



Market Metrics for DOE Congestion Study Overview and Results

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Technical Workshop in Support of the DOE 2009 Congestion Study
Chicago, March 25 - 26, 2009



Trade Secret

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Topics

- Description of “Market” metrics
- Midwest ISO Specific, Market Data, Results, and Issues
- NYISO Specifics, Market Data, Results, and Issues
- PJM Specifics, Market Data, Results, and Issues
- ISONE Specifics, Market Data, Results, and Issues
- Observations and Conclusions



Main Market Metric Categories

- Congestion Frequency (number of hours transmission constraint was binding in 2007)
 - *Criterion: Non-zero constraint shadow price (SP)*
 - *Screening SP Threshold: 5% of Offer Cap (\$50/MWh)*
 - *Screening Frequency Threshold (20 hours/year); or top 50*
 - *Shadow Price "Bin" Break Points*
 - Negative Shadow Prices: -\$500/MWh, -\$200/MWh, and -\$50/MWh
 - Positive Shadow Prices: \$50/MWh, \$200/MWh, and \$500/MWh
- Congestion Rent (CR)
 - *Defined for Binding Constraints as Shadow Price * Flow (or Shadow Price * Constraint Limit)*
 - *Where Flow and/or Constraint Limit data were unavailable, Sum of Shadow Prices for the constraint over the period in question was used as surrogate instead*



Main Market Metric Categories (continued)

- Congestion Component of LMP (LMPCC)
 - *Screening LMPCC Threshold: 2% of Offer Cap (\$20/MWh)*
 - *Screening Frequency Threshold (20 hours/year); or top 50*
 - *LMPCC "Bin" Break Points*
 - *Negative LMPCC: -\$20/MWh, -\$40/MWh, -\$100/MWh*
 - *Positive LMPCC: \$20/MWh, \$40/MWh, \$100/MWh*
- Markets: Day-Ahead (primary for NYISO, PJM, and ISONE); Real-time (primary for MISO)
- Temporal Breakdown
 - *MISO: Annual (peak; off-peak; all hours); February (peak); April (off-peak); August (peak); October (peak; off-peak)*
 - *NYISO: Annual (peak; off-peak; all hours); January (peak); April (peak); August (peak); October (peak; off-peak)*
 - *PJM: Annual (peak; off-peak; all hours); February (peak); May (off-peak); August (peak); October (off-peak), December (peak)*
 - *ISONE: Annual (peak; off-peak; all hours)*



Data Requirements and Availability

- Shadow Prices
 - *Binding Constraint Shadow Prices (public)*
 - *Markets*
 - Day-Ahead
 - Real-Time
- Flows and/or Constraint Limits (for Computation of Congestion Rents)
 - *NYISO , PJM, and SONE*
 - Unavailable for internal binding constraints
 - Used sum of Shadow prices as a supplemental metric
 - *Midwest ISO*
 - “Commercial Flow” data (not publicly available) was provided to DOE/OATI for use in this study
 - Nevertheless Sum of Shadow Prices is reported here for consistency among markets analyzed



Data Requirements and Availability (continued)

- LMP Congestion Component (LMPCC)
 - *LMPs and LMP components available (public)*
 - Day-Ahead (hourly)
 - Real-Time (hourly average of 5-minute prices)
 - *PJM: No LMPCC data for January through May 2007. Used approximate back computation*
 - *Using LMP data only for specific Node Types to identify import-limited or export-limited "areas"*
 - Midwest ISO: Aggregates, Zones
 - New York ISO: Generators, Zones
 - PJM: Generators, Zones
 - ISONE: Network Nodes, Zones
 - *Clustering*
 - Manual clustering algorithm to combine nodes in each node type category based on proximity of LMPCCs
 - Need geographical coordinates if must show nodal LMPCC (clusters) on the map



Market Metrics Study Results for Midwest ISO



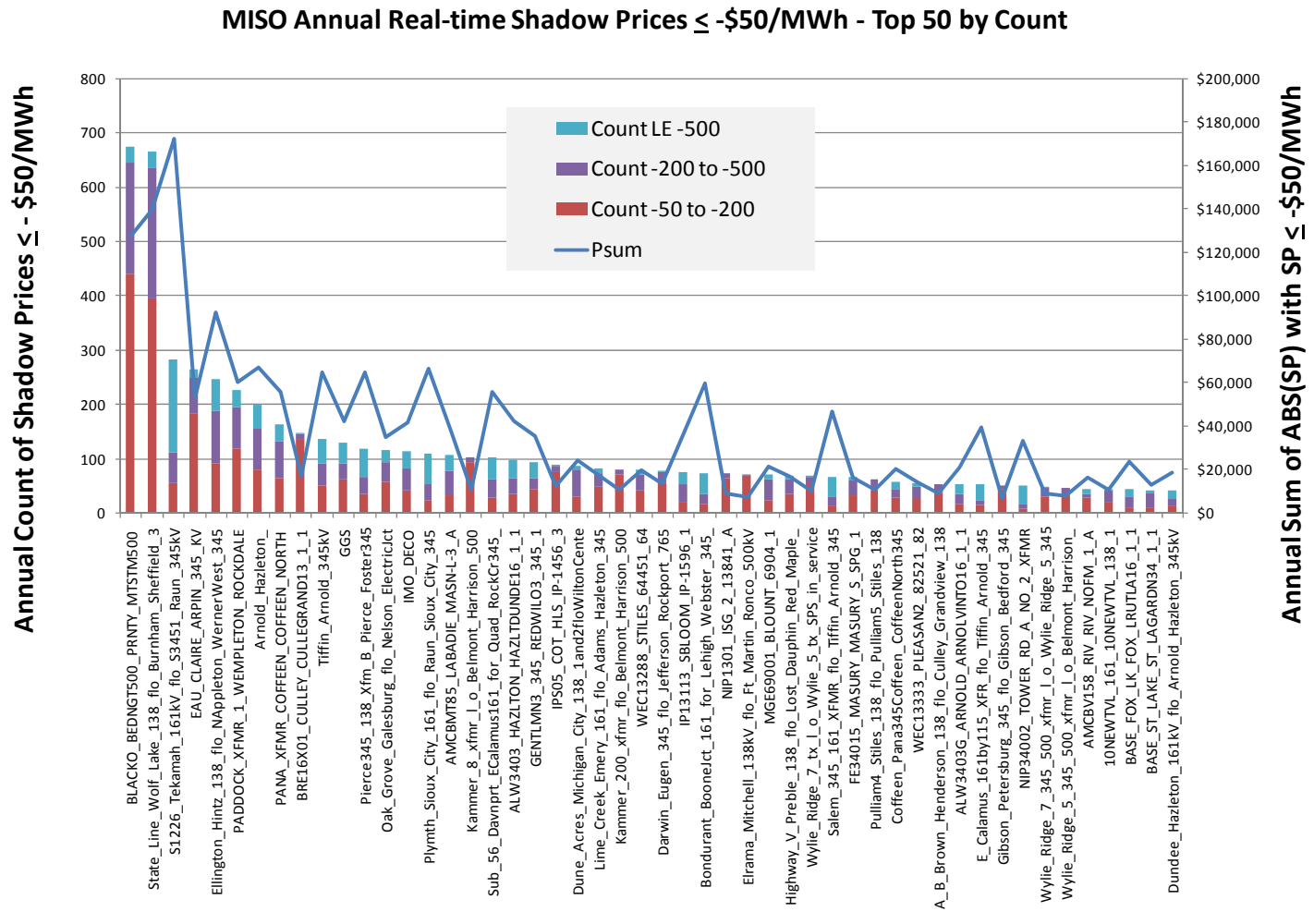
Summary Statistics - Top 25 Frequently Binding Constraints (Midwest ISO Real-Time Market; 2007)

