MidwestISO
Energizing the Heartland

Transmission Plan Based on Economic Studies Paper 08TD0721 Slides

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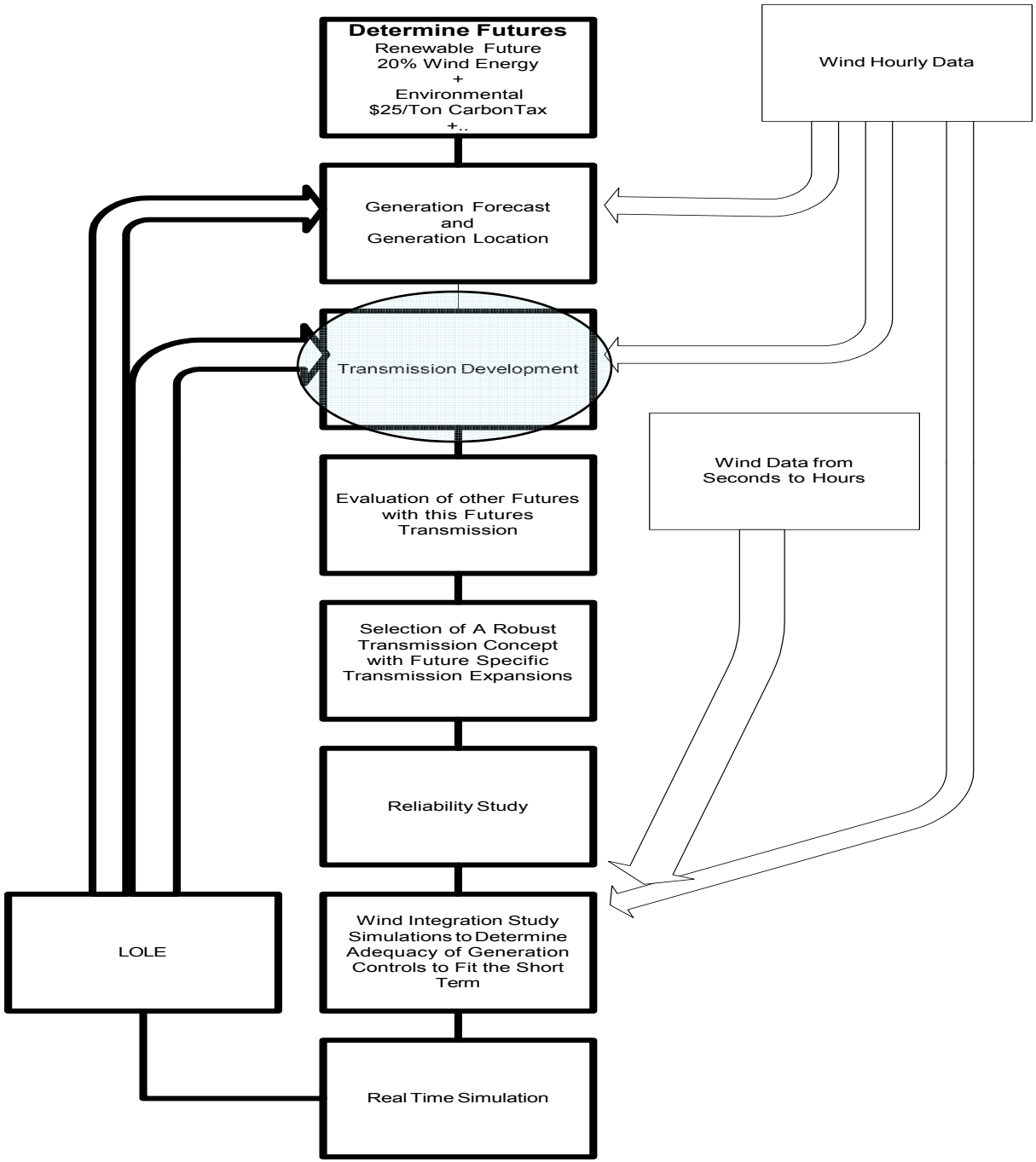
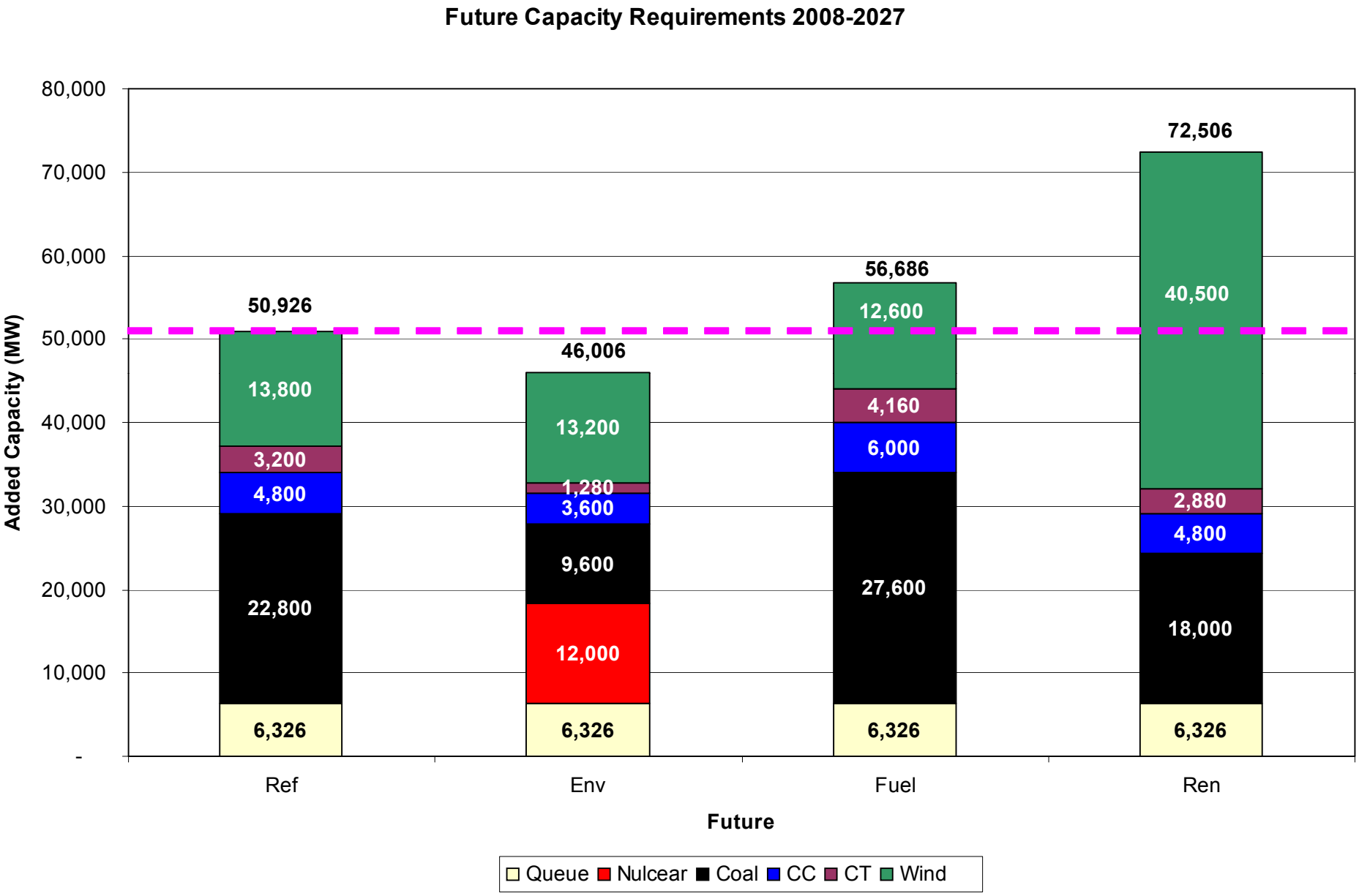
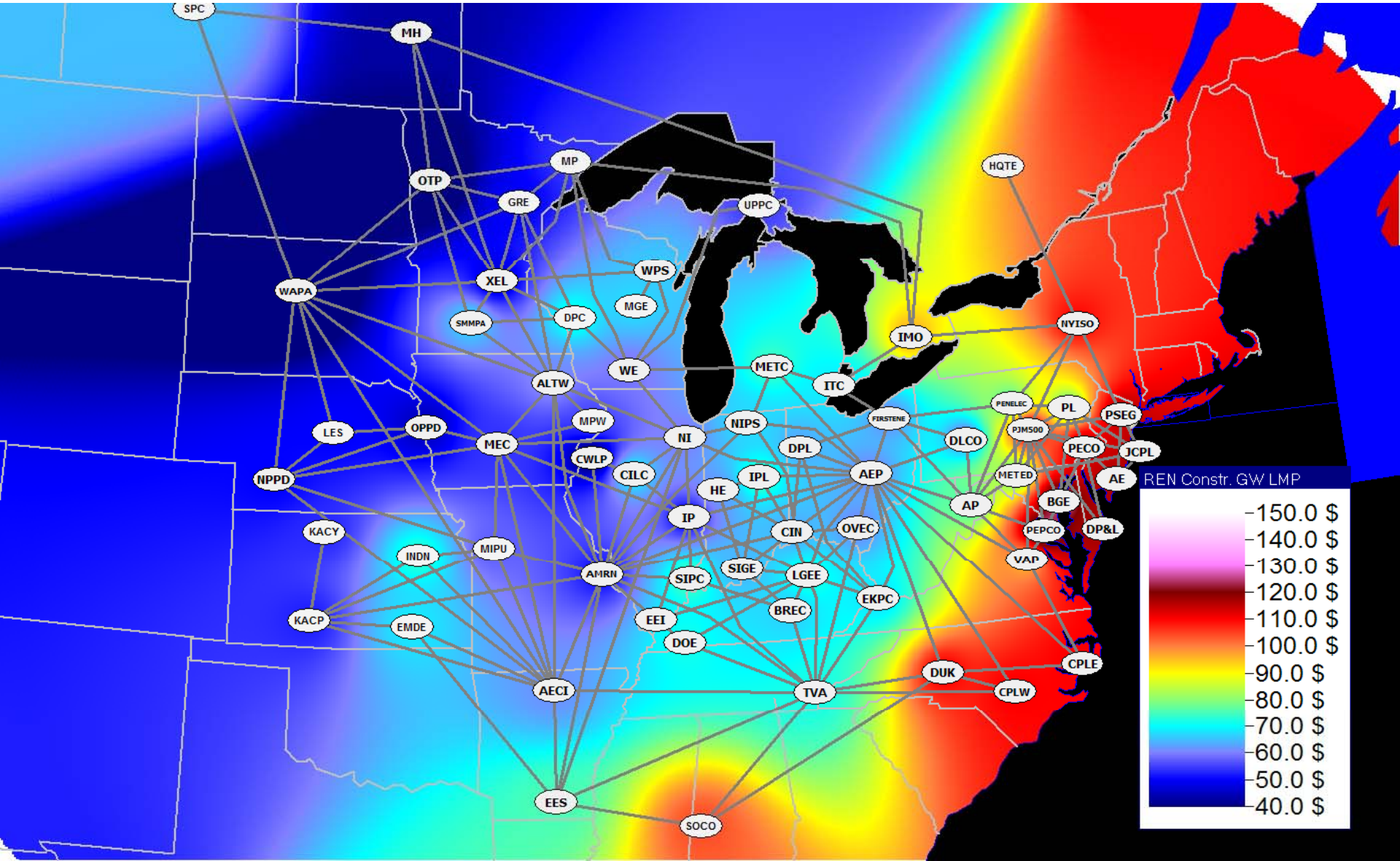
Power System Conceptual Design

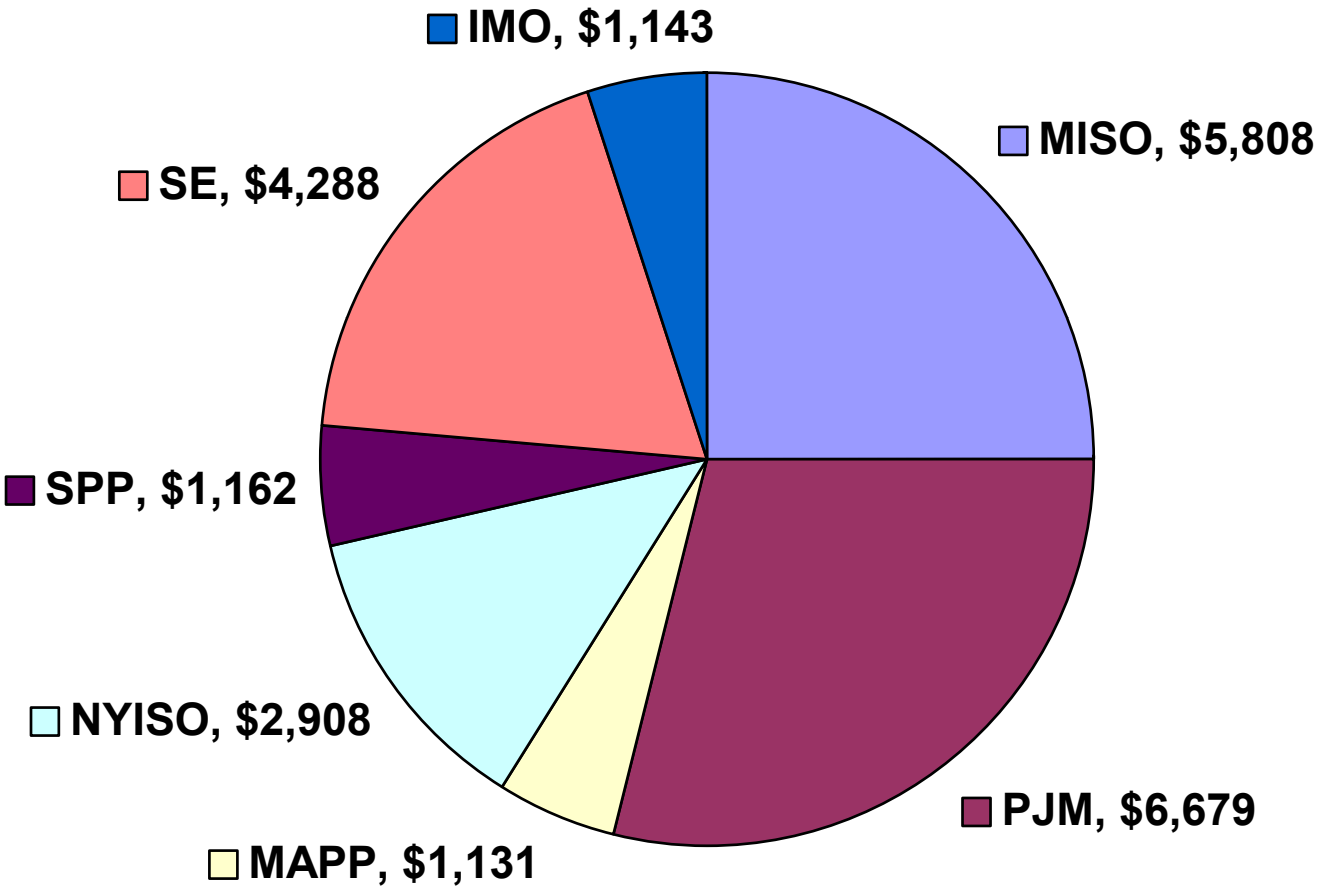



Future Capacity Requirements 2008-2027
Added Capacity (MW)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
50,926
13,800
3,200
4,800
22,800
6,326
46,006
13,200
1,280
3,600
9,600
12,000
6,326
56,686
12,600
4,160
6,000
27,600
6,326
72,506
40,500
2,880
4,800
18,000
6,326
Ref
Env
Fuel
Ren
Future
Queue
Nulcear
Coal
CC
CT
Wind

