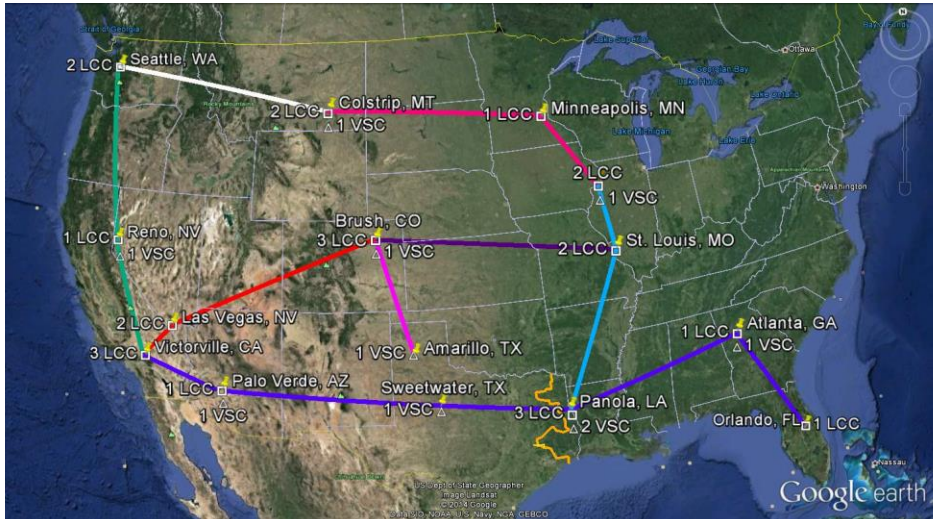

| Value Drivers | |
|---|---|
| Load diversity | 46% |
| Frequency response | 22% |
| Wind diversity | 5% |
| Other Energy Based Products | 27% |