Binding Constraints	Annual Count	Min SP	Max SP	Mean SP	Std Dev	Sum SP
BLACKO_BEDNGT500_PRNTY_MTSTM500	674	-\$970.28	-\$50.12	-\$189.03	\$136.68	-\$127,407
State_Line_Wolf_Lake_138_flo_Burnham_Sheffield_3	666	-\$1,262.98	-\$50.02	-\$208.99	\$149.90	-\$139,185
S1226_Tekamah_161kV_flo_S3451_Raun_345kV	284	-\$1,903.18	-\$50.98	-\$605.62	\$384.20	-\$171,995
EAU_CLAIRE_ARPIN_345_KV	265	-\$2,573.53	-\$50.43	-\$198.67	\$225.30	-\$52,648
Ellington_Hintz_138_flo_NAppleton_WernerWest_345	248	-\$1,964.27	-\$50.21	-\$372.11	\$329.02	-\$92,283
PADDOCK_XFMR_1_WEMPLETON_ROCKDALE	227	-\$1,620.05	-\$50.64	-\$264.04	\$245.99	-\$59,937
Arnold_Hazleton	199	-\$1,628.62	-\$50.46	-\$336.82	\$282.54	-\$67,027
PANA_XFMR_COFFEEN_COFFEEN_NORTH	163	-\$2,816.15	-\$53.47	-\$341.12	\$336.08	-\$55,603
BRE16X01_CULLEY_CULLEGRAND13_1_1	148	-\$501.75	-\$50.19	-\$113.50	\$60.63	-\$16,799
Tiffin_Arnold_345kV	136	-\$1,921.58	-\$52.28	-\$474.05	\$467.13	-\$64,471
GG5	130	-\$986.63	-\$50.39	-\$321.95	\$249.31	-\$41,853
Pierce345_138_Xfm_B_Pierce_Foster345	120	-\$2,226.64	-\$55.25	-\$537.31	\$466.78	-\$64,477
Oak_Grove_Galesburg_flo_Nelson_ElectricJct	117	-\$1,203.69	-\$50.65	-\$295.38	\$258.60	-\$34,559
IMO_DECO	114	-\$1,635.71	-\$50.04	-\$364.65	\$280.38	-\$41,570
Plymth_Sioux_City_161_flo_Raun_Sioux_City_345	109	-\$1,459.73	-\$58.37	-\$605.57	\$415.68	-\$66,007
AMCBMT85_LABADIE_MASN-L-3_A	107	-\$1,211.25	-\$50.79	-\$357.36	\$238.23	-\$38,237
Sub_56_Davnprt_ECalamus161_for_Quad_RockCr345	103	-\$2,220.05	-\$57.59	-\$541.74	\$478.54	-\$55,799
Kammer_8_xfmr_l_o_Belmont_Harrison_500	103	-\$399.89	-\$50.02	-\$103.03	\$61.50	-\$10,612
ALW3403_HAZLTON_HAZLTDUNDE16_1_1	99	-\$1,966.09	-\$64.65	-\$426.98	\$370.39	-\$42,271
GENTLMN3_345_REDWILO3_345_1	94	-\$1,360.80	-\$58.21	-\$373.21	\$335.84	-\$35,081
IPS05_COT_HLS_IP-1456_3	90	-\$545.05	-\$53.04	-\$136.35	\$97.99	-\$12,271
Dune_Acres_Michigan_City_138_1and2floWiltonCente	87	-\$742.28	-\$57.28	-\$279.62	\$158.78	-\$24,327
Lime_Creek_Emery_161_flo_Adams_Hazleton_345	83	-\$737.07	-\$53.70	-\$209.22	\$162.95	-\$17,365
Kammer_200_xfmr_flo_Belmont_Harrison_500	82	-\$497.68	-\$50.23	-\$127.91	\$80.56	-\$10,488
WEC13288_STILES_64451_64	80	-\$798.31	-\$50.46	-\$247.18	\$176.54	-\$19,774

Note: Not all constraints are in MISO footprint.



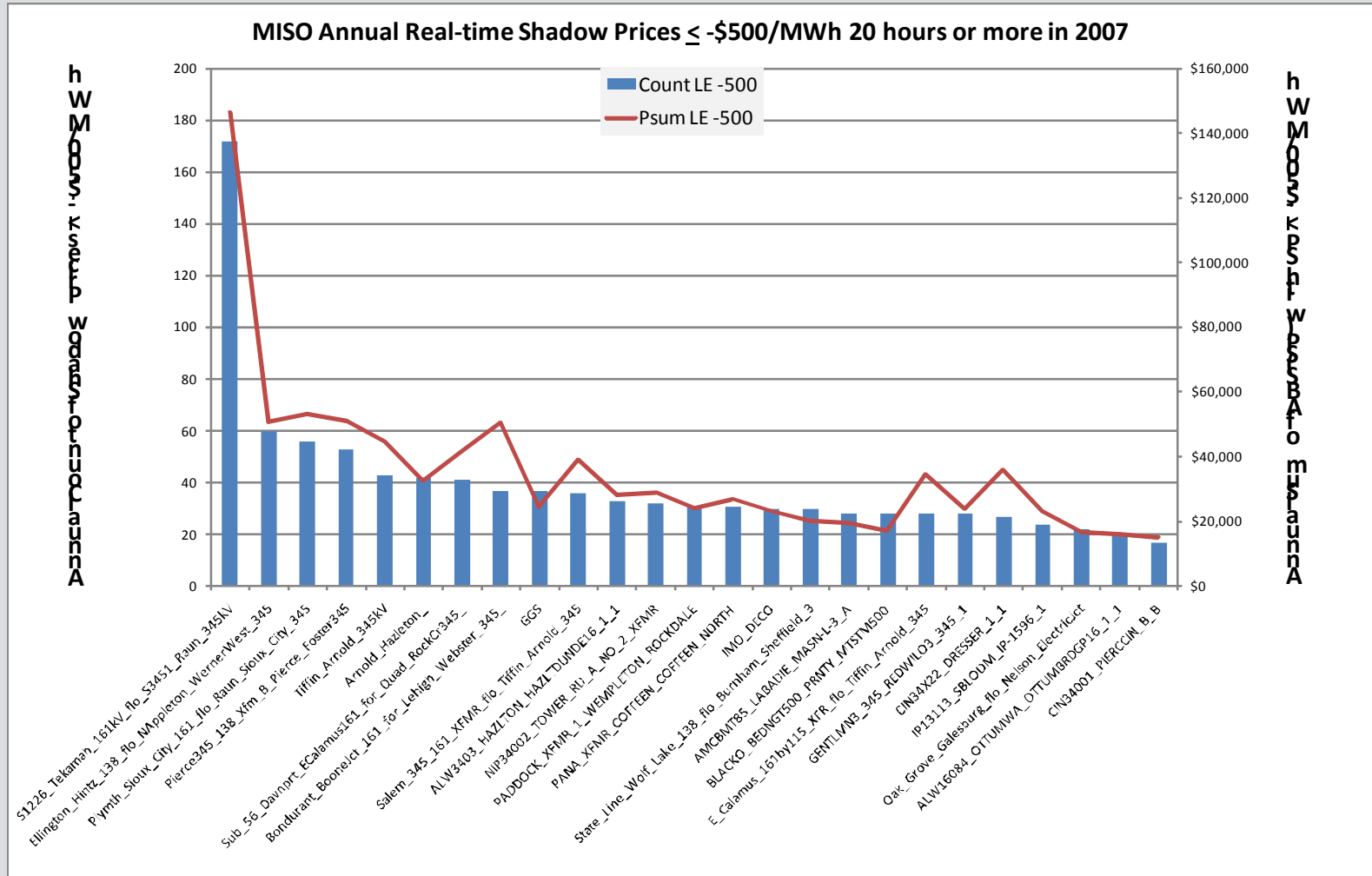
MISO - Top 50 Most Frequently Congested Constraints (RT Market; Annual : All hours)



Note: Not all constraints are in MISO footprint.