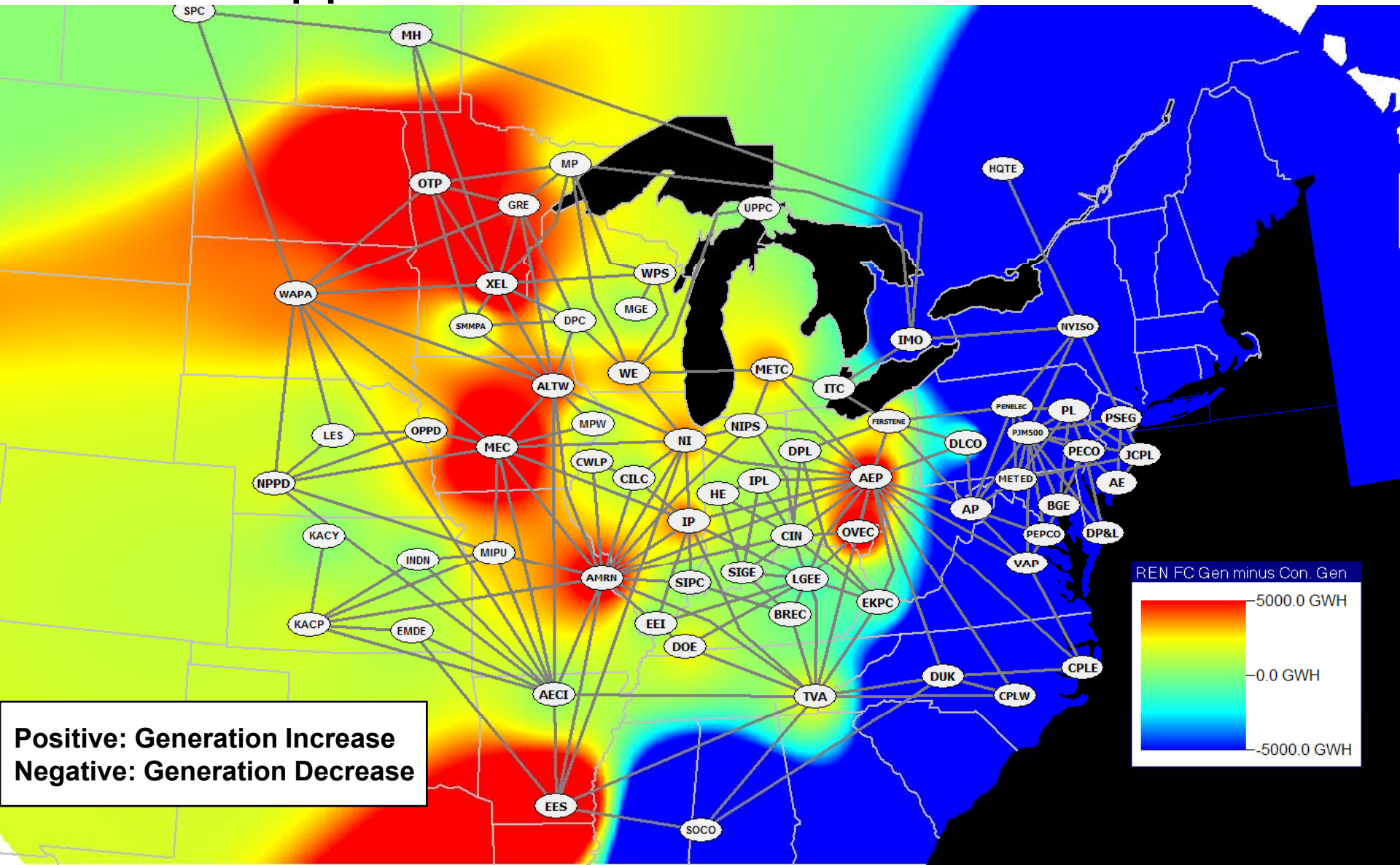
Full Constrained Case
Annual Gen Weighted LMP