# HVDC Sketch Differences

Jan 8th, 2014



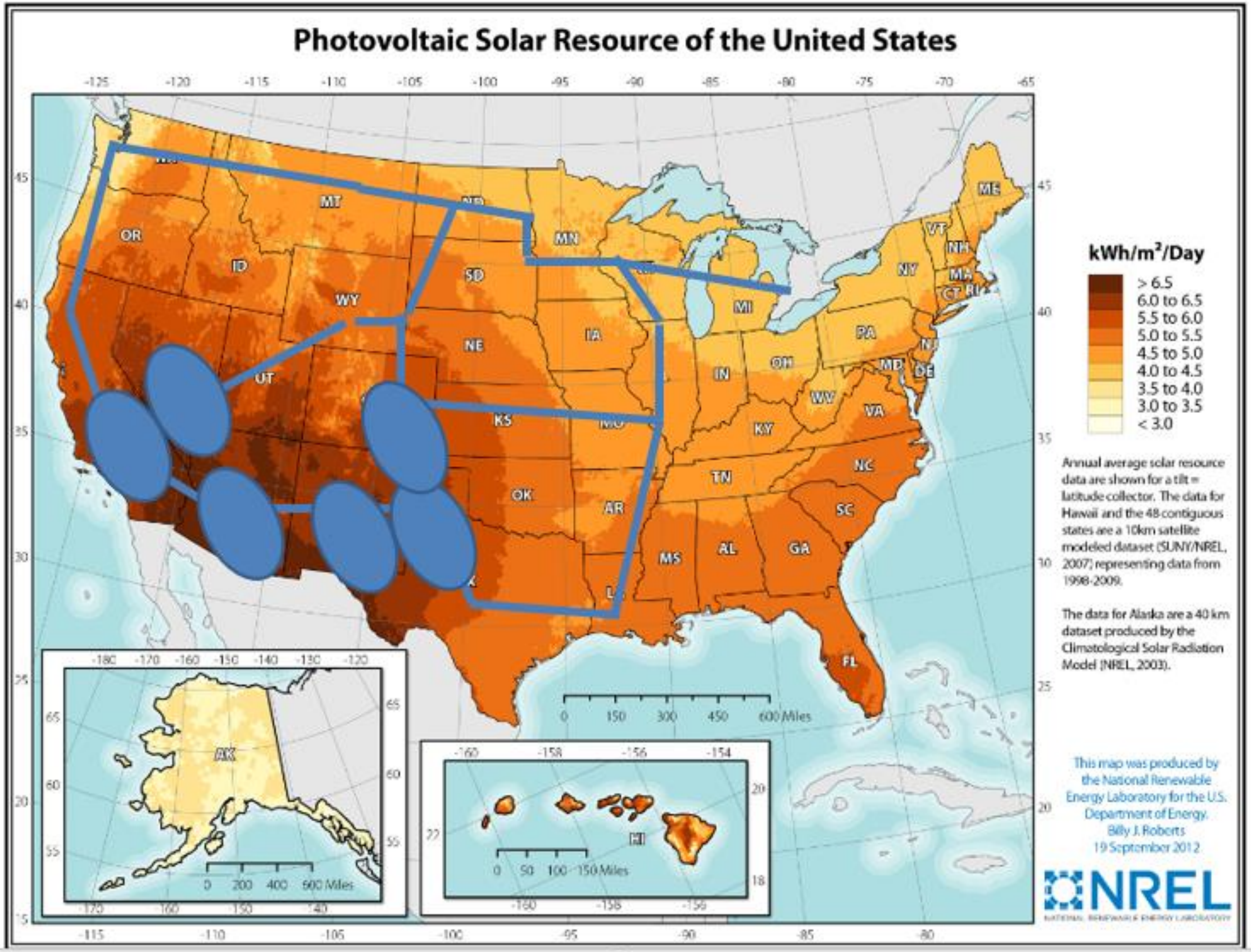
Oct 16th, 2014



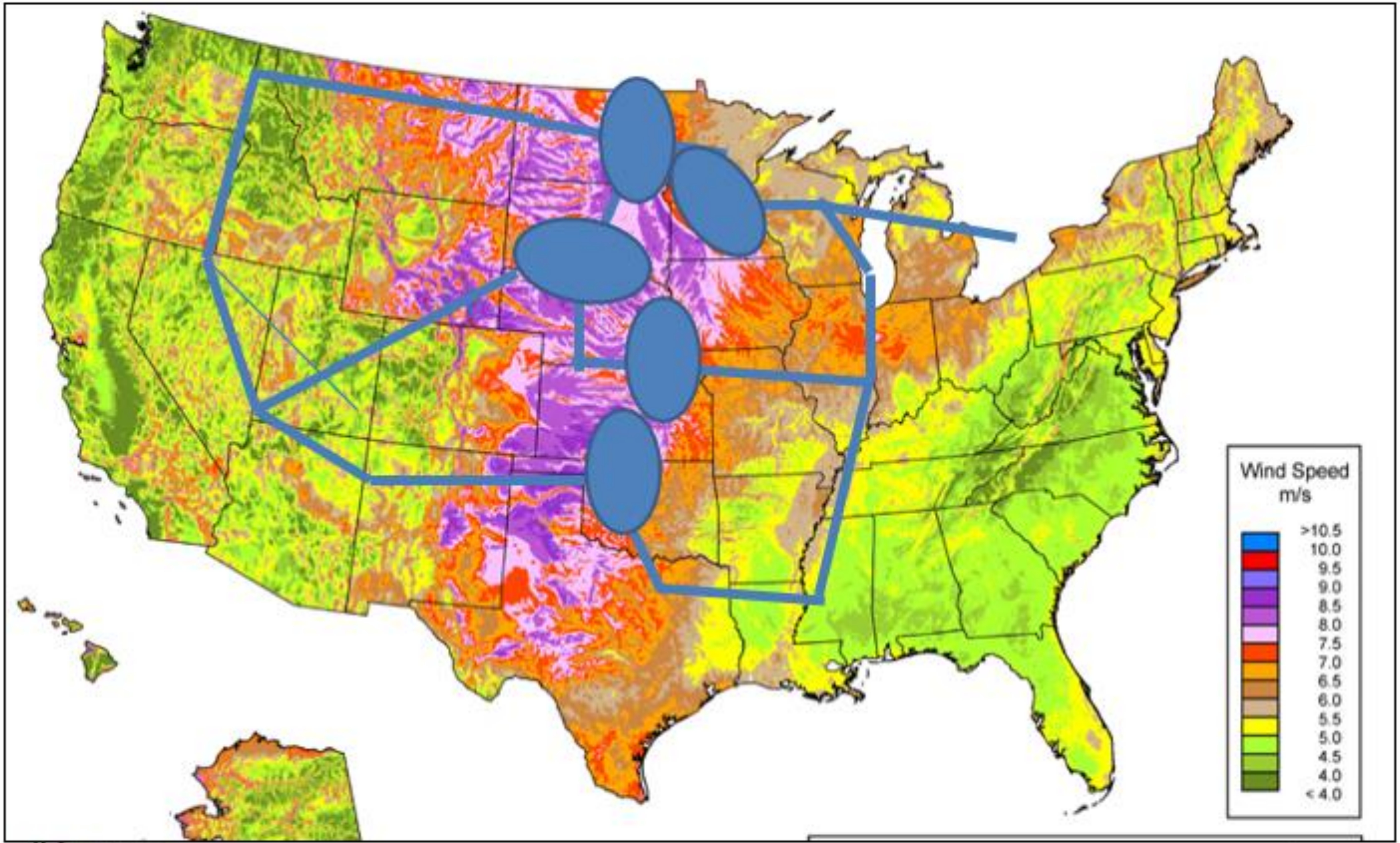

**<u>Bottom Up</u> Topology**
**23,000 MW of diversity and renewables**

- **<u>Top Down</u> Topology**
- **Based first on Load Diversity**
- **2006-2012 Load Data**
- **70,100 MW of diversity and renewables**