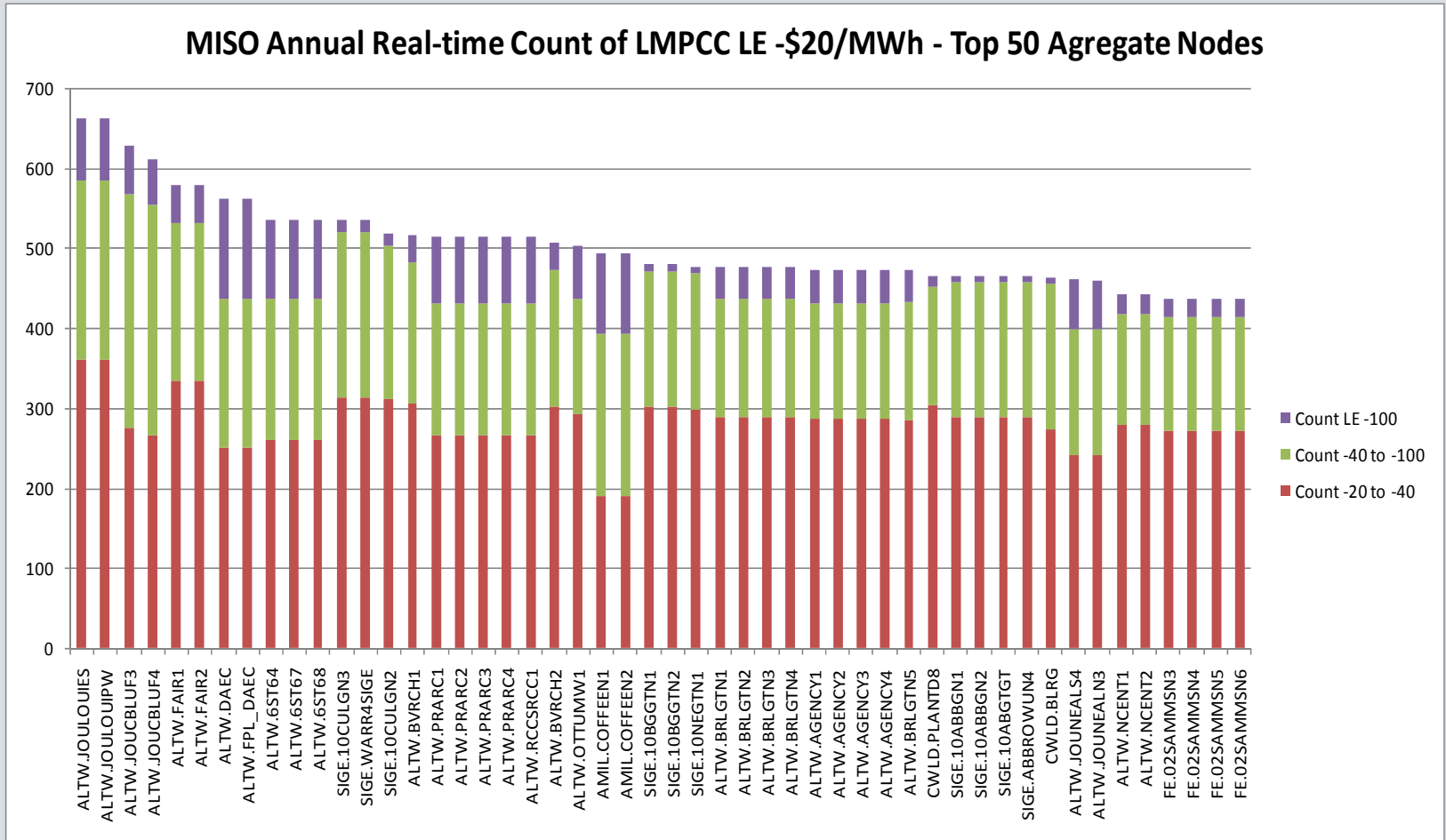
MISO - Count and Psum of Real-Time Shadow Prices with ABS(SP) ≥ \$500/MWh (Annual : All hours)



Note: Not all constraints are in MISO footprint.

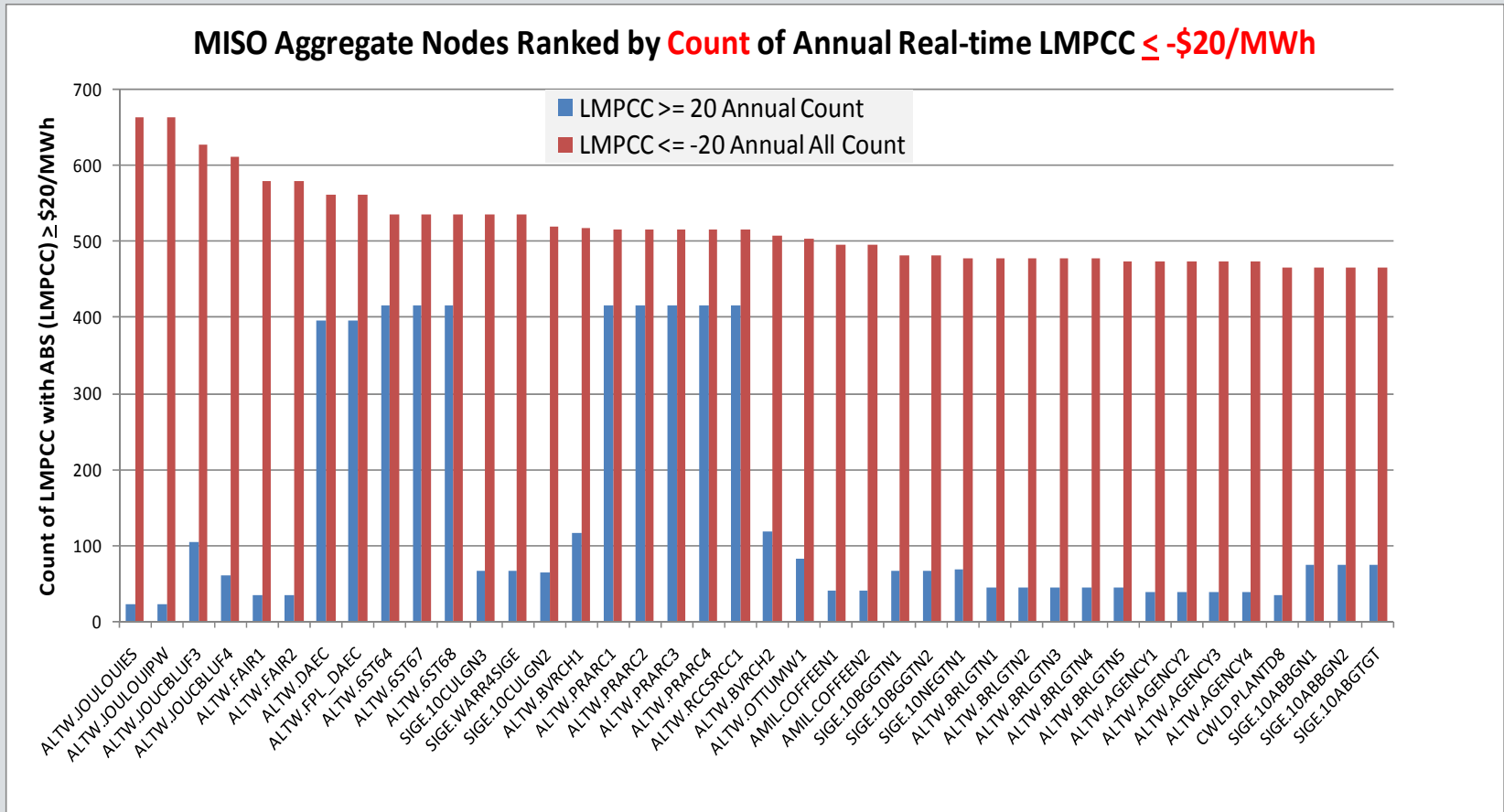


Top 50 Aggregate Nodes with Negative LMPCC (Annual; Real-Time; Count)





MISO Top 40 Aggregate Nodes Ranked by Negative LMPCC (Annual; Real-Time; Count)





Observations

- Shadow Prices
 - *MISO Real-Time Shadow Prices are Non-positive*
 - *There were quite a number of constraints with Shadow Prices exceeding \$500/MWh in magnitude for 20 hours or more during the year 2007*
- LMPCCs
 - *Some Aggregate Node LMPCCs show little change of sign during the year. They are either predominantly negative (in constrained-out areas) or positive (in constrained-in areas)*
 - *Some Aggregate Node LMPCCs do change sign substantially and may not be consistently labeled as constrained-in or constrained out*



Market Metrics Study Results for New York ISO



Specific Considerations for NYISO

- NYISO Shadow Price Data
 - *NYISO Day-ahead Shadow Prices are posted with mixed signs (positive and negative)*
 - *Negative Shadow Prices are due to misalignment of reference directions of constraints and flows*
 - *NYISO provided direction correction to align data*
- NYISO LMPCCs
 - *Often multiple generator nodes are electrically close (units in a power plant)*
 - *Performed pre-processing of generation nodes to retain only one generator from among those with the same first 6 characters in generator name for further analysis*