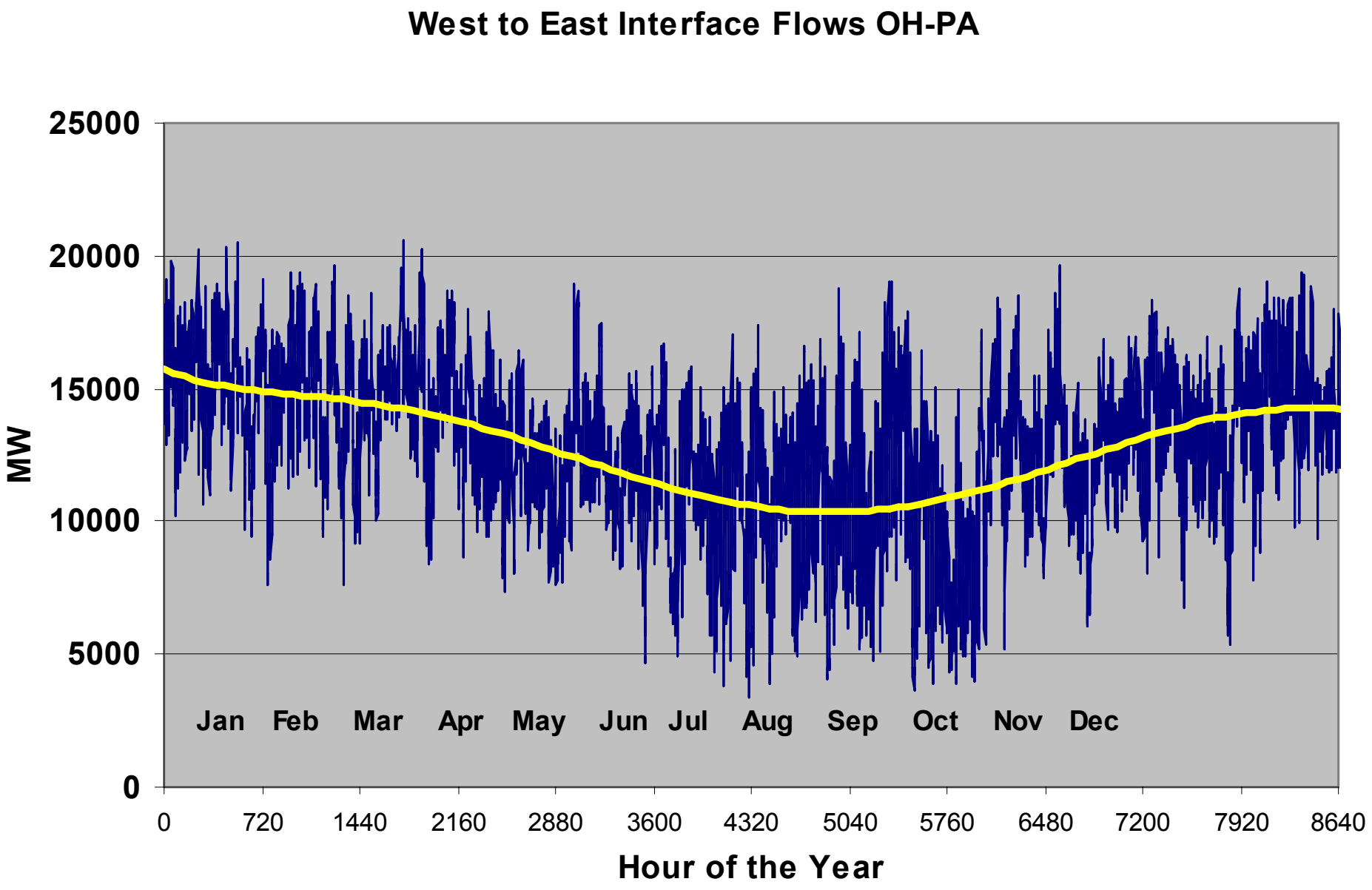


Potential Congestion Relief $M/yr

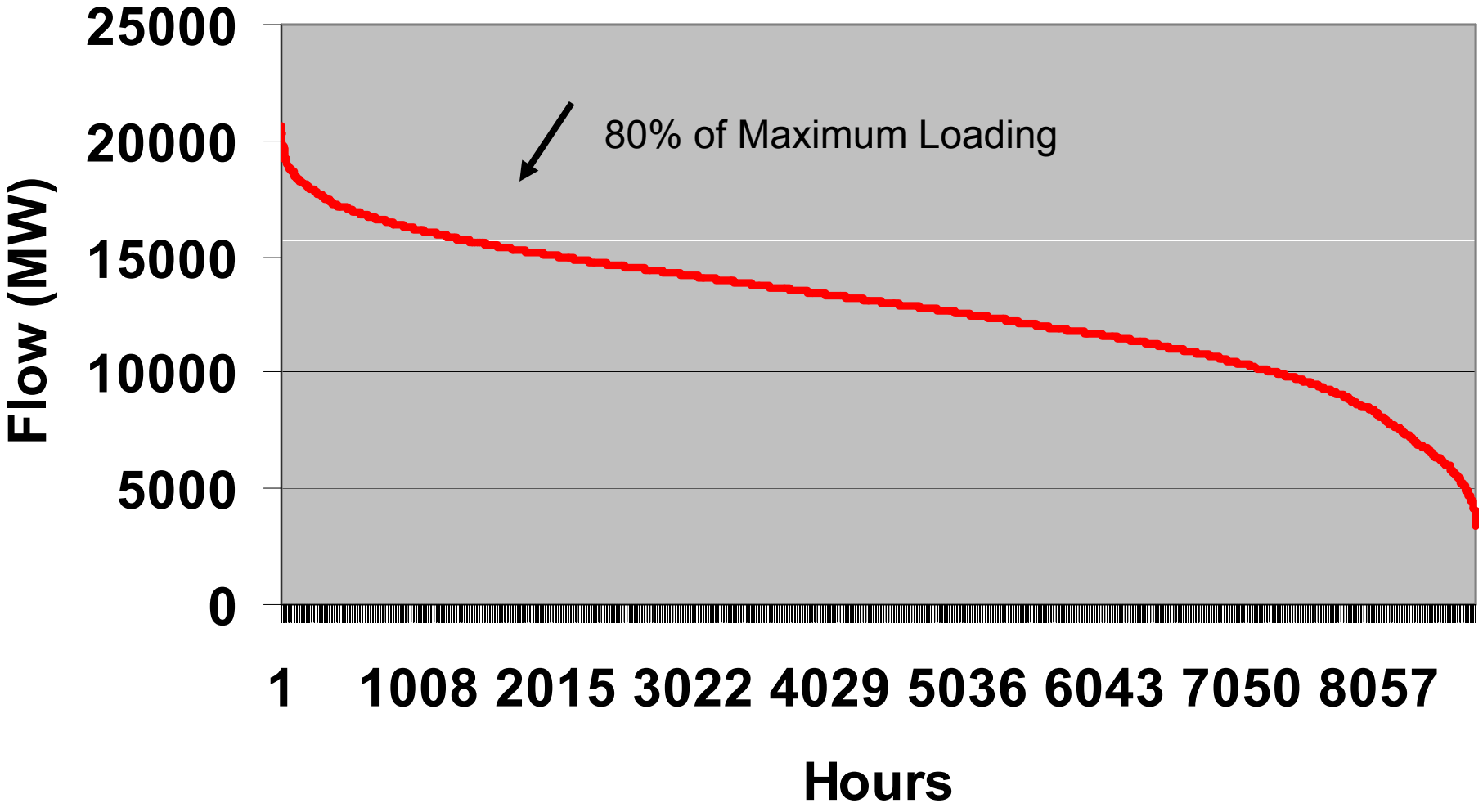


Generation Difference:
Full Copper Sheet and Full Constrained Cases

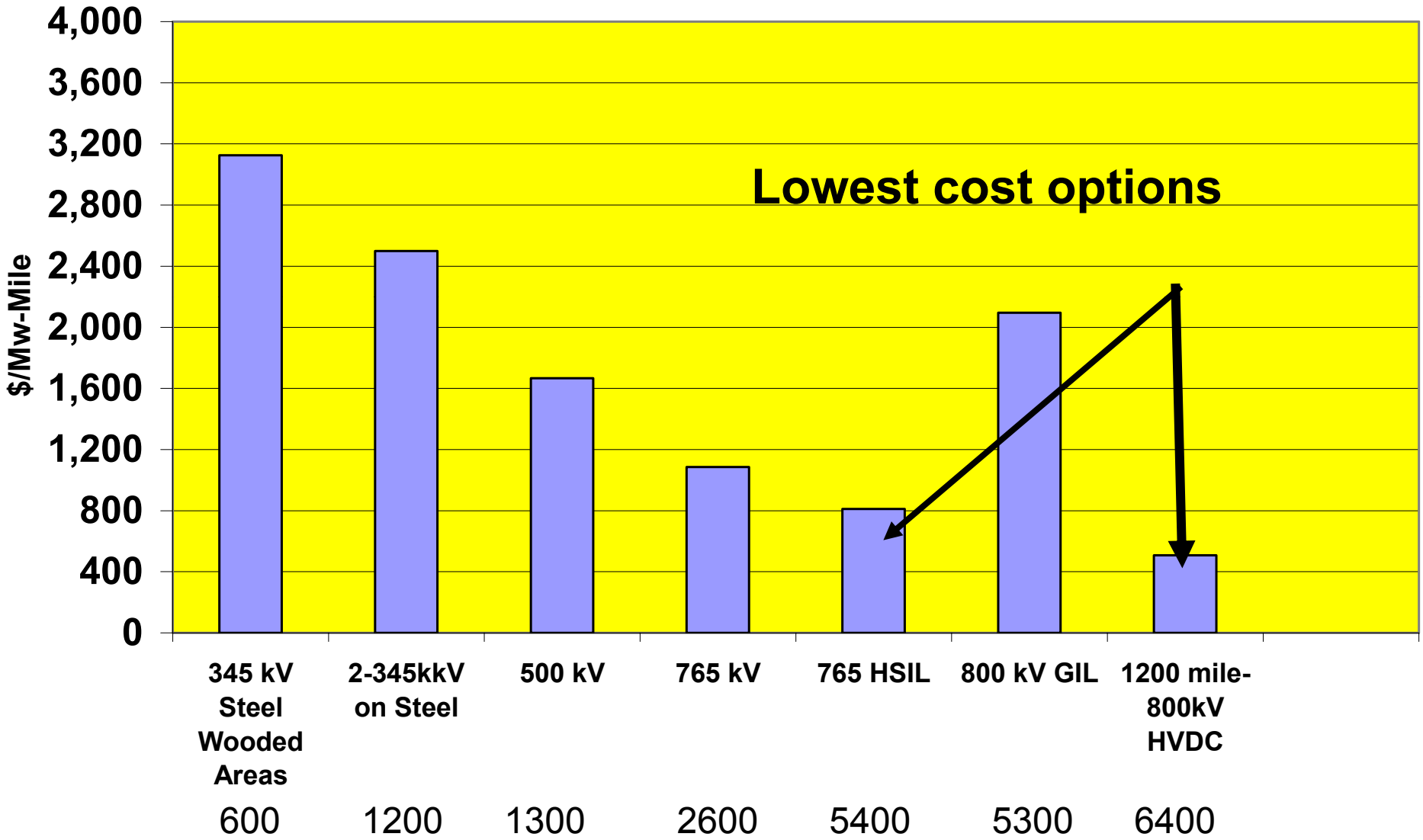



West to East Interface Flows OH-PA
25000
20000
15000
10000
5000
0
MW
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0
720
1440
2160
2880
3600
4320
5040
5760
6480
7200
7920
8640
Hour of the Year

West to East Flow with HVDC



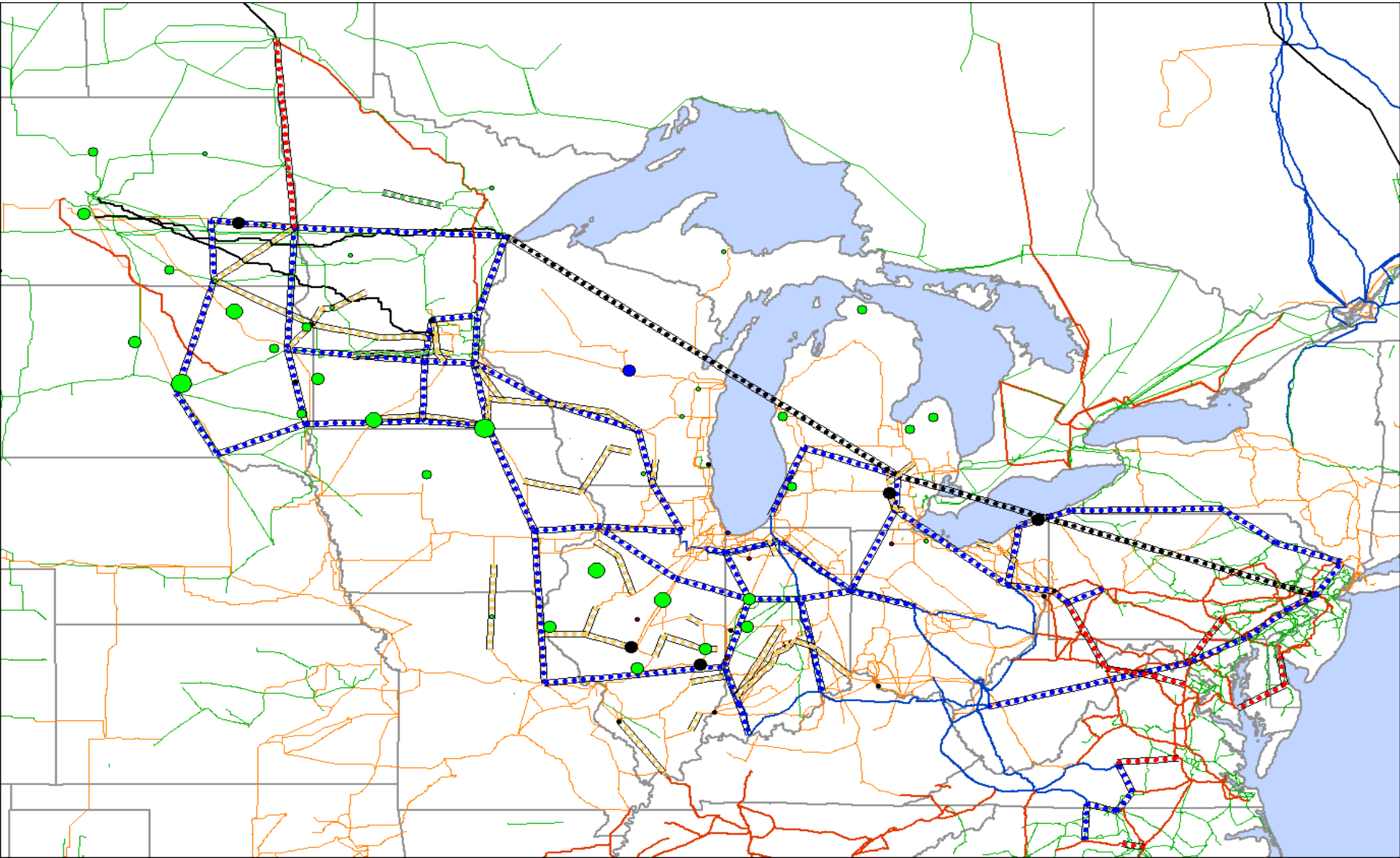
Transmission and Substation Costs per Mw-mile by Transmission Voltage And Type of Construction



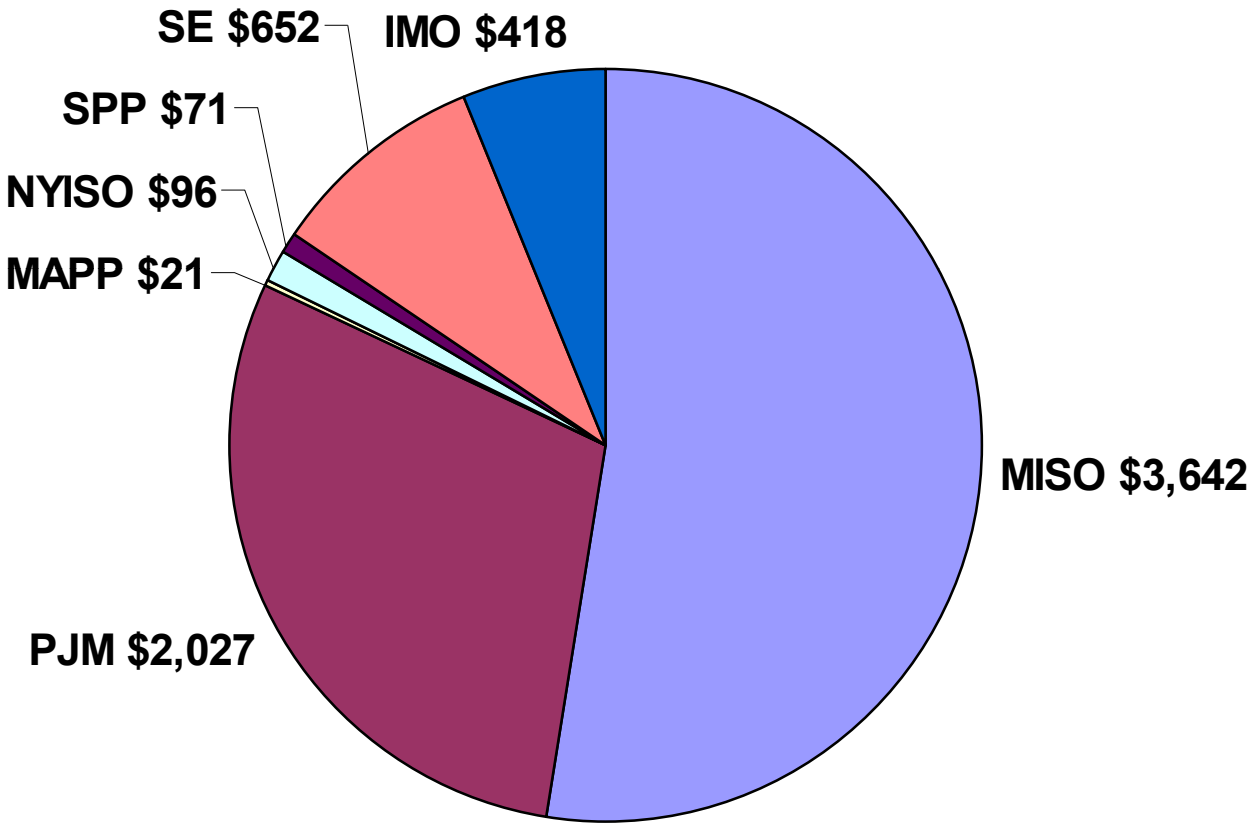
Target typical planned loading Mw, use economics to choose voltage