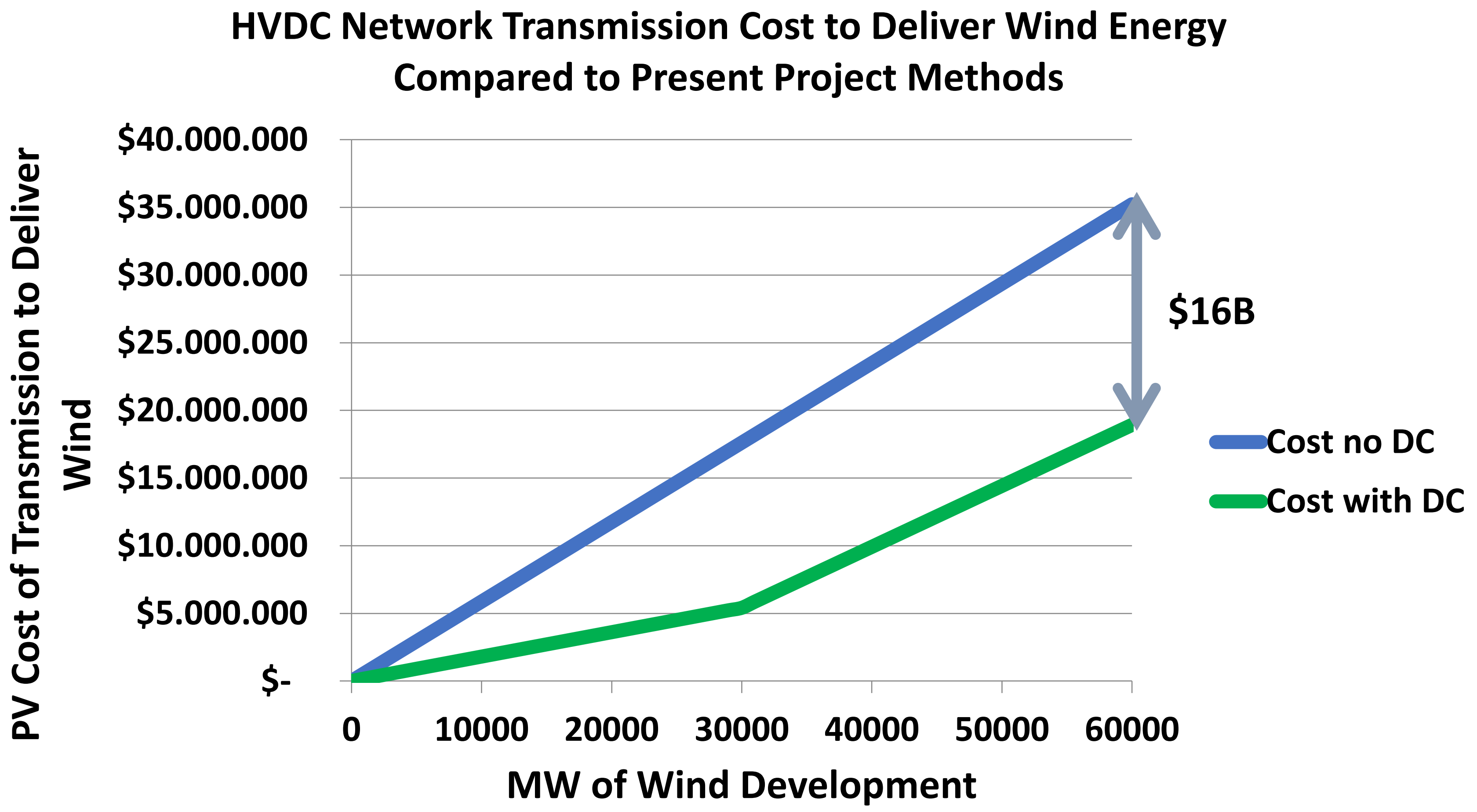
Increased scope by ~33% of MISO total load



Photovoltaic Solar Resource of the United States
kWh/m²/Day
> 6.5
6.0 to 6.5
5.5 to 6.0
5.0 to 5.5
4.5 to 5.0
4.0 to 4.5
3.5 to 4.0
3.0 to 3.5
< 3.0
Annual average solar resource data are shown for a tilt = latitude collector. The data for Hawaii and the 48 contiguous states are a 10km satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2009.
The data for Alaska are a 40 km dataset produced by the Climatological Solar Radiation Model (NREL, 2003).
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.
Billy J. Roberts
19 September 2012
NREL
OR
ID
MT
WY
UT
SD
NE
KS
OK
AR
MN
IA
MO
MI
IN
OH
PA
NY
VT
NH
ME
MA
CT
RI
NJ
MD
DE
WV
VA
KY
TN
NC
SC
GA
AL
MS
FL
AK
HI
0 150 300 450 600 Miles
0 200 400 600 Miles
0 50 100 150 Miles