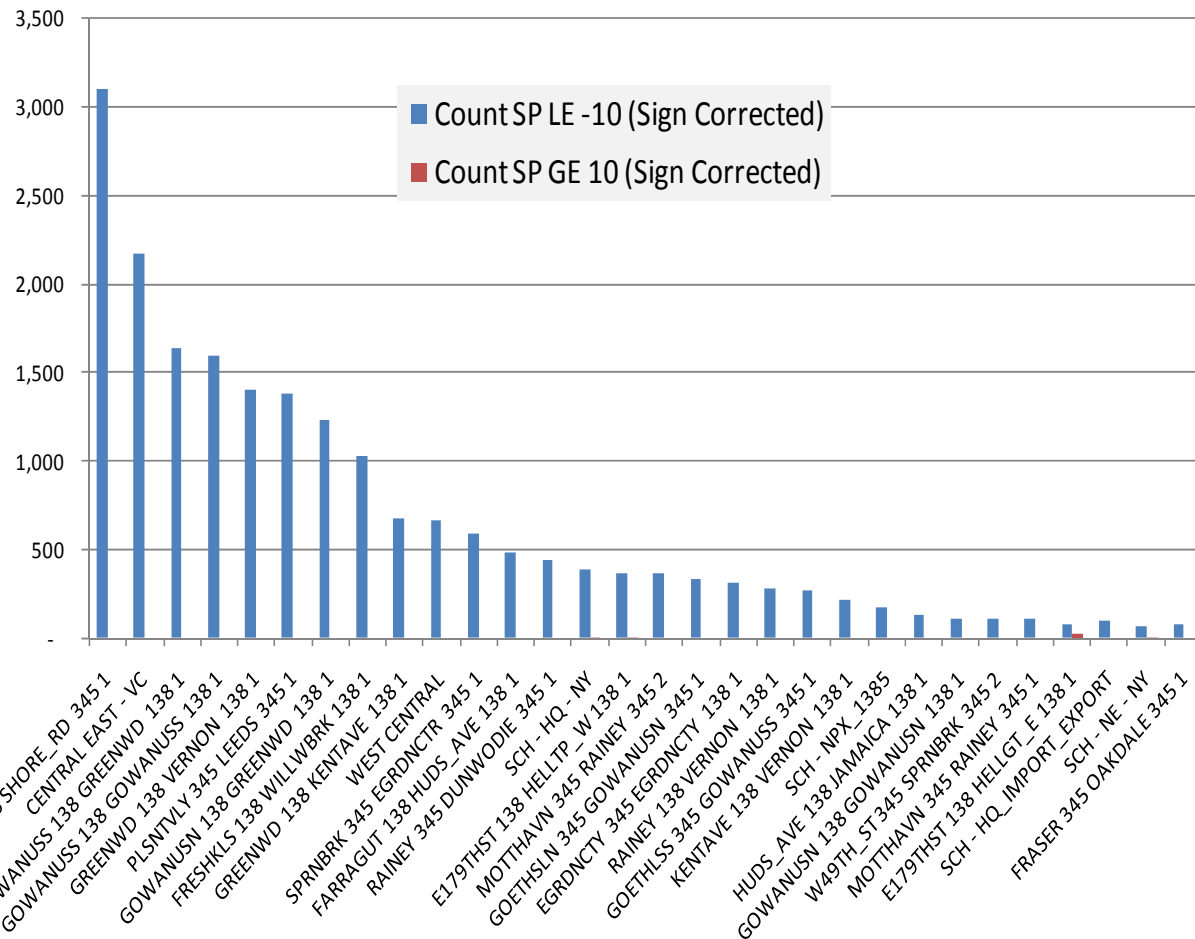
Summary Statistics - Top 25 (Count) Binding NYISO Day-Ahead Constraints in 2007 (no sign correction)

Binding Constraints	Annual Count	Min SP	Max SP	Mean SP	Std Dev	Sum SP
DUNWODIE 345 SHORE_RD 345 1	3091	\$10.00	\$239.10	\$25.29	\$16.30	\$78,167
CENTRAL EAST - VC	2163	\$10.00	\$109.29	\$31.27	\$19.19	\$67,629
GOWANUSS 138 GREENWD 138 1	1634	\$10.01	\$240.37	\$48.14	\$35.72	\$78,659
GOWANUSS 138 GOWANUSS 138 1	1594	-\$324.28	-\$10.00	-\$67.80	\$46.14	-\$108,073
GREENWD 138 VERNON 138 1	1400	-\$347.08	-\$10.03	-\$64.57	\$49.84	-\$90,396
PLSNTVLY 345 LEEDS 345 1	1373	-\$461.48	-\$10.03	-\$63.24	\$54.51	-\$86,821
GOWANUSN 138 GREENWD 138 1	1232	\$10.01	\$146.25	\$34.09	\$24.10	\$41,995
FRESHKLS 138 WILLWBRK 138 1	1021	\$10.02	\$790.99	\$82.63	\$65.73	\$84,364
GREENWD 138 KENTAVE 138 1	676	-\$336.13	-\$10.14	-\$68.40	\$61.19	-\$46,238
WEST CENTRAL	657	\$10.02	\$67.71	\$22.92	\$10.13	\$15,056
SPRNBK 345 EGRDNCTR 345 1	592	\$10.03	\$66.50	\$19.51	\$10.93	\$11,547
FARRAGUT 138 HUDS_AVE 138 1	483	-\$187.54	-\$10.02	-\$32.93	\$27.70	-\$15,906
RAINEY 345 DUNWODIE 345 1	435	-\$122.71	-\$10.08	-\$28.16	\$16.27	-\$12,248
SCH - HQ - NY	385	\$10.01	\$55.20	\$31.60	\$12.26	\$12,166
E179THST 138 HELLTP_W 138 1	365	\$10.04	\$143.57	\$19.42	\$11.34	\$7,087
MOTTHAVN 345 RAINEY 345 2	361	\$10.01	\$54.54	\$20.80	\$8.49	\$7,510
GOETHSLN 345 GOWANUSN 345 1	332	\$10.19	\$183.88	\$45.70	\$36.86	\$15,172
EGRDNCTY 345 EGRDNCTY 138 1	305	\$10.03	\$112.16	\$25.39	\$18.08	\$7,744
RAINEY 138 VERNON 138 1	276	\$10.26	\$143.56	\$24.53	\$16.13	\$6,770
GOETHLSS 345 GOWANUSS 345 1	266	\$10.02	\$396.55	\$43.82	\$41.24	\$11,655
KENTAVE 138 VERNON 138 1	213	-\$331.68	-\$10.40	-\$111.97	\$105.72	-\$23,849
SCH - NPX_1385	166	\$10.07	\$105.08	\$41.96	\$27.32	\$6,965
HUDS_AVE 138 JAMAICA 138 1	123	\$10.55	\$173.80	\$53.77	\$38.93	\$6,614
GOWANUSN 138 GOWANUSN 138 1	108	-\$477.36	-\$10.27	-\$82.07	\$98.30	-\$8,863
W49TH_ST 345 SPRNBK 345 2	106	-\$70.49	-\$10.30	-\$33.34	\$12.98	-\$3,534



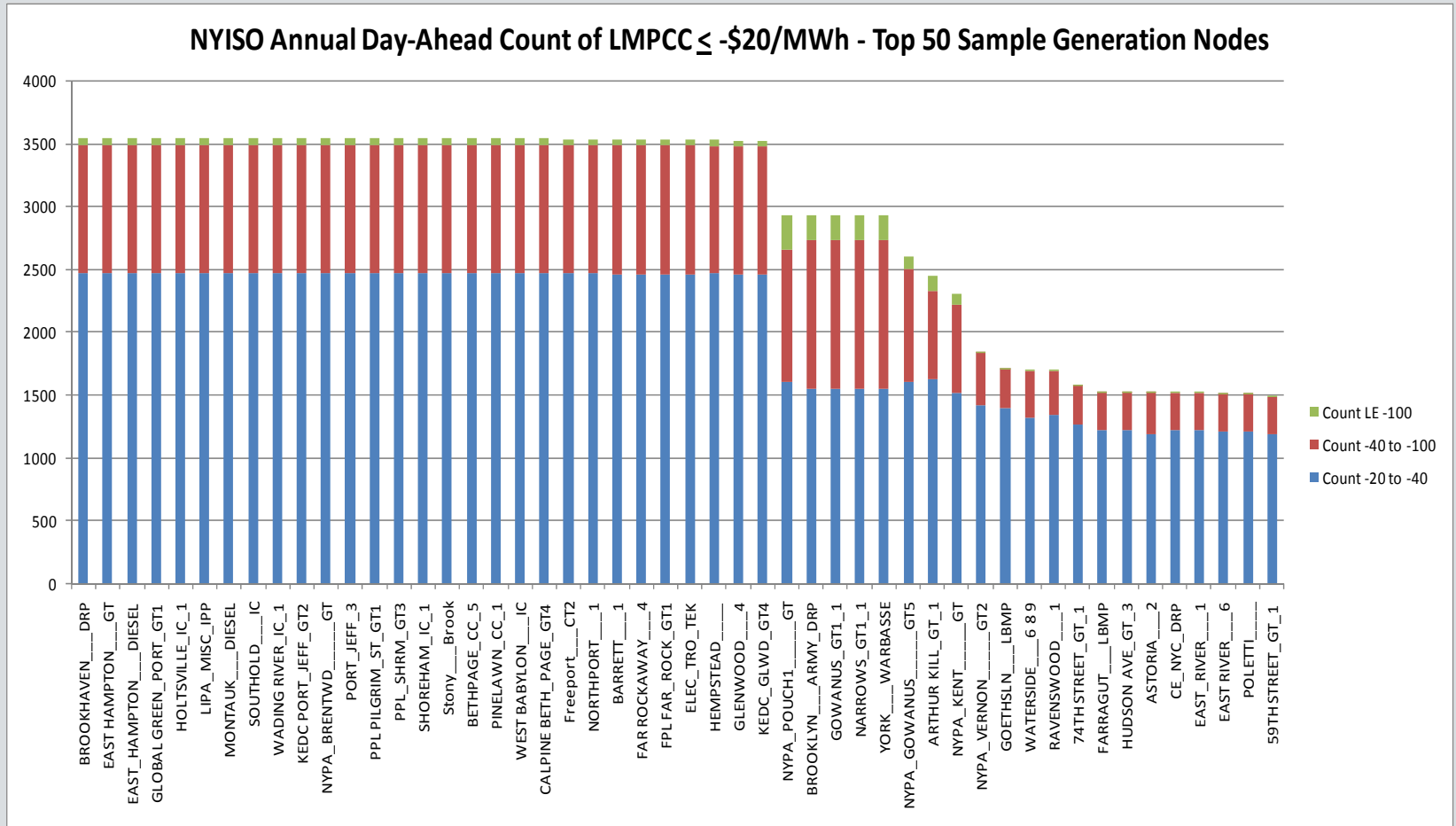
NYISO - Shadow Price Sign Reversal for Top 30 Day-Ahead Constraints with ABS(SP) > \$10/MWh