MTEP08
October 5, 2007
Overlay for
Step 4 Analysis

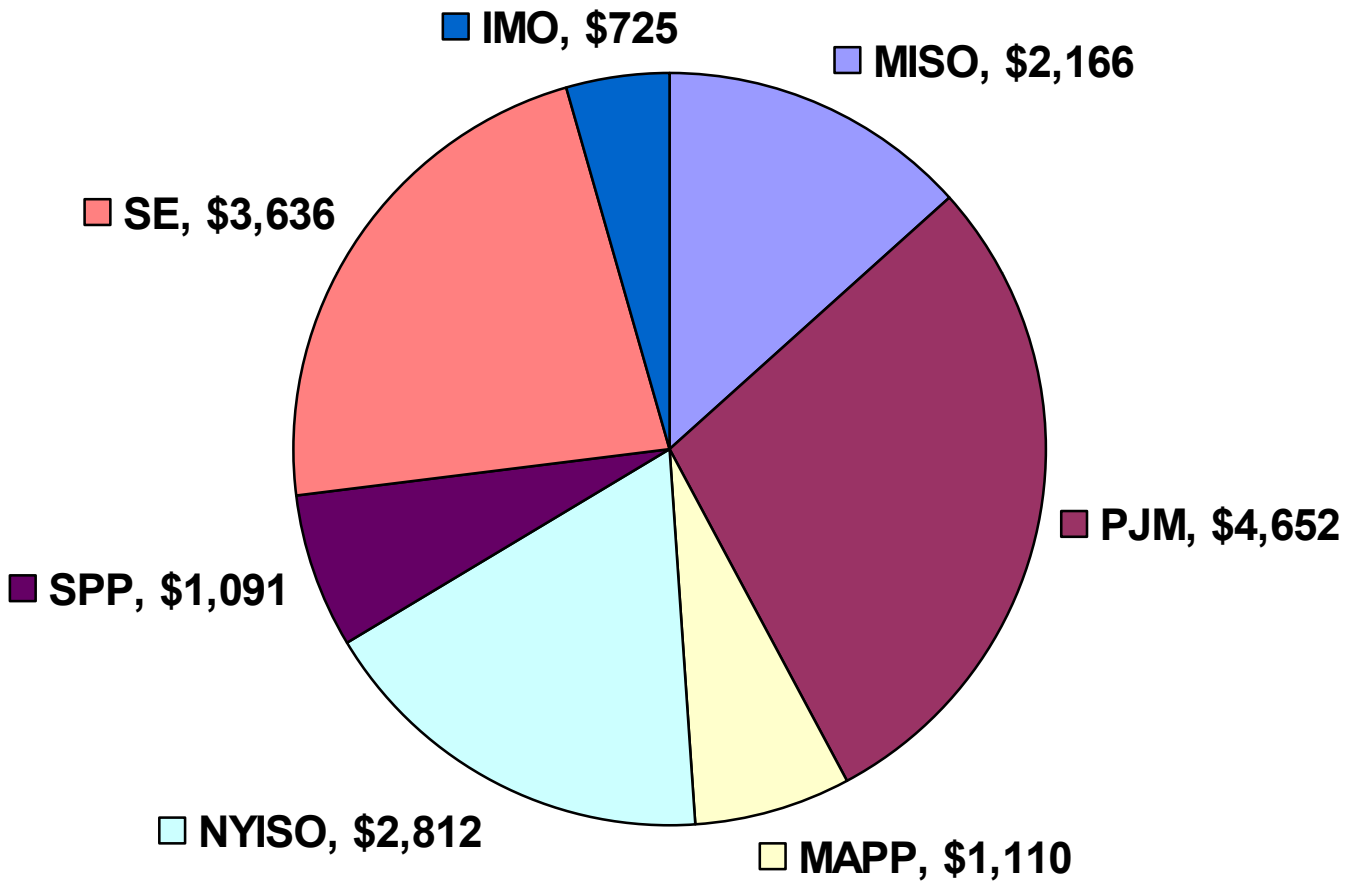
Final Skeleton – EI Overlay



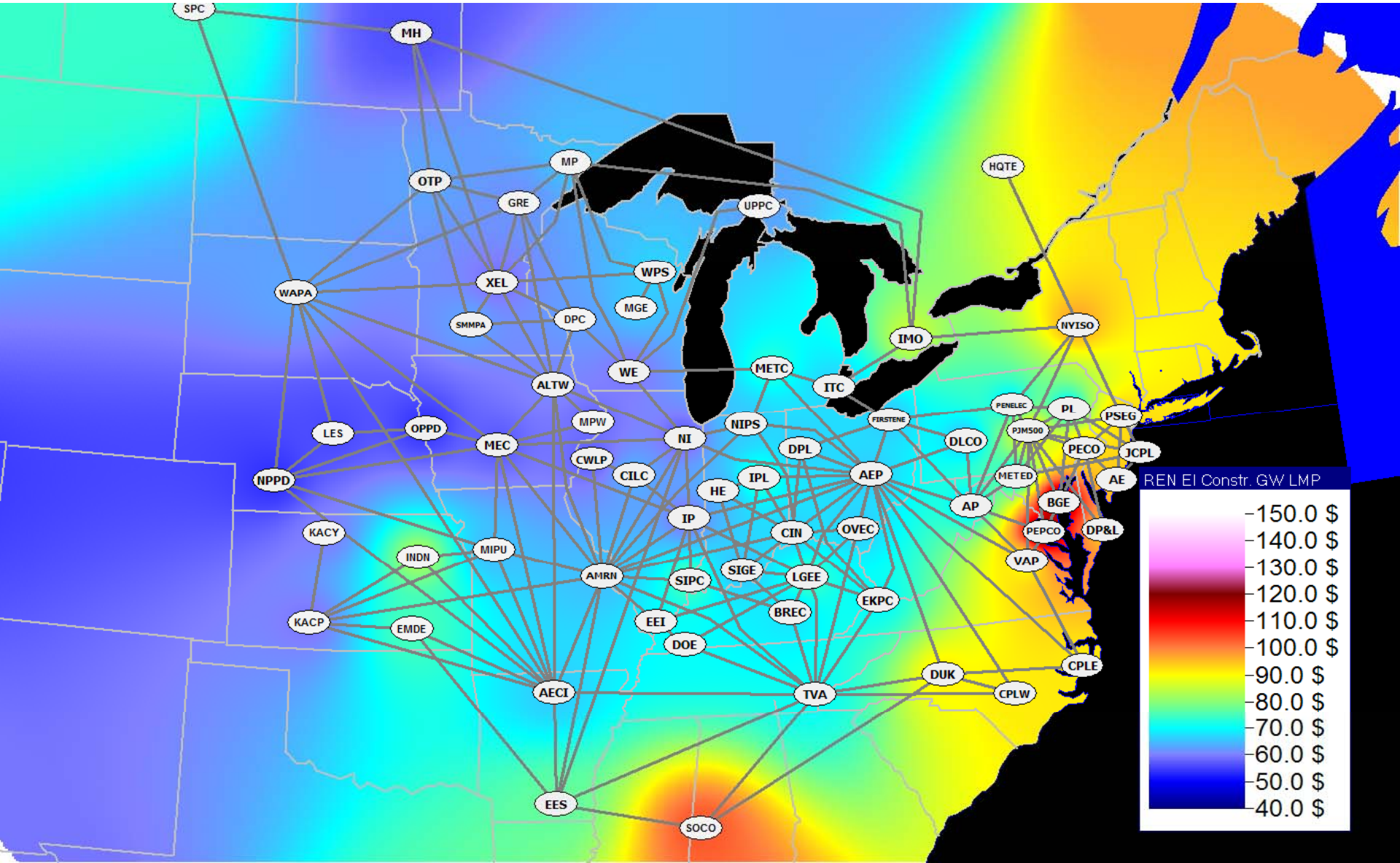
Potential Benefits from Expansion $M/yr



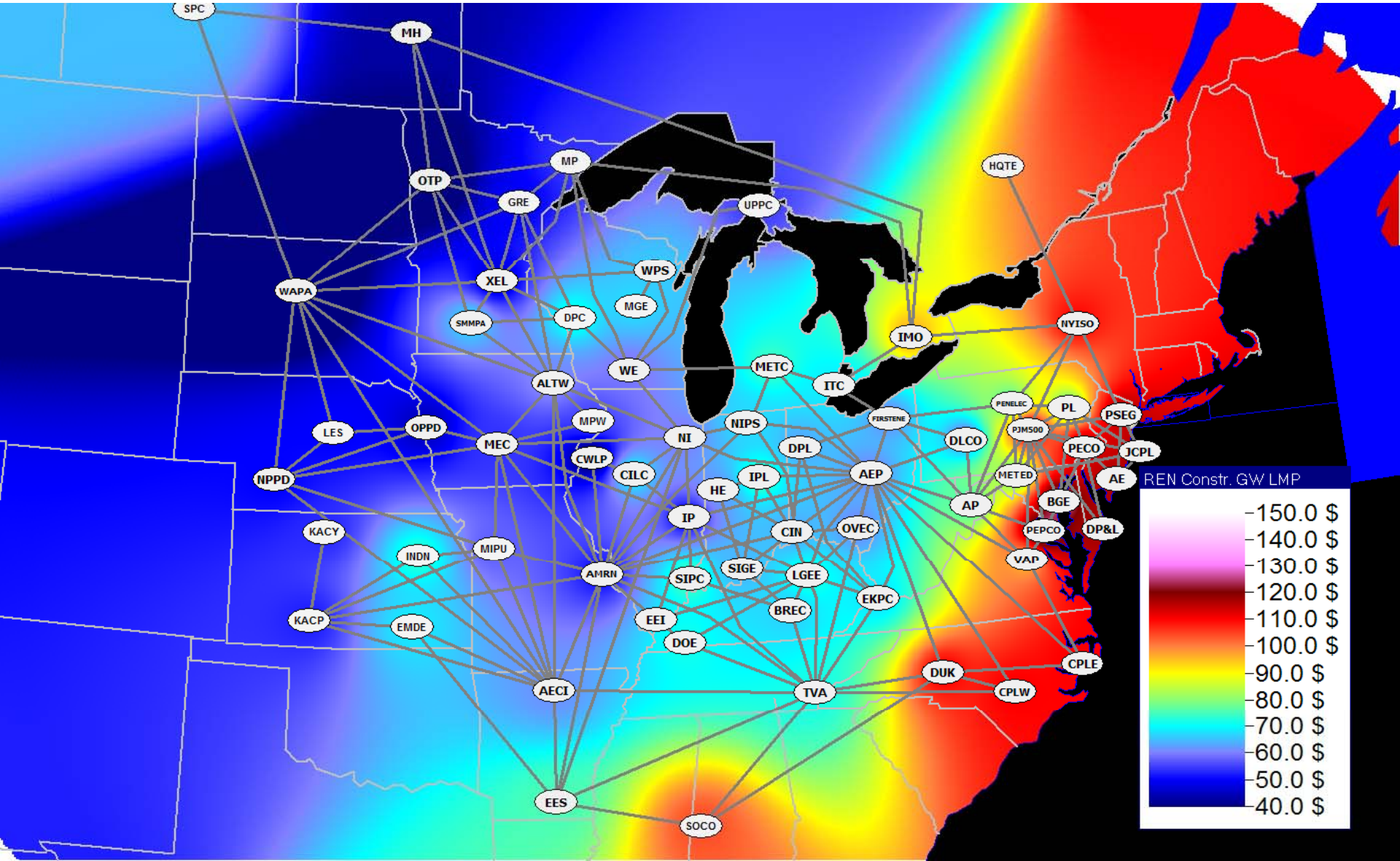
Remaining Congestion With Transmission Expansion



Full Constrained Case
with EI Annual Gen Weighted LMP



Full Constrained Case
Annual Gen Weighted LMP



Cost and Benefit Comparison (All in 2021 $) EI Overlay

		EI	B/C Ratio
	10 year NPV costs (M$)	APC 10 year NPV Savings (M$)	
Reference	34,102	40,167	1.18
Renewable	51,039	56,280	1.10
Environmental	36,441	32,094	0.88
Fuel	37,086	60,525	1.63

Top Binding Constraints – EI Overlay

Top 10 Binding Constraints outside of MISO	Total Binding Hours	Total Shadow Price (k$/MW)	Area
01DOUBS 20459 01AQUEDT 20456 330	4881	3043.8	PJM
01DOUBS 20105 01DOUBS 20459 1	1354	2581.14	PJM
NEWROAD6 50403 6W.NROAD 98414 1	4866	2214.78	SPP
PLAT T#1 79593 WILLIS E 79595 1	8035	1556.87	NYISO
MED-LDG3 58773 MED-LDG4 58774 1	3305	1522.73	SPP
WHITPAIN 15 WHITPAN3 4601 1	2026	1454.97	PJM
MANOR 3071 MILLWOOD 3104 363	1132	1259.23	PJM
NIAGAR2W 79592 PA27 REG 81516 1	4538	1057.59	NYISO-IMO
CRAIGJT4 54015 ASHWEST4 53226 19	4956	957.17	SPP
INTERFACE ISONE - CAPITAL 10 1	8435	861.17	ISONE

Top 10 Binding Constraints in MISO	Total Binding Hours	Total Shadow Price (k$/MW)	Area
MT VRNON 32328 ASHLEY 32334 216	1861	873.72	IP
CENTER 3 66791 JAMESTN3 63369 1	1451	494.92	OTP
PR ISLD3 60105 REDROCK3 60236 209	5783	445.83	NSP
08WHITST 25380 16GUION 27821 255	2026	362.59	PSI-IPL
CENTER 4 66751 HESKETT4 67342 1	910	288.29	OTP-MDU
QUAD ; 36382 ROCK CK3 34036 1	2384	222.66	ALTW-COED
QUAD ; 36382 ROCK CK3 34036 273	3251	195.78	ALTW-COED
EASTDALE 33307 E SPFLD 33158 197	687	142.32	AMREN
DUCK CRK 33161 IPAVA 30788 1	755	119.53	AMREN
MNVLTAP4 60150 GRANITF4 66550 1	279	113.52	NSP-WAPA

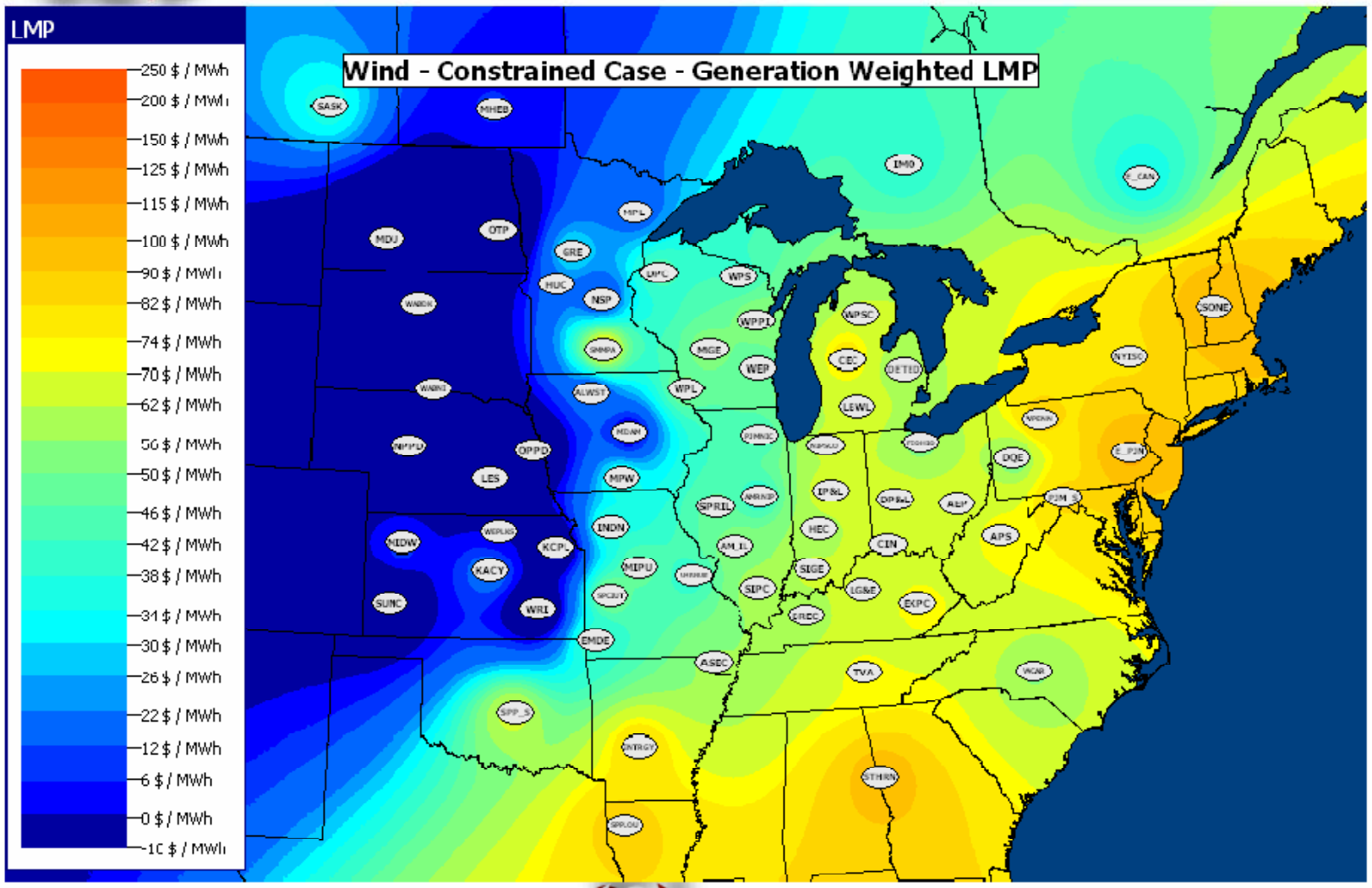
Conclusion

- A process has been implemented that produces transmission expansion conceptual plans that appear to be economically supportable from benefits derived from the existing energy markets.
- A transmission system for a 20% wind energy for the MISO footprint was developed.