Wind Speed
m/s
>10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
< 4.0

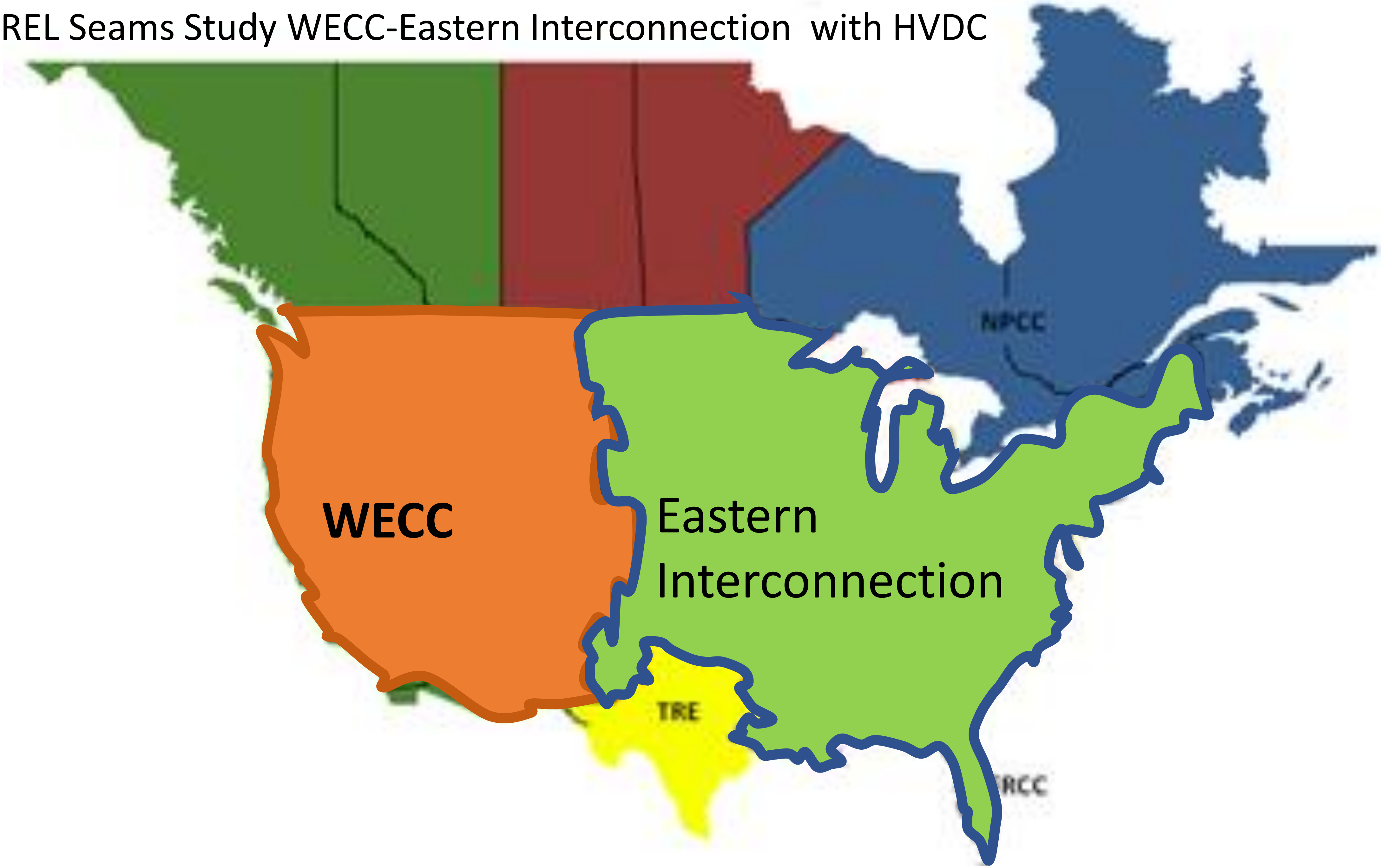
# Basic Infrastructure of the HVDC Network Lowers the Cost of Future Transmission Expansion



# Studies with the Macro Grid

- The U.S. Department of Energy (DOE) Grid Modernization Initiative funded the National Renewable Energy Laboratories study of tying the Eastern Interconnection of the U.S. with the western interconnection with HVDC transmission. The study is the SEAMS study and is expected to be completed later in 2017. MISO is participating in the scenario with the Macro Grid in the study as a reviewer and for suggestions. The value in the NREL study to MISO is the information about how MISO would fit into a national future grid. MISO has a Road Map that determines how MISO may integrate future resources, particularly renewable resources into the transmission system. There are too many combinations to be analyzed without a systematic process or study.
- DOE also funded the Pacific Northwest National Laboratory to study HVDC controls. The Macro Grid has been placed into a power systems dynamic model and the concepts for Frequency Response and contingencies for the loss of AC and HVDC components is being studied. MISO is participating in this study.