Top 30 NYISO Annual Day-Ahead Shadow Prices With ABS(SP) \geq \$10/MWh



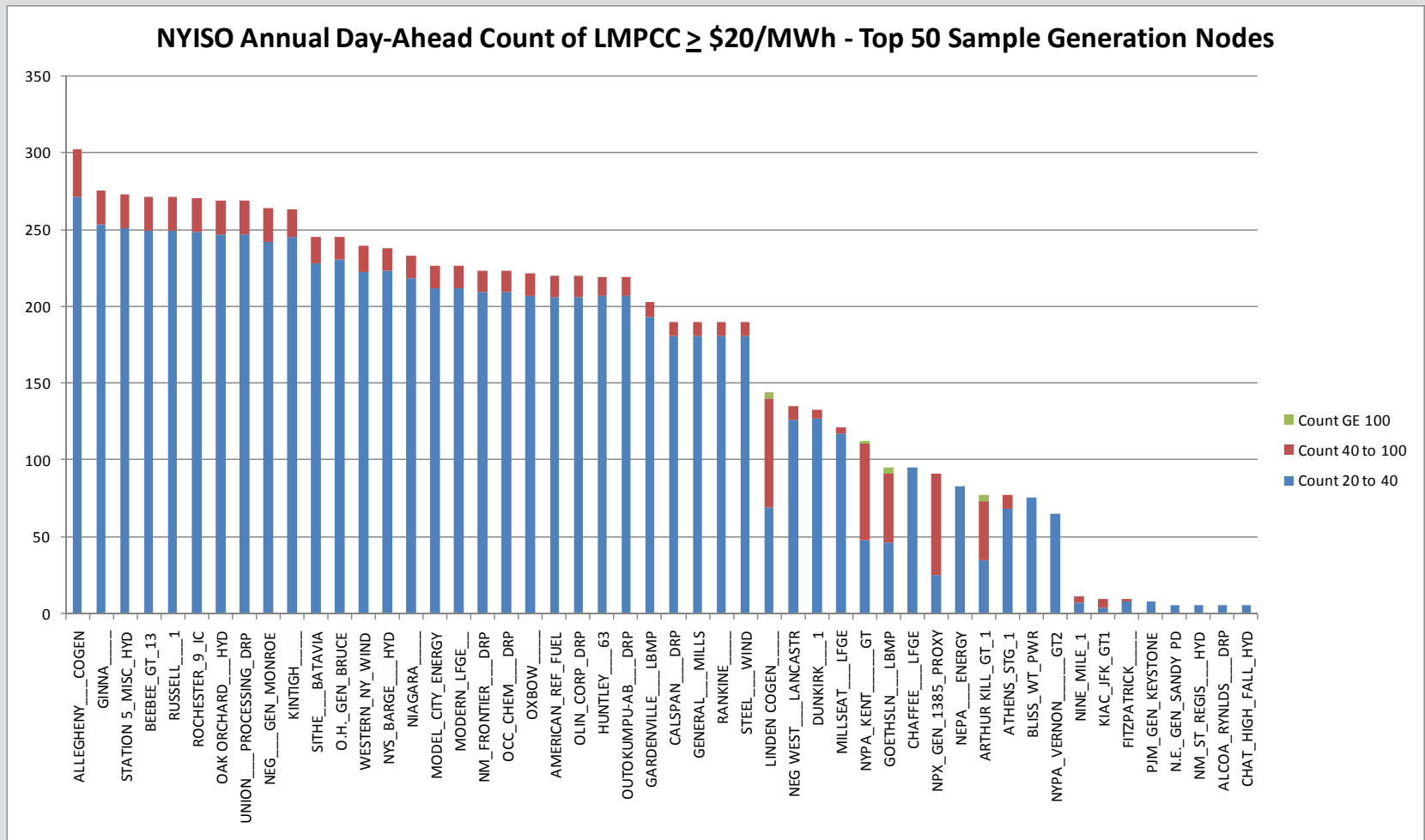


Count of Top 50 NYISO Generator Nodes with LMPCC \leq $-\$20/\text{MWh}$ (Annual; Day-Ahead)



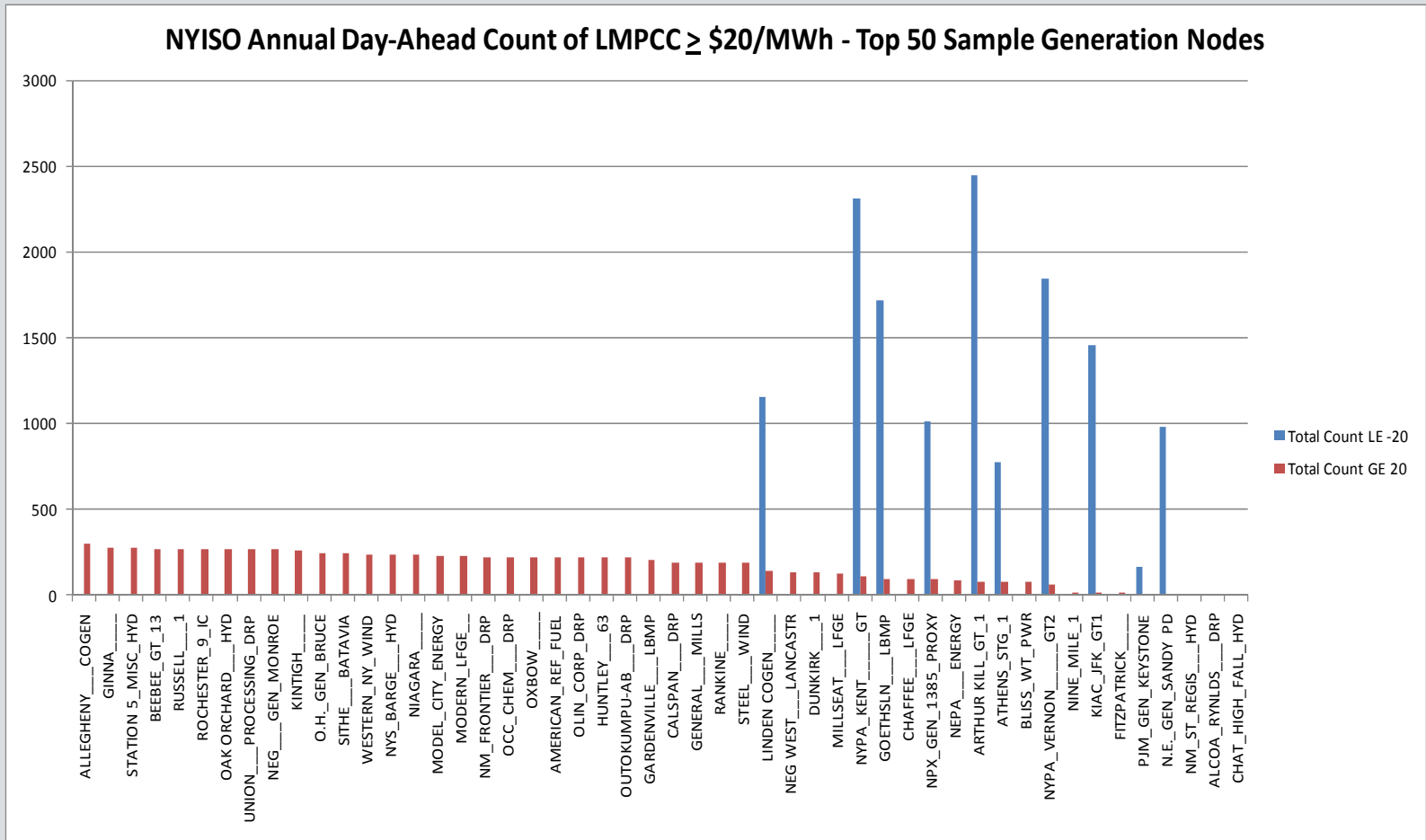


Count of Top 50 NYISO Generator Nodes with LMPCC \geq \$20/MWh (Annual; Day-Ahead)