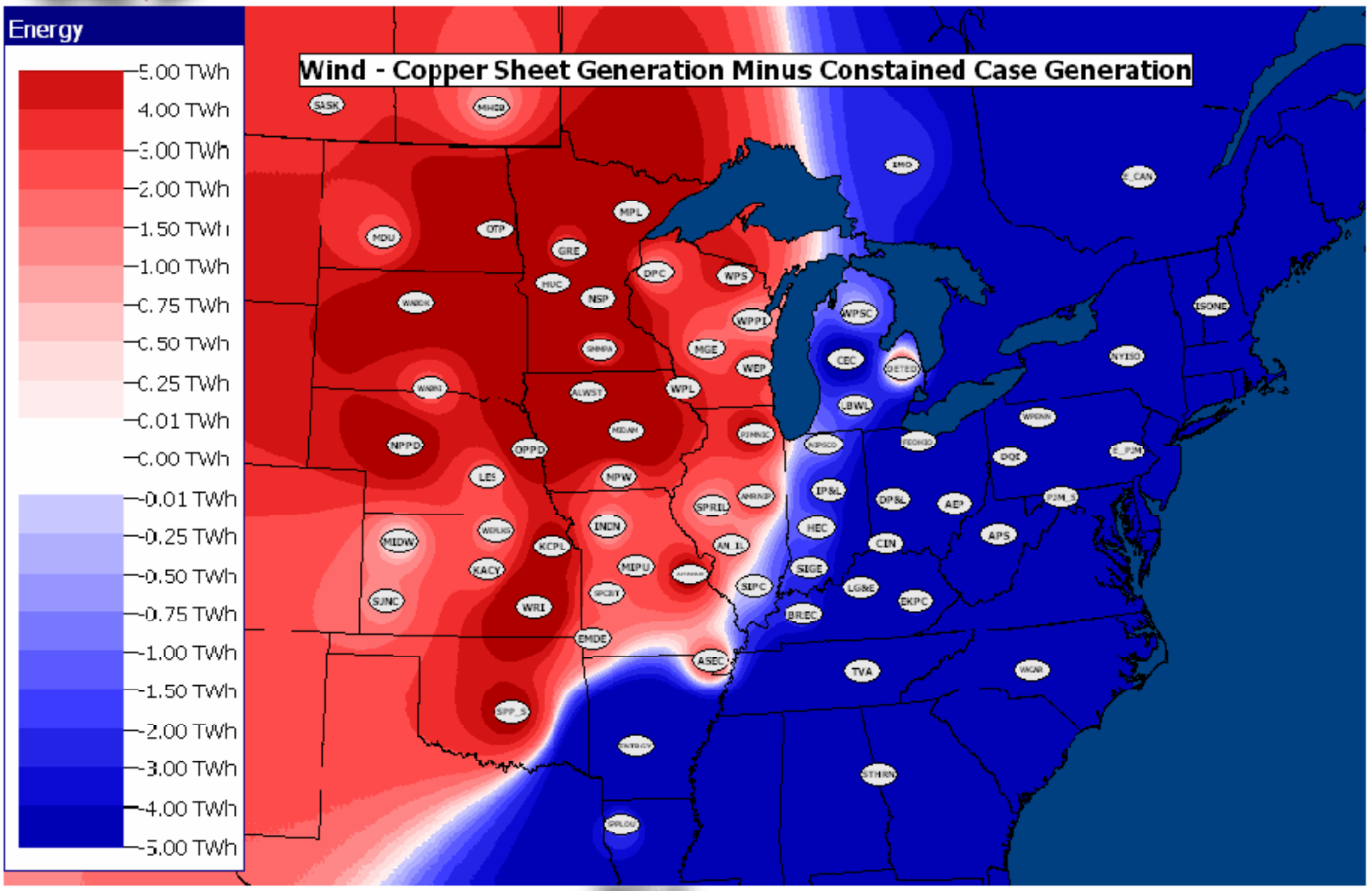
Four Modes of Wind Energy Cost Considerations

- Wind penetration less than 10%-local-local- business as usual
  - Local Wind generation delivering to local load
  - Local utility pays for the capital costs and the transmission
  - Generation is curtailed for constraints
- Wind penetration between 10% and 13%
  - Local generation to mandates and transmission to obtain ancillary services to control the load- MISO is entering this stage.
- Wind level greater than 13% with mandates
  - Transmission is built to export the surplus to the highest priced markets
  - This is the JCSP work
- Wind levels beyond local mandates for the supply area- 20% nationally
  - Remote generation, delivered by transmission under contract
  - Receiver pays for the
    - Capital cost of wind generation
    - Transmission to deliver
    - About an 11% (30% vs 41%) capacity factor difference will pay for the transmission from South Dakota to New Jersey.

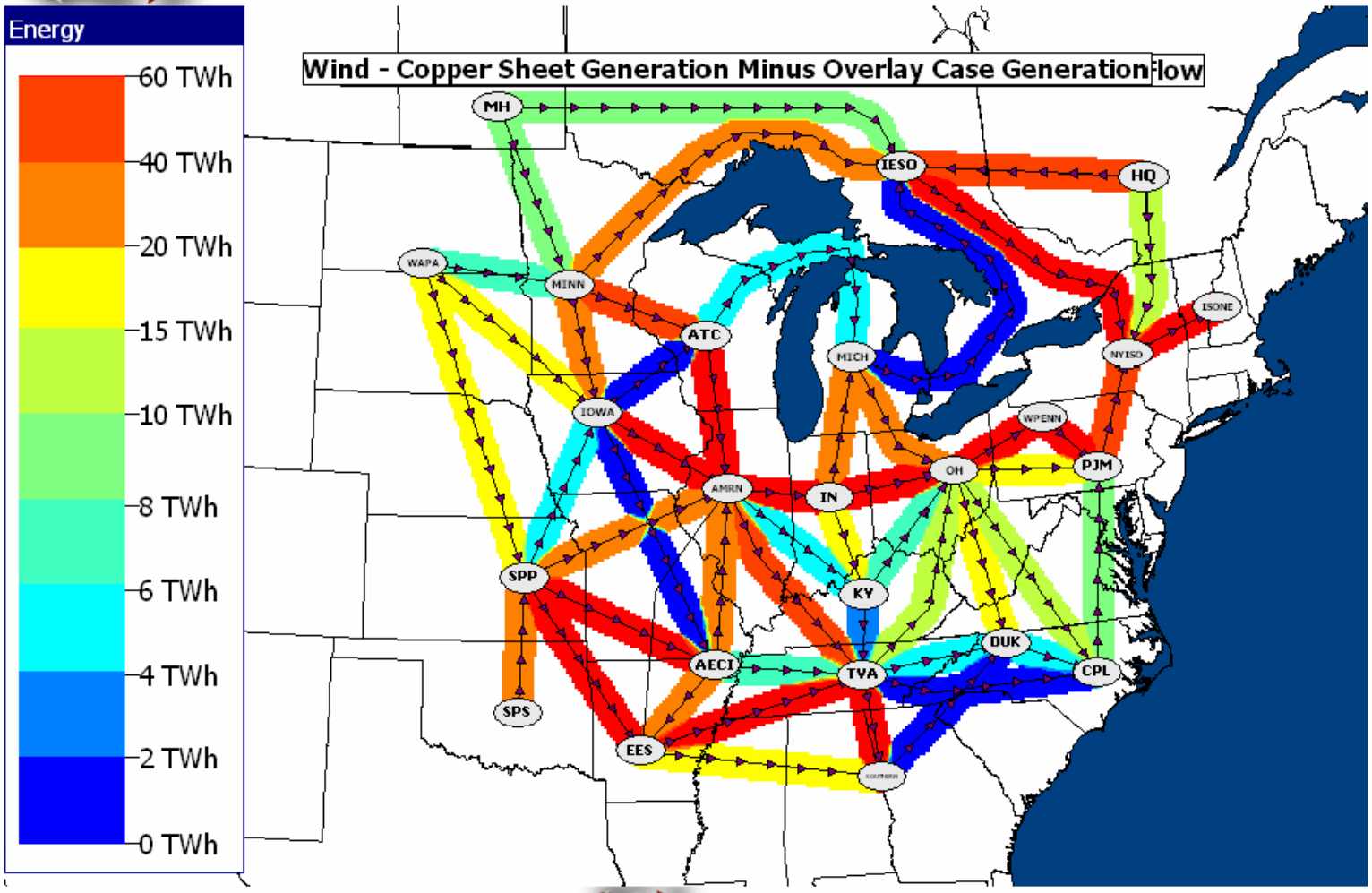
20% Wind Full Constrained Case Annual Gen Weighted LMP



20% Wind Generation Difference: Full Copper Sheet and Full Constrained Cases



20% Wind Interface Contour: Annual Energy Difference
Full Copper Sheet to Full Constrained Case



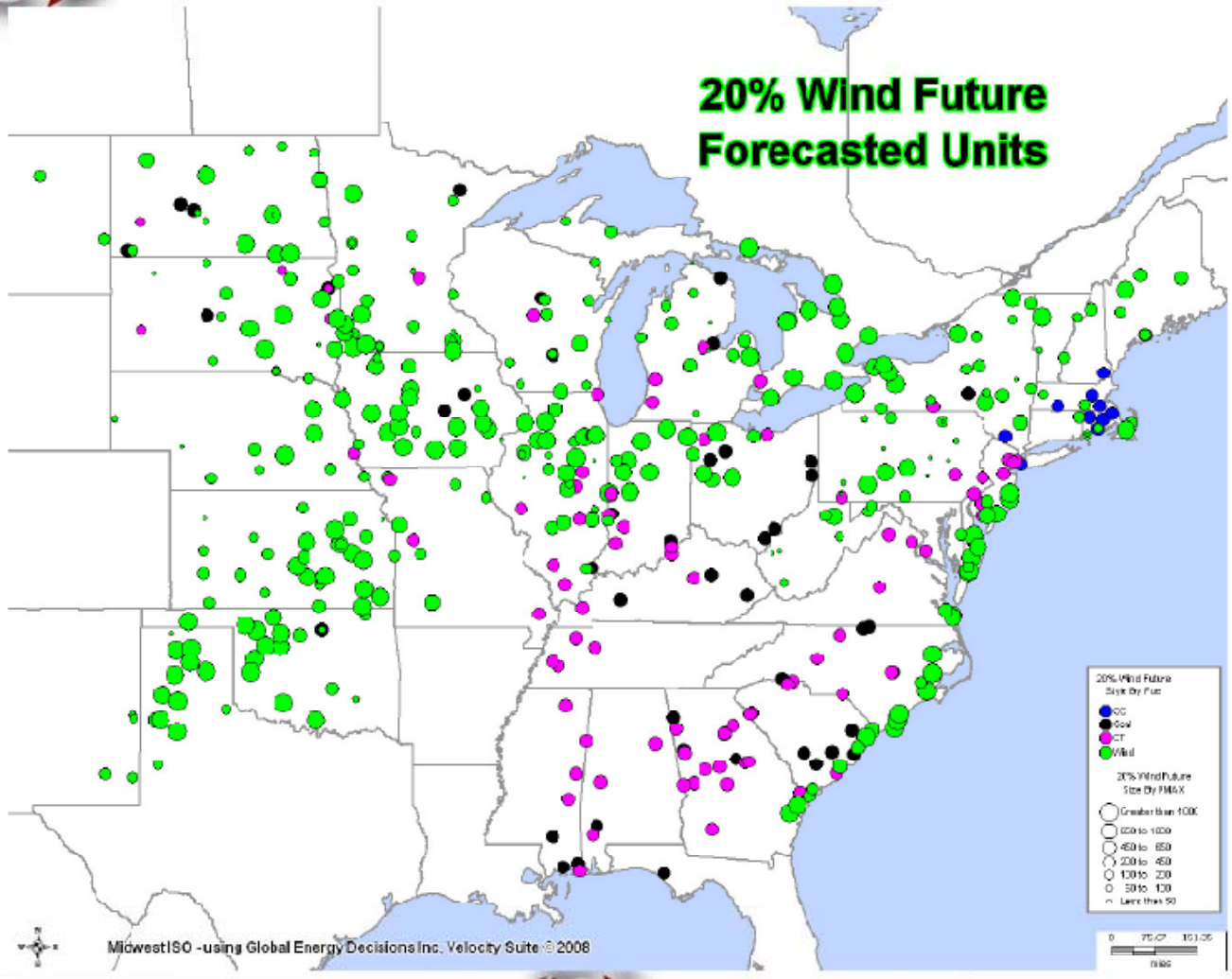
20% Wind Top 25 Interfaces with biggest Energy Difference