# NREL Seams Study WECC-Eastern Interconnection with HVDC

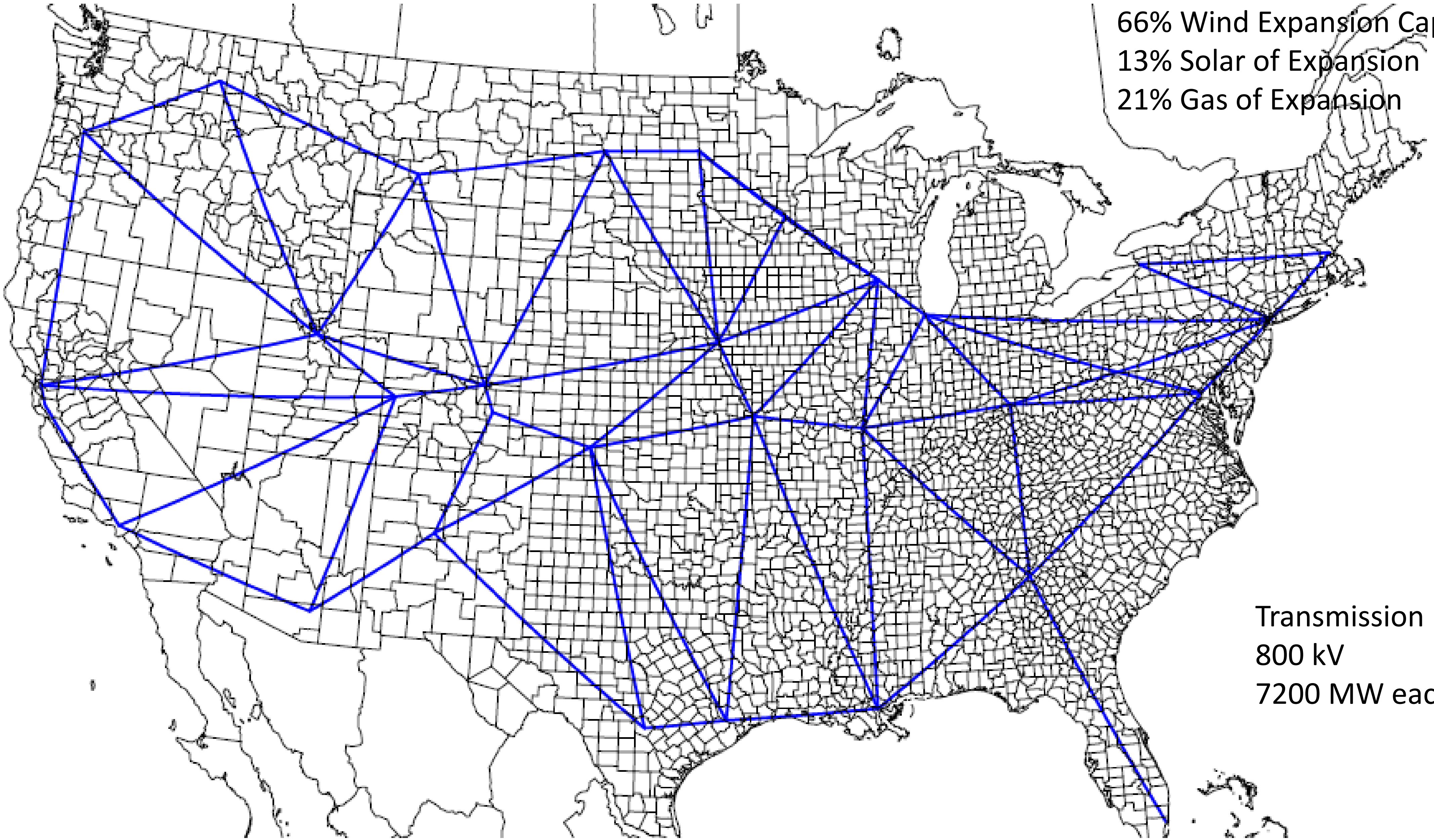


# NREL SEAMS study

- Co-optimization of the generation expansion and bulk transmission expansion to perform studies on a national scale is now possible due to mathematical innovations and and more powerful computers. Dr. Jim McCalley of Iowa State is leading the effort for the co-optimization program to the year 2030. About 70 areas are defined to represent the U.S. Renewable resources are modeled hourly by geographic location.
- The program determines the optimal generation expansion mix for the WECC interconnection together as well as the Eastern Interconnection. The Macro Grid is one of four scenarios being optimized. The Macro Grid transmission and peak generation schedules are placed into the program model, then the program optimizes the rest of the generation and transmission.
- Vibrant Energy (Dr. Christopher Clack) also has a co-optimization program. Dr. Clack has run national scale studies using his program. MISO had Dr. Clack run a Road Map study co-optimizing the MISO system alone for a 30%, 50% and 80% carbon reduction cases. Using the co-optimization program reduced the production time of the MISO Road Map from 36 months to 3 months. MISO uses the Road Map and studies like NREL to guide the preparation the generation alternatives for more detailed studies discussed above and to estimate bulk transmission requirements.
- To date co-optimization programs cannot handle the 10 years of load data used for calculating the highly probable power interchange level ( worst case) for the U.S.