Count of Top 50 NYISO Generator Nodes with LMPCC \geq \$20/MWh (Annual; Day-Ahead)





Observations Regarding NYISO Metrics

- NYISO Shadow Price Metrics
 - *Very few Shadow Prices are positive after sign correction*
 - *Very few Shadow Prices exceed \$500/MWh in magnitude (only 4 occurrence in 2007)*
- NYISO Generation LMPCCs
 - *Constrained Generator Nodes are predominantly "Constrained out" (negative LMPCCs)*
 - *Most Generator Node LMPCCs show little change of sign during the year*
 - *Some Generator Node LMPCCs do change sign but they are predominantly either constrained-in or constrained out*



Market Metrics Study Results for PJM



Specific Considerations for PJM

- LMPCC Metrics
 - *No data for January to May 2007. Computed LMPCC for January to May as follows*
 - For each hour computed simple average of load node LMPs and used as Reference Node LMP (LMPref)
 - For each node (Generation, Load, Zone, etc.) for each hour computed the LMPCC of that node as (LMPnode - LMPref)
 - *Often multiple generator nodes are electrically close (units in a power plant)*
 - *For presentation of results, retained only one Generator node from among those with the same initial 8 characters and with Count difference less than 5*



Summary Statistics - Top 25 Frequently Binding PJM Day-Ahead Constraints in 2007 with $SP \leq -\$50/\text{MWh}$

Binding Constraints	Annual Count	Min SP	Max SP	Mean SP	Std Dev	Sum SP
BED-BLA	2518	-\$478.99	-\$50.02	-\$100.43	\$45.72	-\$252,886
Cloverdale - Lexington 500 kV	1285	-\$271.08	-\$50.01	-\$70.75	\$20.60	-\$90,914
BRANCHBU230 KV BRA-REA	981	-\$933.00	-\$50.11	-\$148.82	\$127.45	-\$145,990
BECKET 69KV BEC-PAU	581	-\$877.61	-\$50.80	-\$347.39	\$198.71	-\$201,834
ETOWANDA115 KV 3 TX	577	-\$463.94	-\$50.06	-\$161.84	\$89.39	-\$93,384
MEADOWBR138 KV TRAN 3	475	-\$1,847.66	-\$50.01	-\$151.85	\$152.90	-\$72,129
BEDINGTO138 KV BED-NIP	332	-\$624.57	-\$50.04	-\$119.93	\$85.22	-\$39,817
KAMMER2 765 KV .200	319	-\$206.22	-\$50.00	-\$76.81	\$29.06	-\$24,503
ATLANTIC230 KV ATL-LAR	314	-\$499.00	-\$50.03	-\$102.72	\$70.06	-\$32,255
WYLIERID500 KV TRAN 7	298	-\$232.82	-\$50.00	-\$86.87	\$39.26	-\$25,886
GARDNERS115 KV GAR-HUN	279	-\$1,645.89	-\$50.30	-\$117.94	\$151.36	-\$32,905
MITCHELL138 KV MIT-SHE	232	-\$273.70	-\$50.04	-\$109.39	\$48.23	-\$25,379
BEDINGTO138 KV TRAN 1	222	-\$1,382.27	-\$50.13	-\$382.98	\$339.19	-\$85,022
APSOUTH	220	-\$225.03	-\$50.03	-\$89.68	\$38.85	-\$19,729
KERRDAM 115 KV 22C	213	-\$363.98	-\$50.06	-\$127.11	\$71.68	-\$27,075
TIDD_AEP138 KV MAH-TID	187	-\$278.03	-\$50.30	-\$104.88	\$50.97	-\$19,613
CARS DUQ138 KV CAR-HOM	184	-\$523.48	-\$50.91	-\$169.21	\$94.76	-\$31,134
HUNTERST115 KV 4 BANK	165	-\$296.27	-\$50.68	-\$130.98	\$64.19	-\$21,611
BRANCHBU230 KV BRA-FLA	160	-\$431.90	-\$51.57	-\$118.22	\$66.72	-\$18,914
HALIFAX 115 KV 33C	149	-\$350.81	-\$50.32	-\$119.24	\$65.71	-\$17,767
AMOS 345 KV 7-P	147	-\$365.45	-\$50.11	-\$136.63	\$78.34	-\$20,084
BEDINGTO138 KV TRAN 2	145	-\$519.60	-\$52.24	-\$127.50	\$88.04	-\$18,487
BED-BLA contingency 8	137	-\$220.54	-\$50.76	-\$106.60	\$43.95	-\$14,604
ALBRIGHT138 KV ALB-MTZ	133	-\$433.91	-\$50.82	-\$124.60	\$80.24	-\$16,571
AXTONAEP765 KV . 1	127	-\$208.80	-\$50.46	-\$95.28	\$37.29	-\$12,100

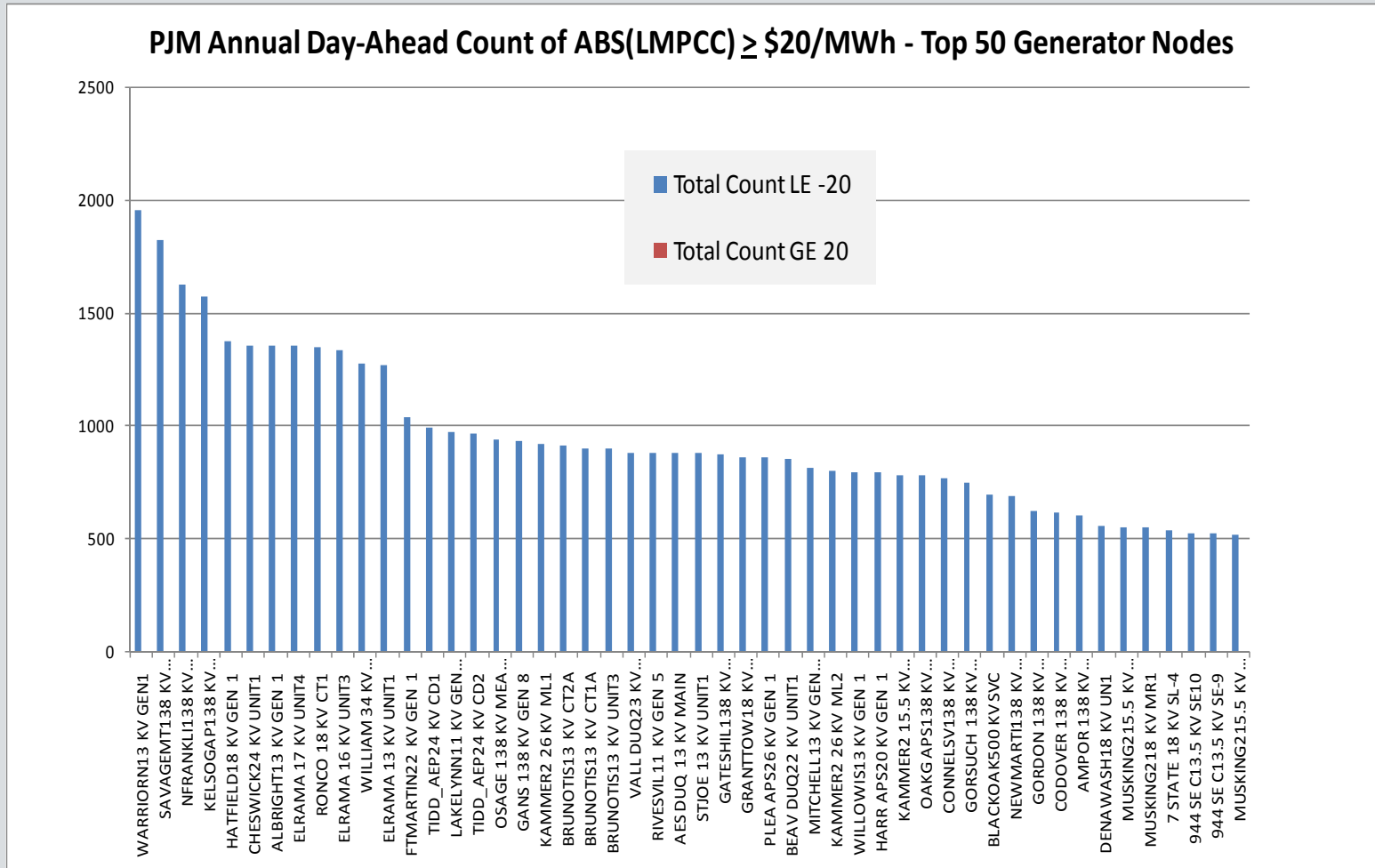


Top Frequently Binding Day-Ahead Constraints with ABS (SP) \geq 500/MWh (PJM Annual All Hours)