Top	INTERFACE	Total Positive Energy (TWh)	Total Negative Energy (TWh)	Average Energy (GWh)	80% CAP (MW)
1	AMRN - IN	235	0	27	26878
2	IN - OH	177	0	20	19334
3	OH - WPENN	129	0	15	13942
4	SPP - EES	107	0	12	12567
5	AMRN - IOWA	0	-106	-12	12204
6	WPENN - PJM	111	0	13	11891
7	ISONE - NYISO	0	-88	-10	10331
8	TVA - EES	0	-75	-9	9472
9	SOUTHERN - TVA	0	-82	-9	8860
10	IESO - NYISO	69	0	8	8678
11	NYISO - PJM	5	-55	-6	8430
12	ATC - AMRN	69	0	8	8068

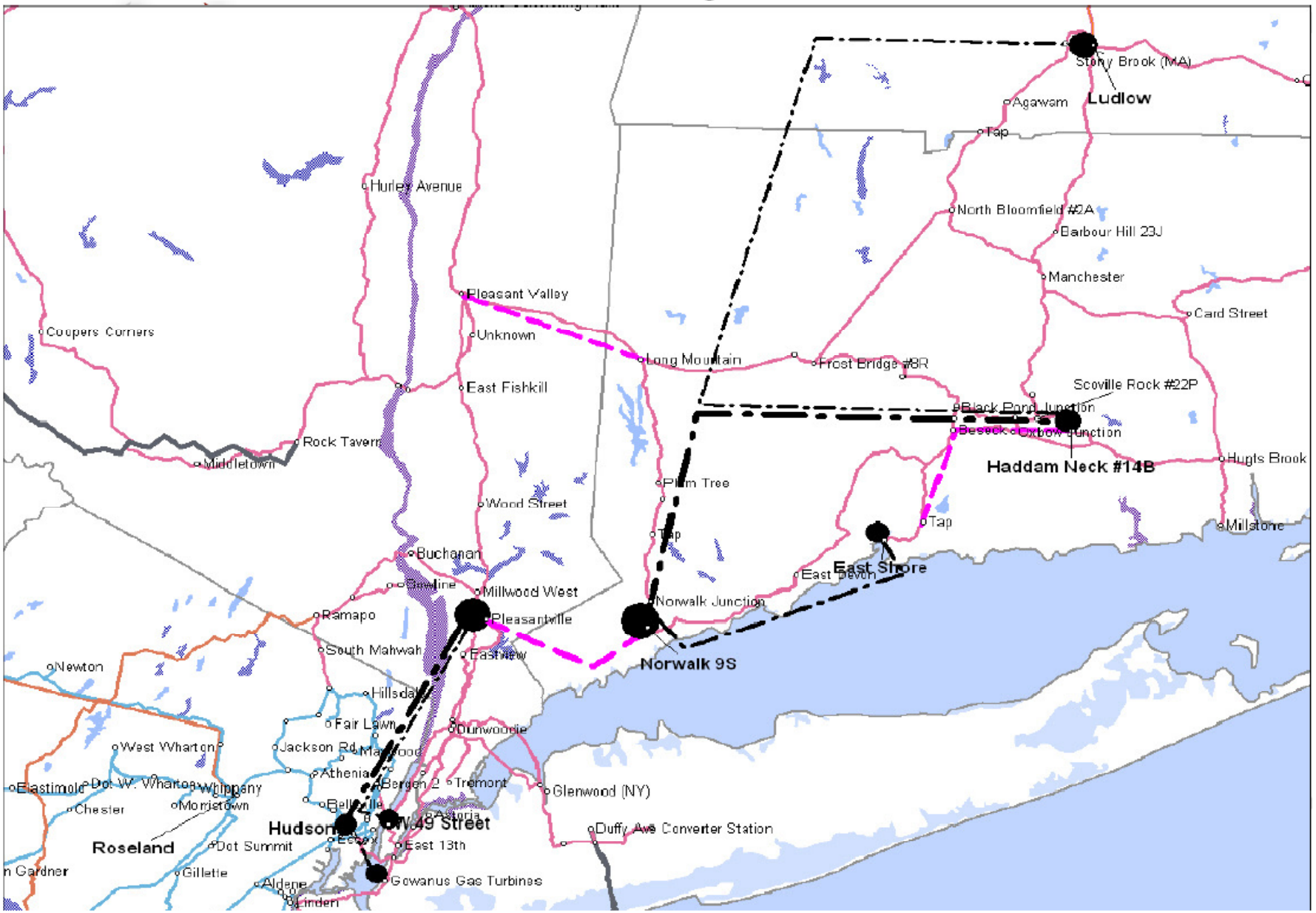
20% Wind Annual Economic Information

	Net Generation Revenue Increase(M$)	Adj. Production Cost Saving (M$)	Load Cost Saving (M$)
Whole EI	-12,905	24,045	52,402
MISO	4,623	269	-4,987
PJM	-14,967	5,585	27,446
MRO	5,186	-2,136	-7,659
NYISO	-746	4,459	8,903
SERC	-13,848	8,096	27,586
SPP	6,703	-2,930	-11,698
ISONE	-2,653	3,518	7,893
TVA	-3,926	1,481	5,248
E_CAN	4,795	4,470	752
IMO	1,927	1,235	-1,082

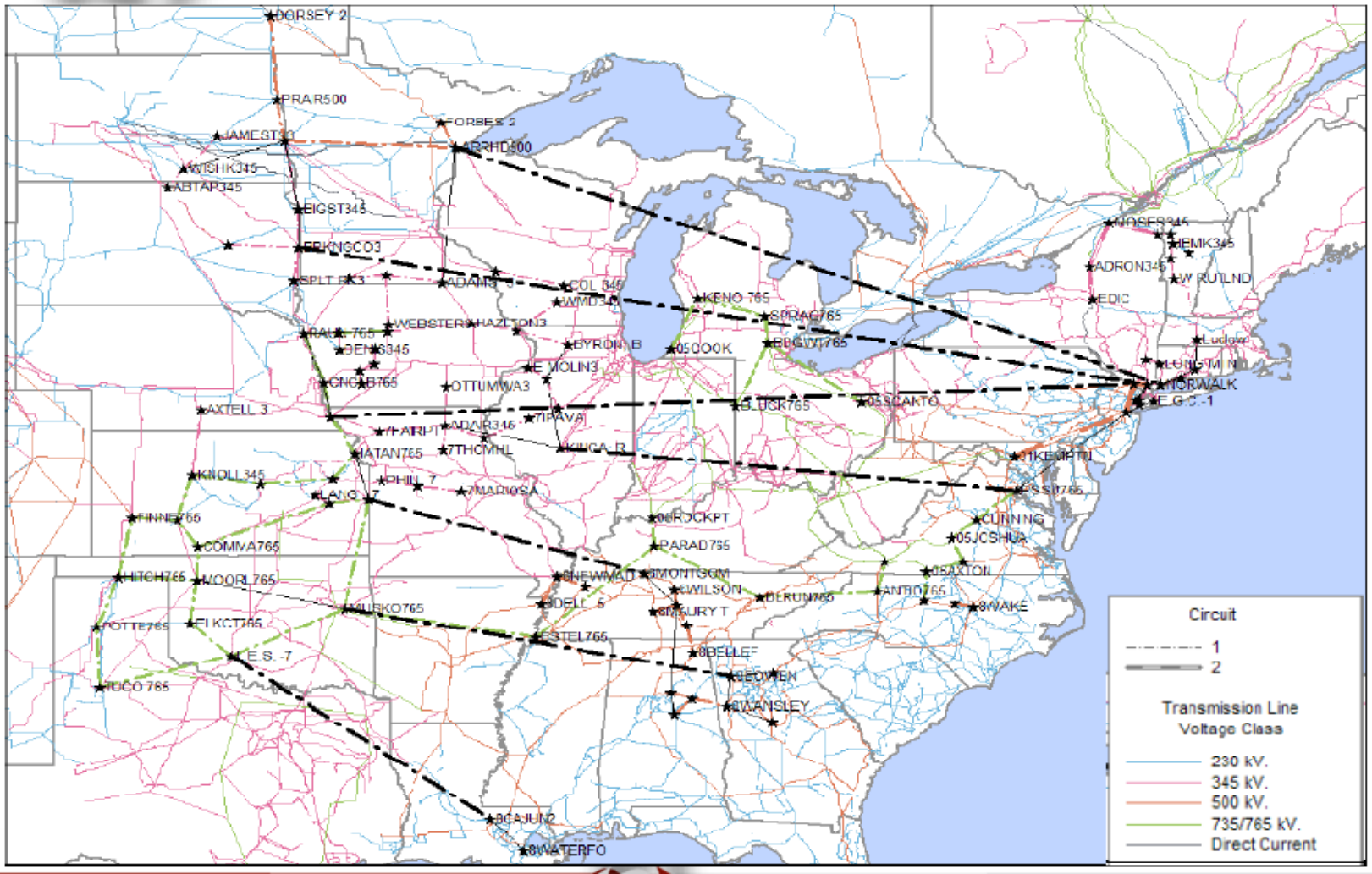
20% Wind Forecasted Units



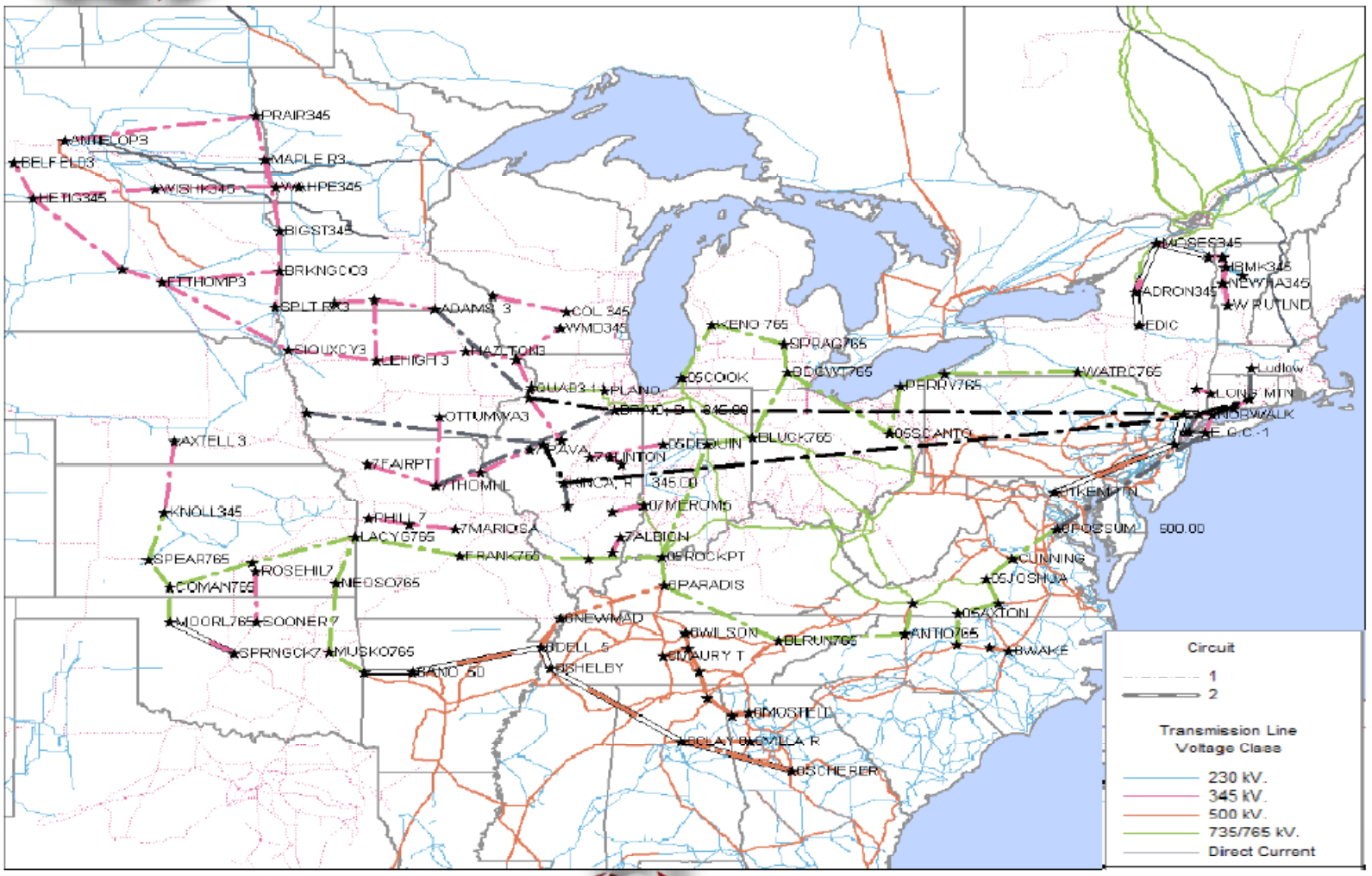
20% Wind Future DC Tie Design for ISONE and NYISO