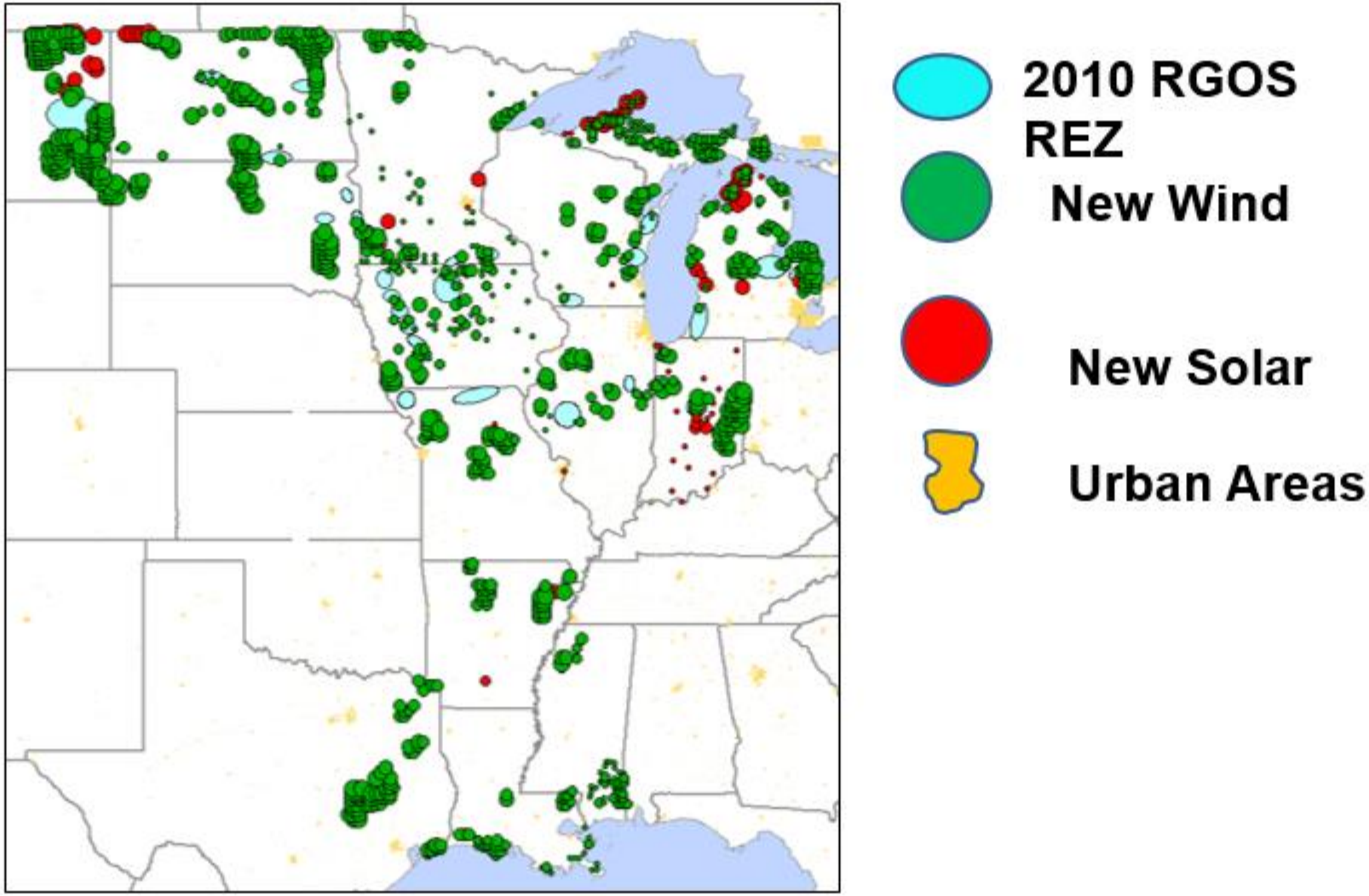
# HVDC Transmission

82% Renewable Energy
66% Wind Expansion Capacity
13% Solar of Expansion
21% Gas of Expansion