Binding Constraints	Annual Count	Min SP	Max SP	Mean SP	Std Dev	Sum SP
BECKET 69KV BEC-PAU	143	-\$877.61	-\$502.18	-\$615.44	\$83.97	-\$88,008
BEDINGTO138 KV TRAN 1	63	-\$1,382.27	-\$521.81	-\$840.55	\$275.67	-\$52,954
BRANCHBU230 KV BRA-REA	24	-\$933.00	-\$502.32	-\$709.91	\$106.91	-\$17,038
DOUBS 500 KV 500-3	20	-\$964.57	-\$502.79	-\$764.00	\$152.88	-\$15,280
JACK ME 115 KV 4 BA-S	11	-\$961.43	-\$619.98	-\$785.55	\$101.60	-\$8,641
BECKETT 69 KV BEC-PAU	10	-\$760.32	-\$511.99	-\$654.10	\$101.69	-\$6,541
MEADOWBR138 KV TRAN 3	10	-\$1,847.66	-\$506.27	-\$950.91	\$440.07	-\$9,509
NSEAFORD138 KV AT-1	9	-\$1,762.46	-\$581.64	-\$896.08	\$353.38	-\$8,065
EUREKA 138 KV EUR-WIL	6	-\$762.99	-\$522.90	-\$670.56	\$73.68	-\$4,023
KMF-PM	5	-\$568.61	-\$514.82	-\$546.25	\$21.05	-\$2,731
BELMONT 500 KV TRAN 3	4	-\$1,186.21	-\$999.20	-\$1,090.35	\$66.58	-\$4,361
GARDNERS115 KV GAR-HUN	4	-\$1,645.89	-\$874.96	-\$1,238.17	\$286.96	-\$4,953
KINGWOOD138 KV KIN-PRU	4	-\$598.15	-\$509.50	-\$547.98	\$34.34	-\$2,192
ALLELUD4138 KV ALL-SPR	3	-\$842.95	-\$570.49	-\$719.16	\$112.62	-\$2,157
BEDINGTO138 KV BED-NIP	3	-\$624.57	-\$528.69	-\$580.94	\$39.61	-\$1,743
CLAYSBUR115 KV CLA-CUR	3	-\$544.28	-\$510.21	-\$526.33	\$13.97	-\$1,579
OX4 500 KV TX2	3	-\$848.28	-\$602.83	-\$692.07	\$110.83	-\$2,076
ALBRIGHT138 KV ALB-SNO	2	-\$876.83	-\$619.84	-\$748.34	\$128.50	-\$1,497
ALTAVSTA115 KV 30A	2	-\$1,319.03	-\$1,288.34	-\$1,303.69	\$15.35	-\$2,607
GLENDON 115 KV GLE-HOS	2	-\$535.03	-\$501.21	-\$518.12	\$16.91	-\$1,036
PLYMOUTH230 KV PLY-WHI4	2	-\$532.62	-\$502.29	-\$517.46	\$15.17	-\$1,035



Generator Nodes with ABS (LMPCC) \geq \$20/MWh - Top 50 (PJM Annual; Day-Ahead; Ordered by Count)





Observations

- Shadow Price Metrics
 - *PJM Shadow Prices are Non-positive*
 - *There were quite a number of constraints with Shadow Prices exceeding \$500/MWh in magnitude during the year 2007*
- LMPCC Metrics
 - *The top frequently constrained generators are constrained out (negative LMPCC)*
 - *Most Generator Node LMPCCs show little change of sign during the year*
 - *Some Generator Node LMPCCs do change sign but they are predominantly either constrained-in or constrained out*



Market Metrics Study Results for ISONE

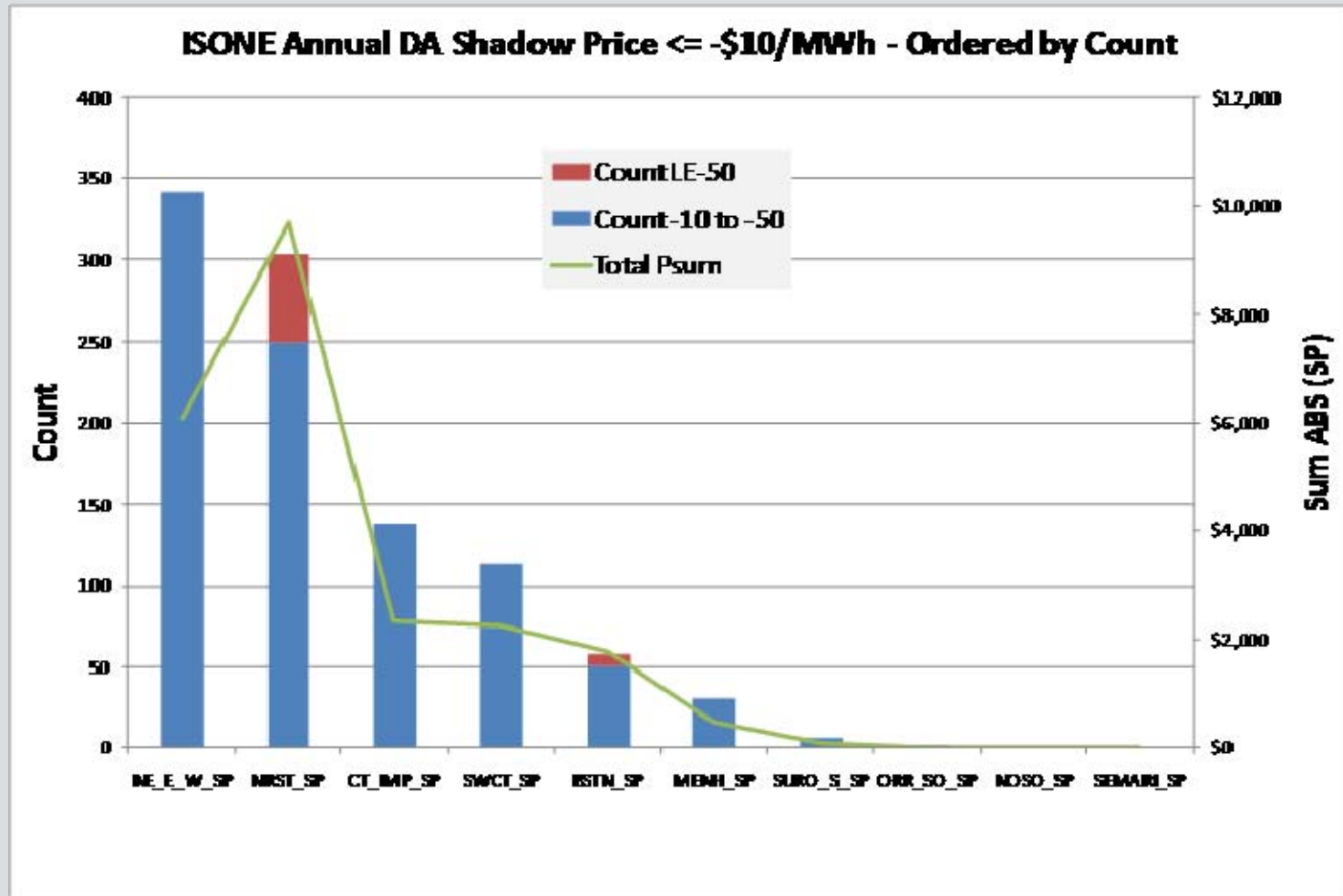


Specific Considerations for ISONE

- Shadow Prices
 - *ISONE Shadow Prices are available only for Interfaces*
 - *No shadow price data for internal ISONE Constraints*
 - *ISONE Shadow Prices are all non-positive*
- Congestion Rent Metrics
 - *ISONE provided "Flow" data for Interfaces*
 - *For consistency sum of ABS(Shadow Price) was used as surrogate for congestion rent*
- LMPCC Metrics
 - *LMPCC data is available publicly from ISONE website*
 - *Network Nodes were used as primary node types*