20% Wind Scenario – Current Overlay



Reference Scenario – Current Overlay



Line Miles and Transmission Cost Assumptions in 2024$

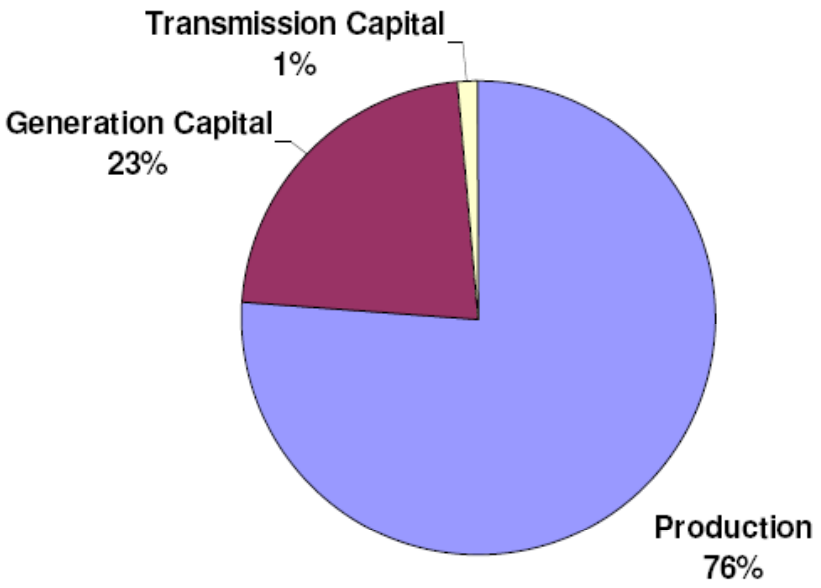
Cost per Mile Assumption							
	345 KV	(2) - 345 kV	500 KV	(2) - 500 kV	765 KV	DC - 400 kV	DC - 800 kV
2024$	2,250,000	3,750,000	2,875,000	4,792,000	5,125,000	3,800,000	6,000,000

Estimated Line Mileage Summary (Miles)								
	345 KV	(2) - 345 kV	500 KV	(2) - 500 kV	765 KV	DC - 400 kV	DC - 800 kV	Total
Reference	3,329	292	508	946	3,118	282	2,400	10,875
20% Wind	2,042	193	864	279	3,977	0	7,582	14,937

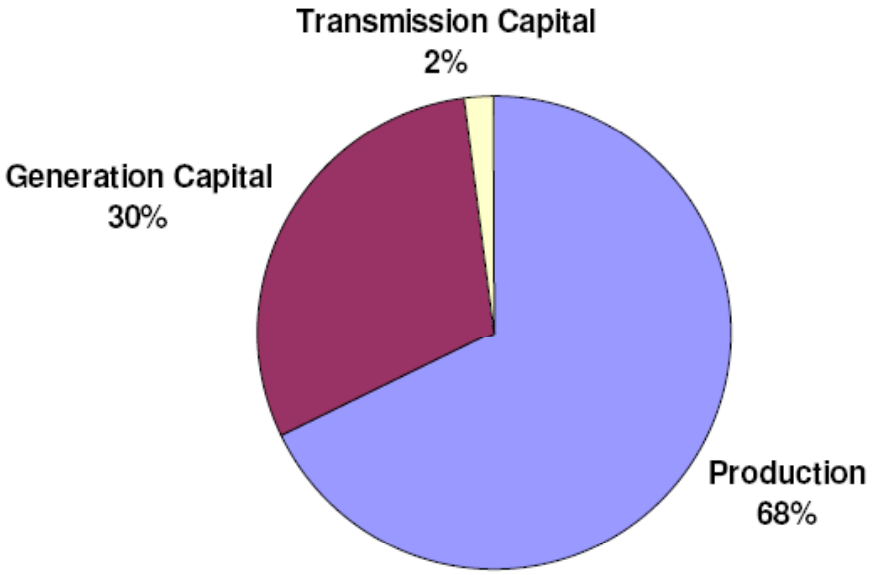
Estimated Cost Summary (Millions of 2024$)								
	345 KV	(2) - 345 kV	500 KV	(2) - 500 kV	765 KV	DC - 400 kV	DC - 800 kV	Total
Reference	9,363	1,371	1,825	5,668	19,975	1,698	14,400	54,298
20% Wind	5,742	905	3,106	1,671	25,478	0	45,492	82,394

Cost Perspective

Reference Future Cumulative Costs through 2024



20% Wind Future Cumulative Costs through 2024



B/C Ratio – Transmission Overlays

Cost and Benefit Comparison (2024$)			
	2024 Annual Transmission Cost	**2024 Adjusted Production Cost Savings**	**2024 Benefit/Cost Ratio**
Reference	8,145	10,029	1.23
20% Wind	12,359	11,082	0.9

Note:

1. Cost includes 25% additional cost to account for the transformer and substation costs, HVDC cost includes terminals, communications, and line costs.

2. Annual cost in 2024$ is calculated using 15% fixed charge rate.

3. APC (Adjusted production cost) savings is calculated by taking difference between overlay case and constrained case for whole East Interconnect footprint.

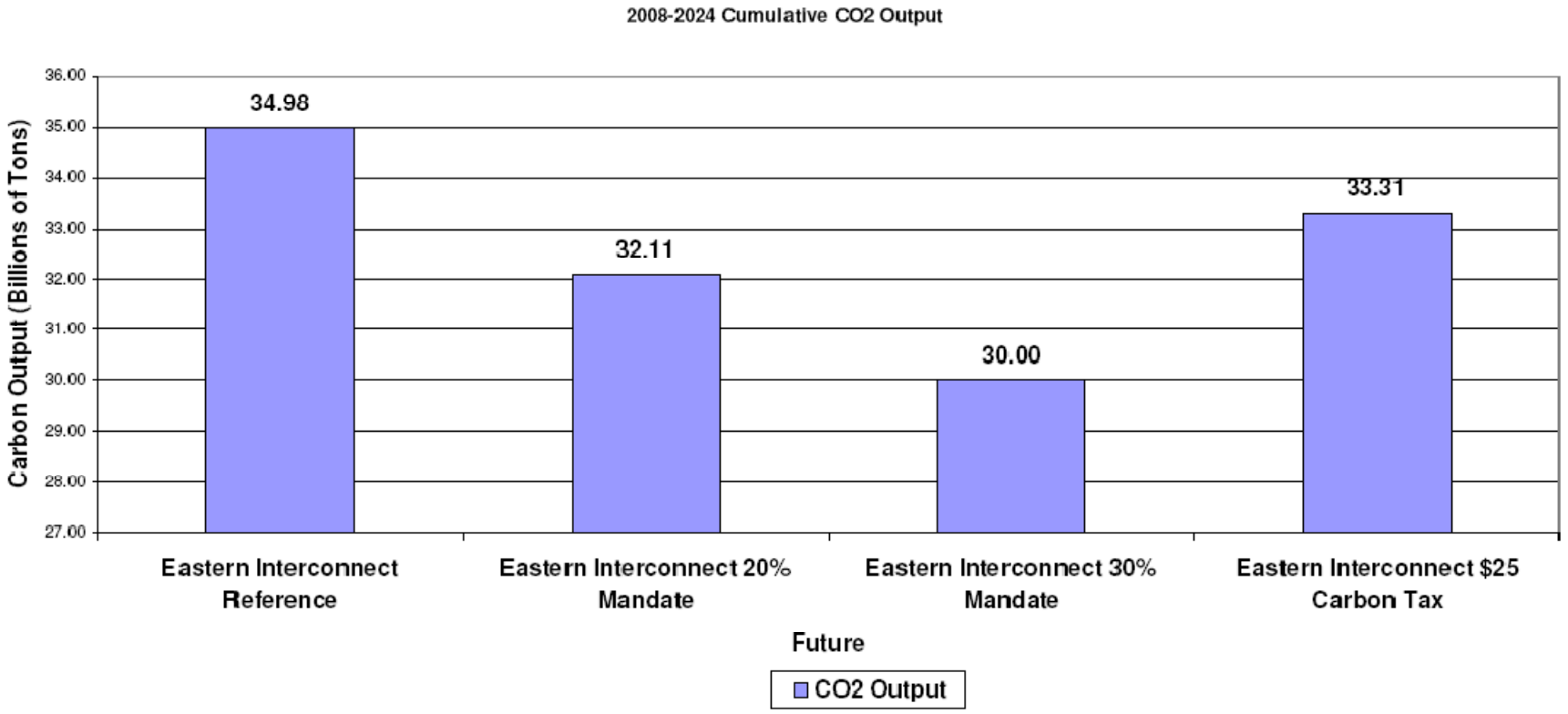
4. Adjusted Production Cost = Production Cost + Import * Load Weighted LMP (or) – Export * Generation Weighted LMP

5. Each value represents year **2024 only**.

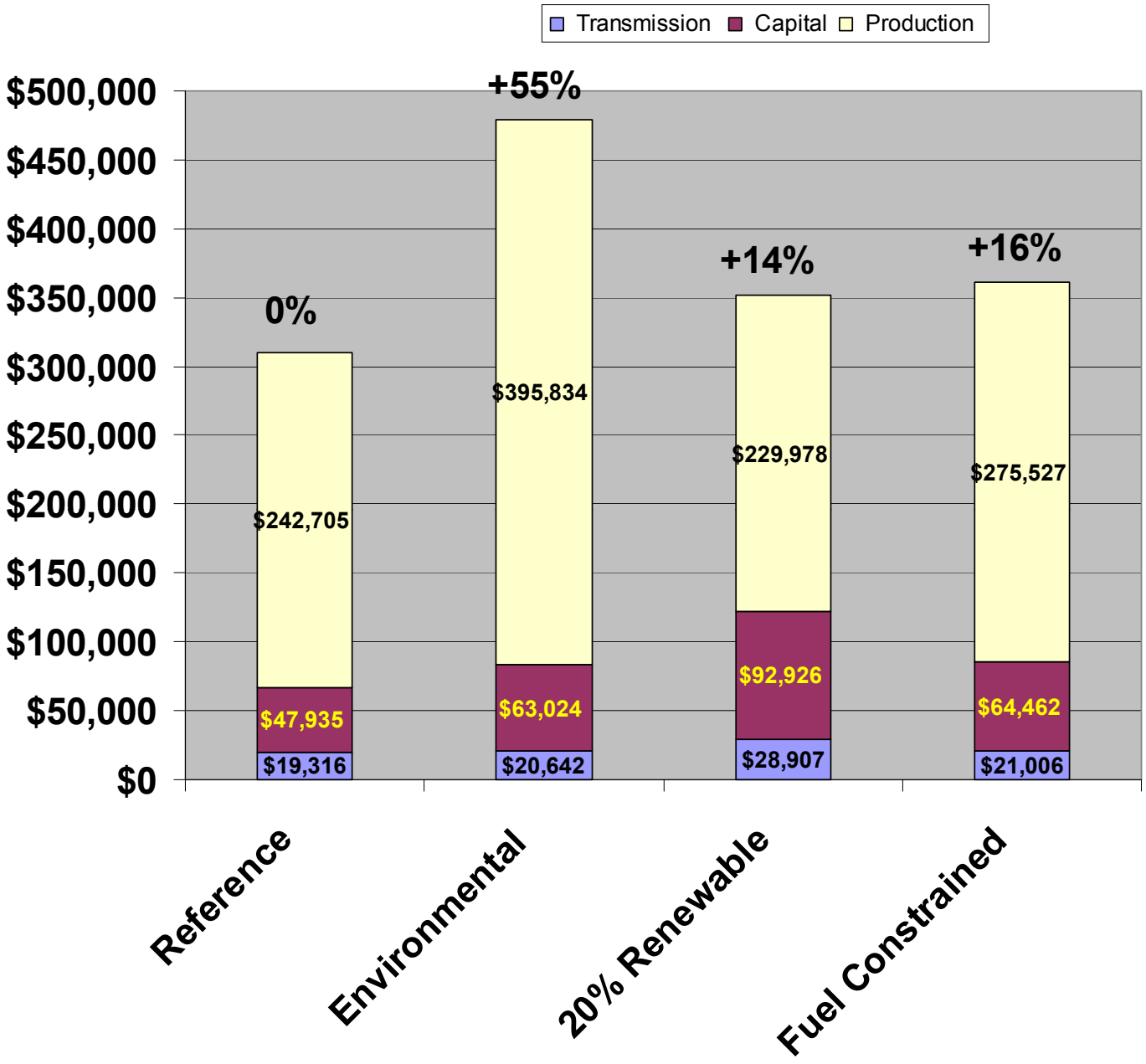
2024 Binding Constraints

Relief of Binding Constraints: Overlay case versus Constrained Case				
Binding Constraints	Reference Future		Wind Future	
	Numbers/ Hours Decrease	Shadow Price Decrease (k$/MW)	Numbers/ Hours Decrease	Shadow Price Decrease (k$/MW)
Total	74,893 (Hrs)	8,833	120,103 (Hrs)	164,149
Removed Binding Constraints	95	4,533	65	19,609
Improved Binding Constraints	187	11,662	231	175,508
New Binding Constraints	49	-1,896	50	-254
Worsened Binding Constraints	111	-5,466	138	-30,714