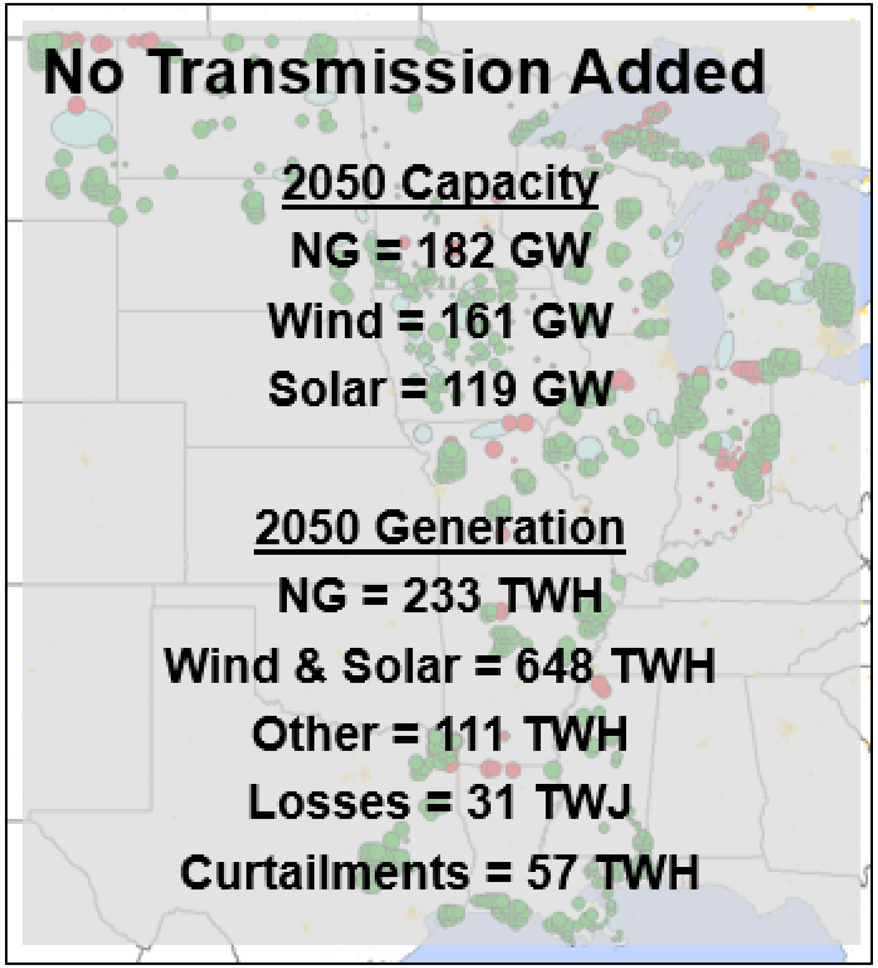


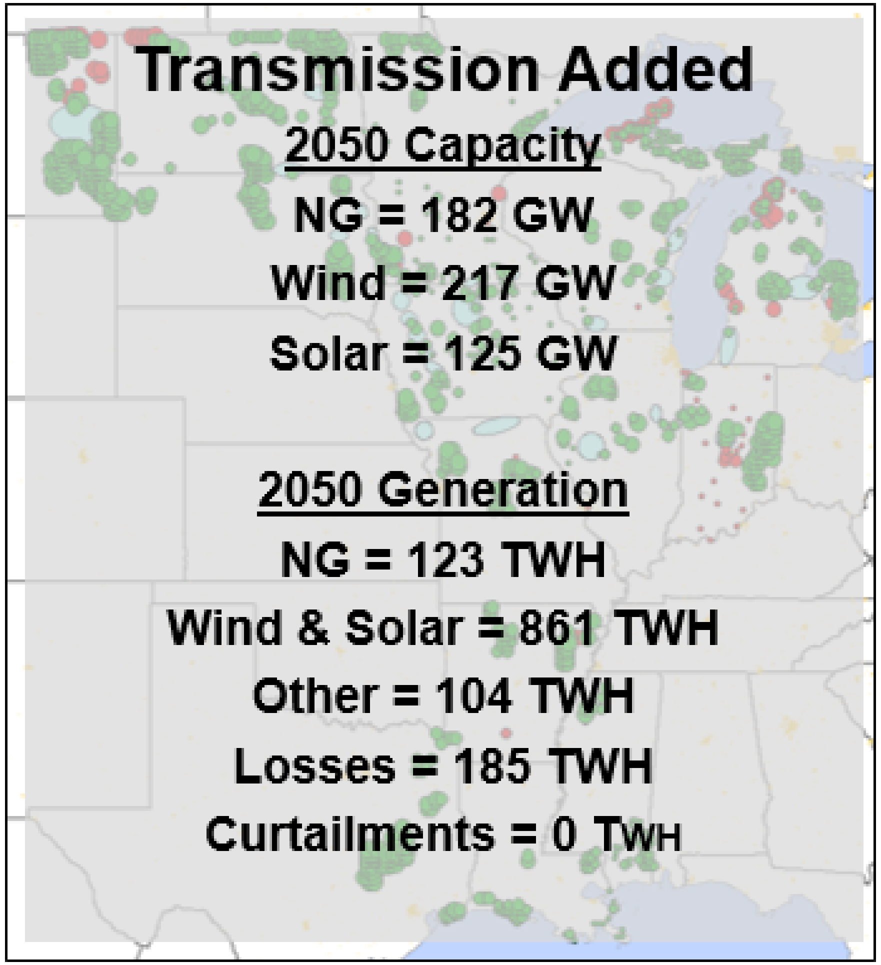
Transmission
800 kV
7200 MW each

# Renewable Co-Optimized Locations



# Effect of Transmission on Optimal Generation Mix

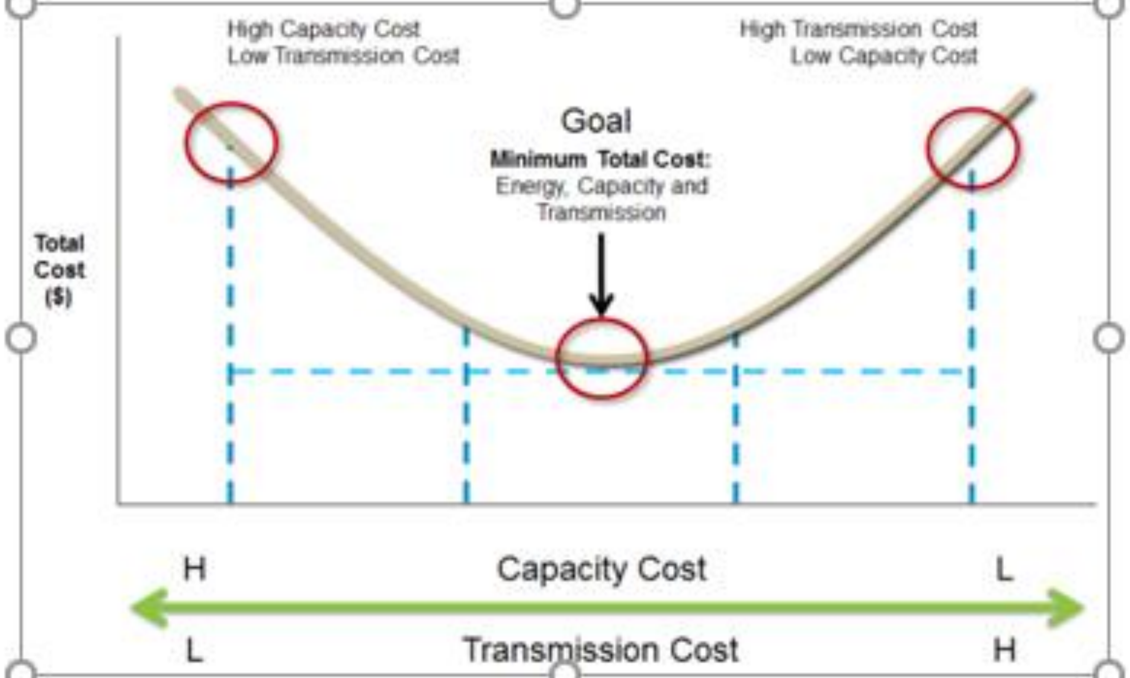


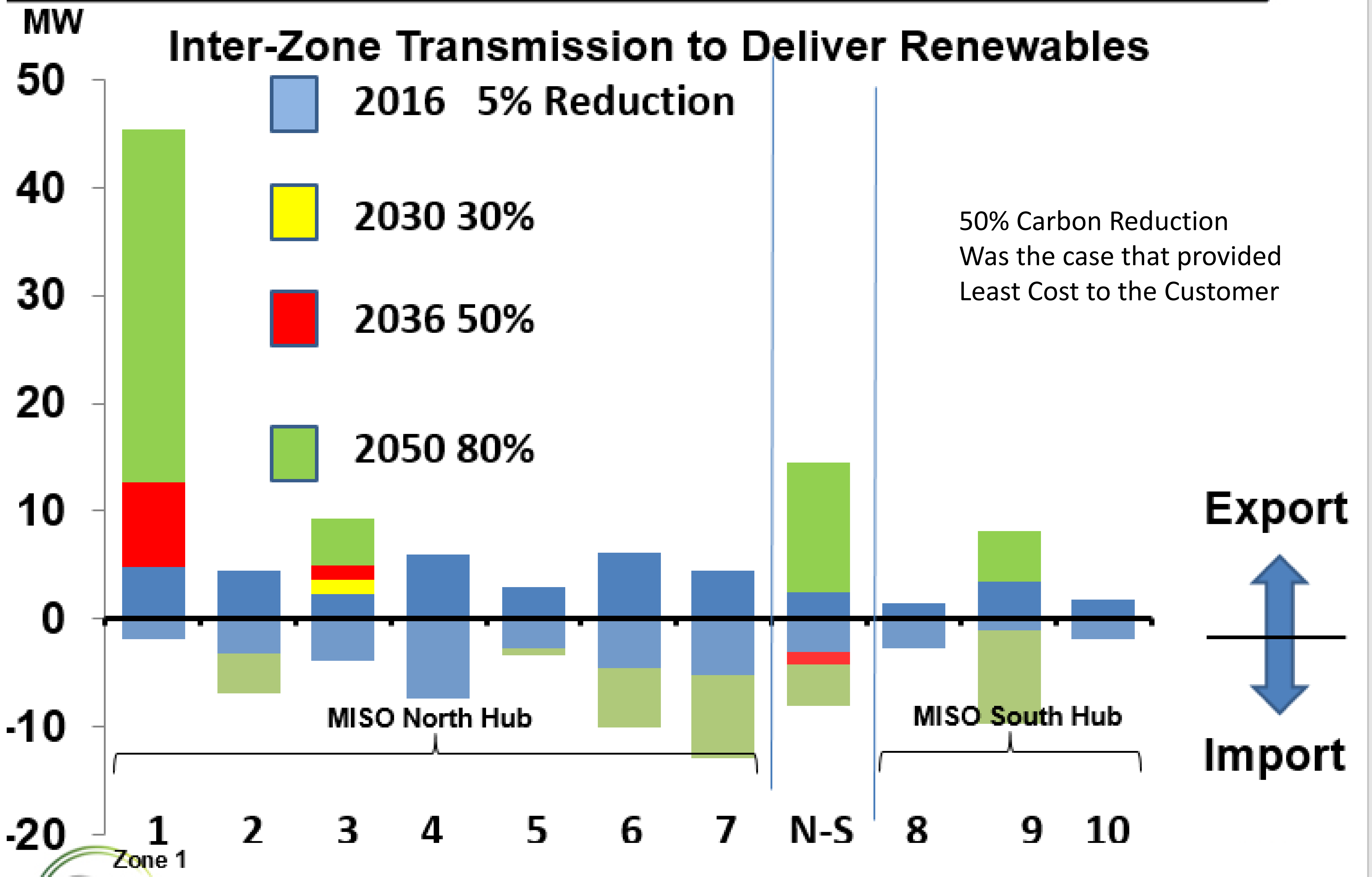

*Results shown are from the load matching optimization which does not consider economics.*

*RGOS = Regional Generator Outlet Study, see https://www.misoenergy.org/Planning/Pages/RegionalGenerationOutletStudy.aspx

# Optimizing Energy Delivered




**MISO's Local Resource Zones**


MW
Inter-Zone Transmission to Deliver Renewables
50
40
30
20
10
0
-10
-20
2016 5% Reduction
2030 30%
2036 50%
2050 80%
50% Carbon Reduction
Was the case that provided
Least Cost to the Customer
Export
Import
MISO North Hub
MISO South Hub
1
2
3
4
5
6
7
N-S
8
9
10
Zone 1

# Step 2 of the Seams Study

- The generation and bulk transmission will be inputs to a production cost simulation model for PLEXOS.
- The PLEXOS program will produce hourly simulations for the two interconnections. This is a first time event.

# Questions?

Dale Osborn

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