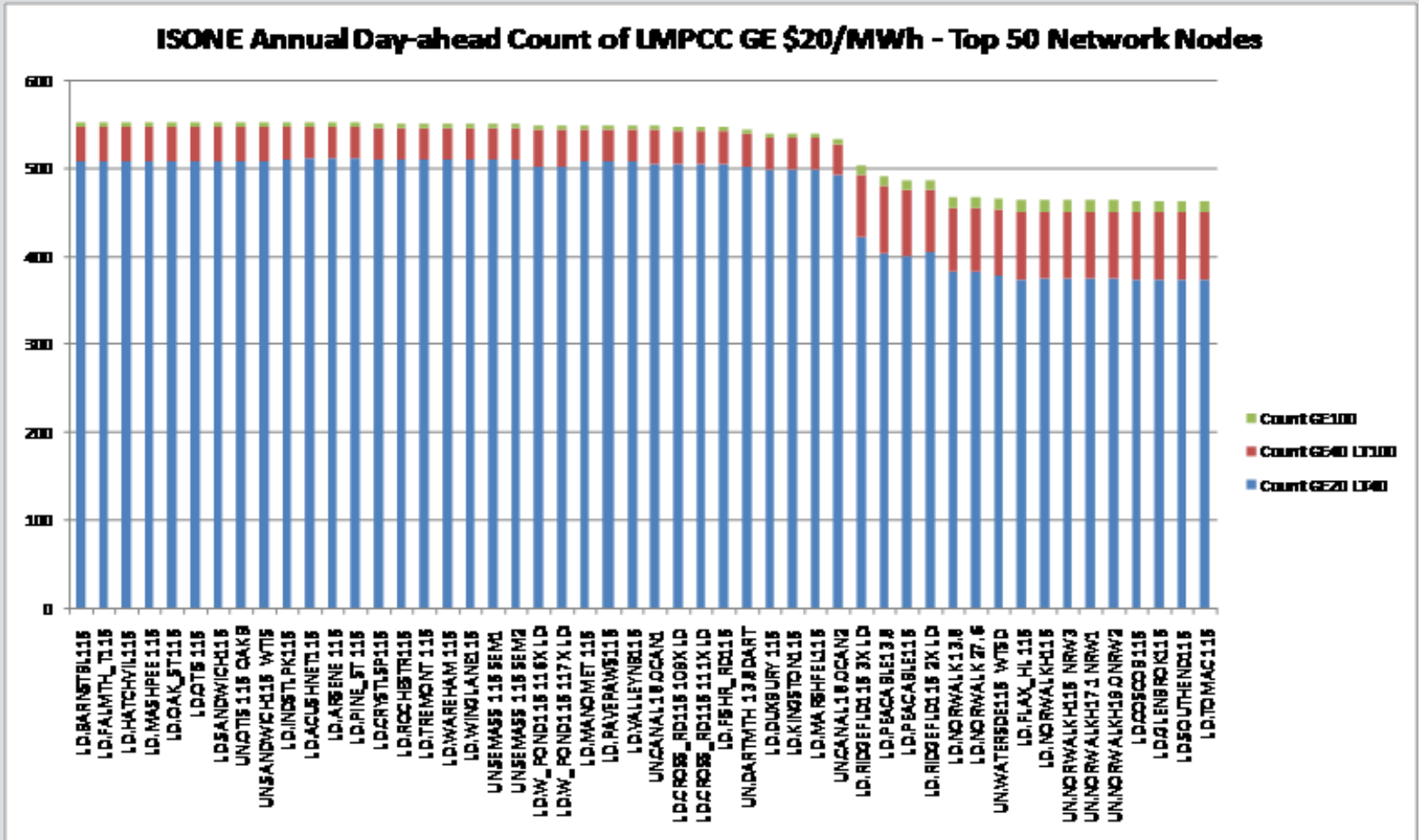


ISONE Day-Ahead Interface Shadow Prices with ABS (SP) \geq \$10/MWh (Ordered by Annual Count)



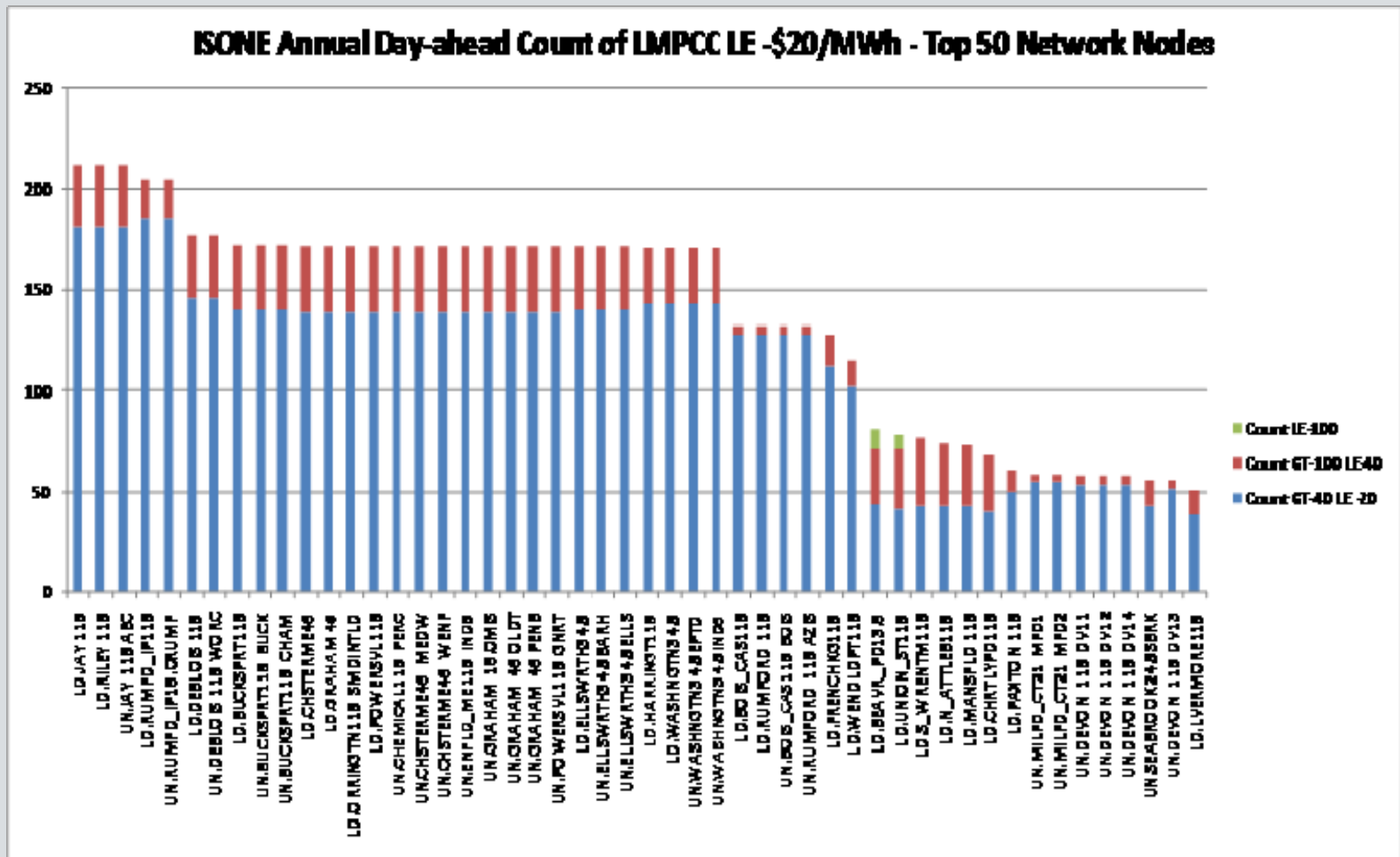


ISONE Annual Day-ahead Network Nodes with LMPCCs \geq \$20/MWh - Top 50 (Ordered by Count)





ISONE Annual Day-ahead Network Nodes with LMPCCs \leq $-\$20/\text{MWh}$ - Top 50 (Ordered by Count)





Observations

- ISONE Shadow Prices are much lower in magnitude and frequency than other markets
- Compared to other markets, ISONE LMPCCs are lower in magnitude and the frequency with which they exceeded the designated thresholds
- These results confirm that there was much less congestion in ISONE in 2007 compared to other markets analyzed



Concluding Remarks

- Market Metrics based on Shadow Prices are more consistent than those based on LMPCC
- LMPCC metrics are still useful for designation of seasonal variations of constrained-out and constrained-in areas
- Among the markets analyzed, MISO and PJM had larger frequency and magnitude of congestion in 2007 than NYISO and ISONE
- ISONE was the least congested



THANK YOU

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