Estimated CO2 Implications by Defined Scenario



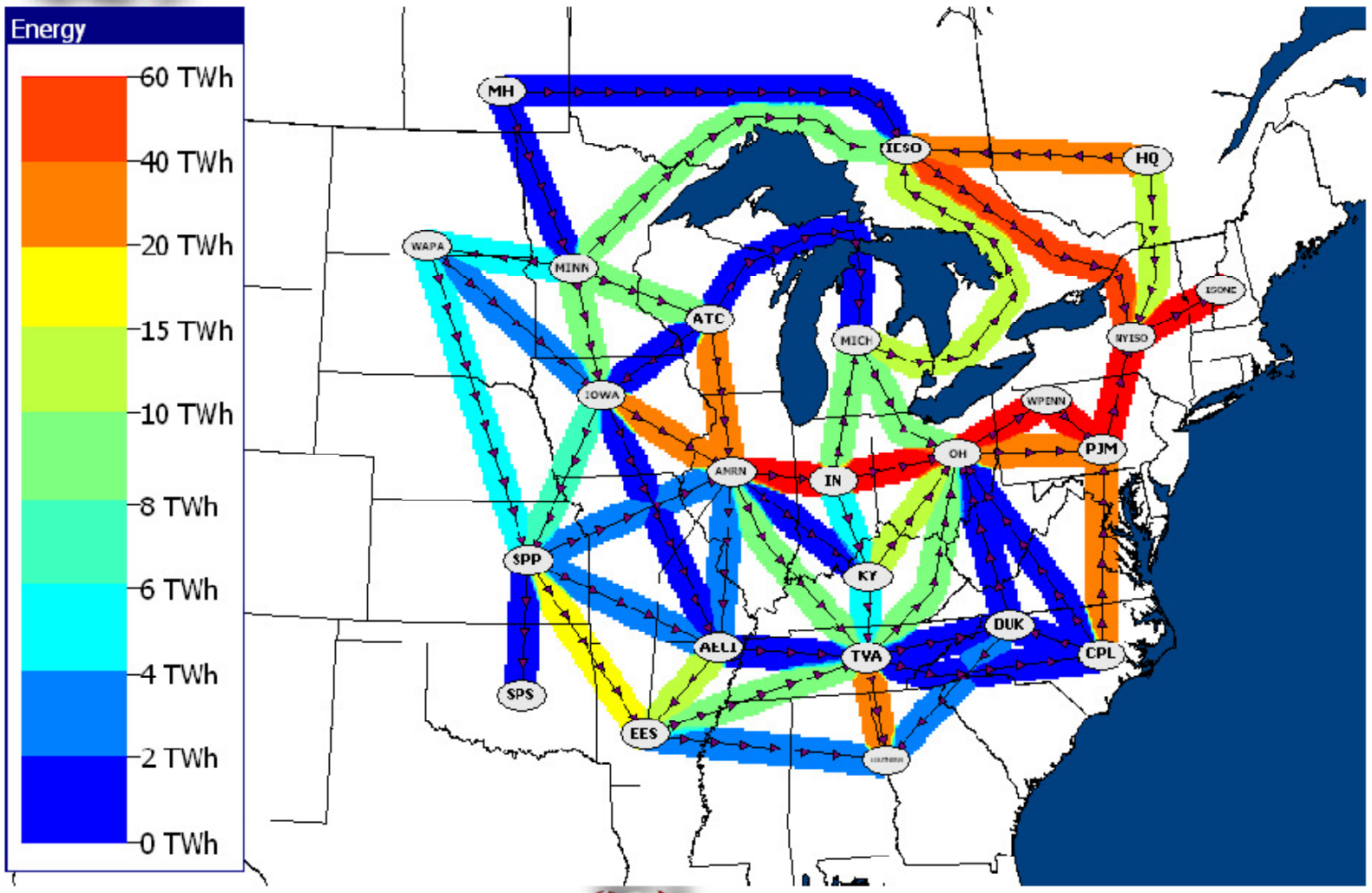
Note: Information provided from the Midwest ISO Transmission Expansion Plan Process


Transmission
Capital
Production
$500,000
$450,000
$400,000
$350,000
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$0
0%
+55%
+14%
+16%
$242,705
$47,935
$19,316
$395,834
$63,024
$20,642
$229,978
$92,926
$28,907
$275,527
$64,462
$21,006
Reference
Environmental
20% Renewable
Fuel Constrained

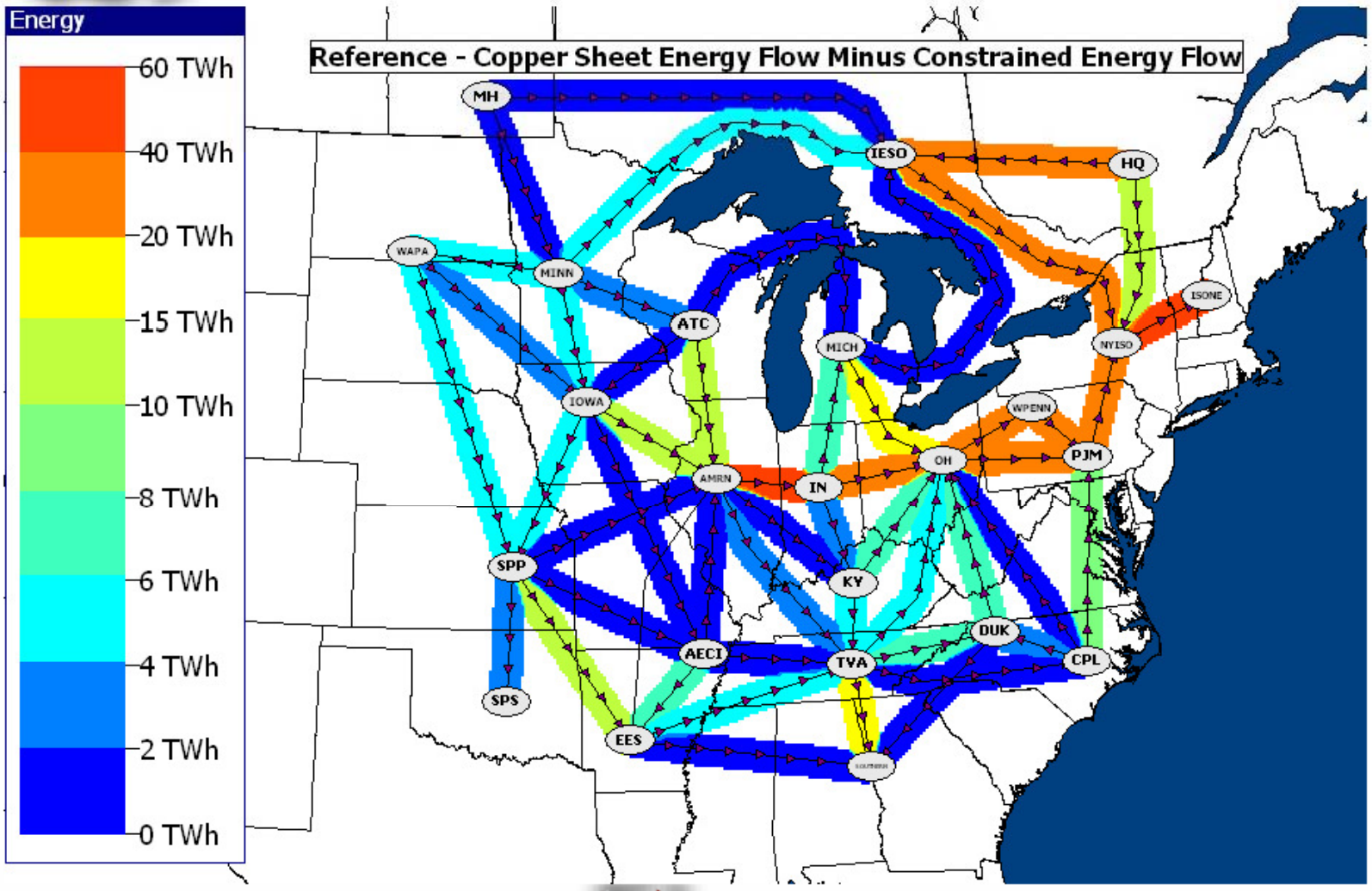
Reference Scenario - Top 20 Interfaces with Largest Annual Energy Difference

INTERFACE (From Area-To Area)	Coppersheet Minus Constrained (Pre-Overlay)			Coppersheet Minus Constrained (Overlay)		
	Total Positive Energy (TWh)	Total Negative Energy (TWh)	Additional Transfer Needed to Deliver 80% Energy (MW)	Total Positive Energy (TWh)	Total Negative Energy (TWh)	Additional Transfer Needed to Deliver 80% Energy (MW)
OH-E_PJM	115	0	12,031	61	-1	7,956
AMRN - IN	75	-1	9,434	41	-6	6,790
ISONE - NYISO	0	-71	9,158	2	-19	5,508
NYISO - E_PJM	2	-74	8,661	7	-31	5,239
IN - OH	69	0	8,143	31	-4	4,921
IESO - NYISO	42	-1	6,027	27	-5	4,664
IESO - HQ	8	-32	5,412	12	-32	5,422
SOUTHERN - TVA	0	-30	4,501	0	-20	3,993
MICH - IESO	19	-5	4,284	10	-11	3,340
PJM - CPL	0	-27	3,754	0	-9	1,780
AMRN - IOWA	0	-18	2,693	2	-5	1,403
ATC - AMRN	18	0	2,631	10	-1	1,786
SPP - EES	17	0	2,585	13	0	2,219
TVA - EES	2	-12	2,341	1	-7	1,606
TVA - KY	3	-8	2,158	1	-5	1,111
SOUTHERN - DUK	0	-6	2,054	0	-4	1,521
MICH - IN	2	-12	2,032	4	-9	1,906
ISONE - HQ	1	0	1,986	1	0	1,637
NYISO - HQ	0	-11	1,888	0	-9	1,688
OH - KY	1	-11	1,805	1	-6	1,221

Reference Interface Contour: Annual Energy Difference
Copper Sheet to Constrained Case

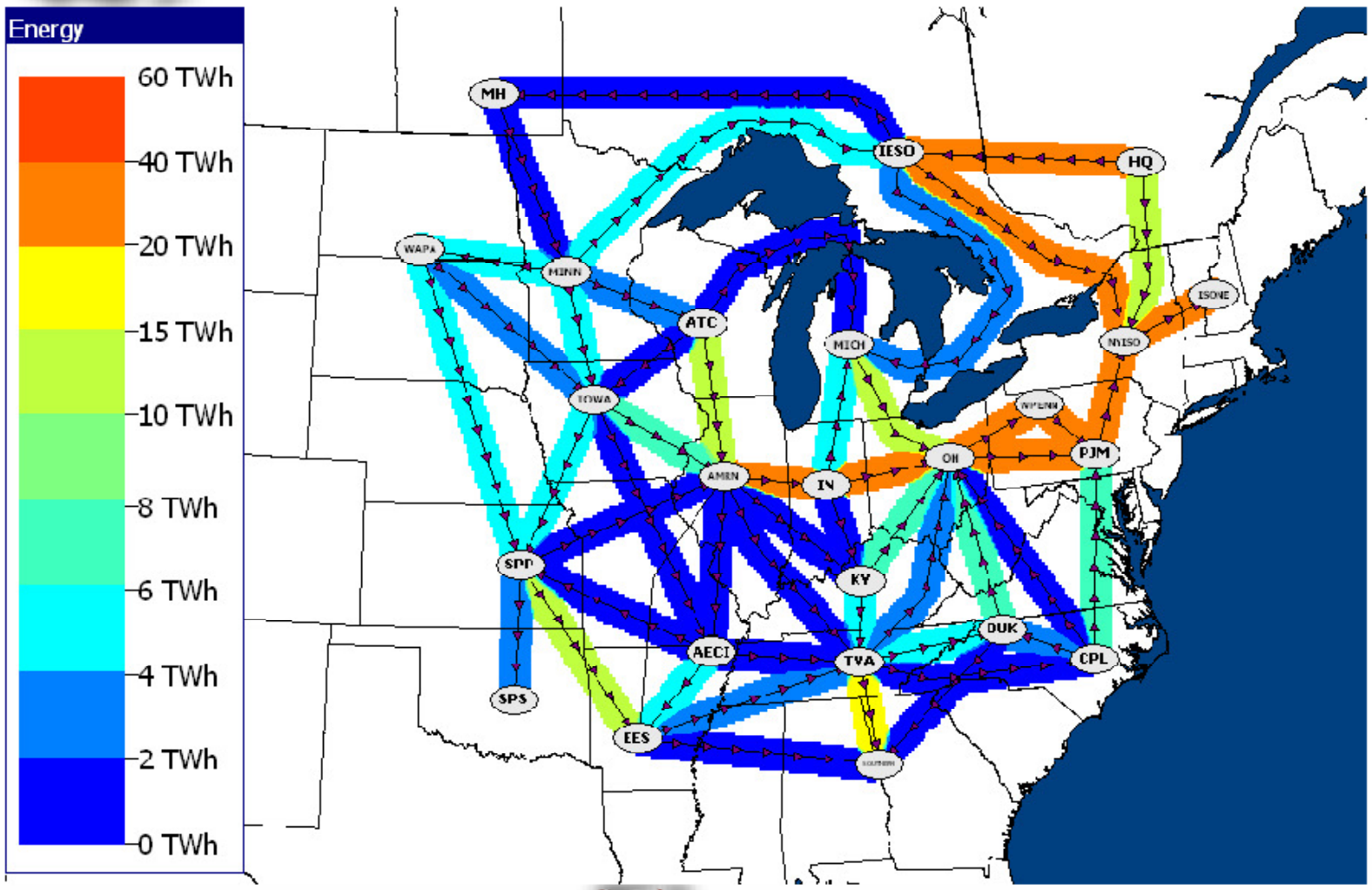


3 Reference Interface Contour: Annual Energy Difference Copper Sheet to Overlay Constrained Case with One West to East DC Line



4

Reference Interface Contour: Annual Energy Difference
Copper Sheet to Overlay Constrained Case with Two West to East DC Lines



B/C Ratio – Reference Transmission Overlays

Cost Summary Million ($)								
Reference	345kV	345kV (2)	500kV	500kV (2)	765kV	DC-400kV	DC-800kV	Total
Workshop	9,363	1,371	1,825	3,001	16,299	0	13,903	45,761
1st Round Changes	9,363	1,371	1,825	5,668	19,975	1,698	7,333	47,231
2nd Round Changes	9,363	1,371	1,825	5,668	19,975	1,698	14,400	54,298
3rd Round: Next workshop Inputs	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Cost and Benefit Comparison (2024 M$)			
Reference	**2024 Annual Transmission Cost**	**2024 Adjusted Production Cost Savings**	**2024 B/C ratio**
Workshop	6,864	7,138	1.04
1st Round Changes	7,085	8,285	1.17
2nd Round Changes	8,145	10,029	1.23
3rd Round: Next workshop Inputs	TBD	TBD	TBD

Note:

1. Cost includes 25% additional cost to account for the transformer and substation costs, HVDC cost includes terminals, communications, and line costs.
2. Annual cost in 2024$ is calculated using 15% FCR
3. APC (Adjusted production cost) savings is calculated by taking difference between overlay case and constrained case for whole East Interconnect footprint.
4. Adjusted Production Cost – Production Cost + Import * Load Weighted LMP (cr) – Export * Generation Weighted LMP
5. Each value represents year **2024 only**.