Results and Assumptions
For
Single Economic Dispatch
Production Cost Study–
PROMOD Component

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1 Introduction

This White Paper serves as the study document for the PROMOD analysis performed for the Single Economic Dispatch Production Cost Study conducted with PJM staff as part of the Joint & Common Market (JCM) analysis. This analysis was performed by the MISO Transmission Asset Management group and the PJM Markets group. The primary analytic tools used in the analysis, for production cost modeling purposes, are the PROMOD IV® model from NewEnergy Associates and the GE MAPS software tool from General Electric. This document serves as the assumption document for the PROMOD simulation. The study year is 2006, and all results are for the full year.

The cases developed for the Single Economic Dispatch Production Cost Study are defined below:

> **Current Market Case:** MISO, PJM, SETRANS, SPP, NYISO, IMO and MAPP-Non-MISO are modeled in the case. There are dispatch hurdle rates and commitment hurdle rates between these entities. For the MISO and PJM interface, 1.5$/MWH, 2.5$/MWH, and 5$/MWH dispatch hurdle rates were tested as part of the process to develop the scheduled interchange benchmark. Base on the results of the scheduled interchange benchmark, results at each of the dispatch hurdle rates is provided to obtain a range of benefits.

> **Single Economic Dispatch Case:** Same as Current Market Case, except that both the dispatch and commitment hurdle rates between MISO and PJM are 0$/MWH.

PROMOD was benchmarked against the actual January 2006 system operation. The benchmark provides a backdrop by which to measure the use of a simulation model as a tool to gauge future performance. A simulation model is needed in order to provide a consistent linkage between past and future expected performance.

The intent of the single economic dispatch study is to determine the level of production cost savings exists between the current market case, using an implied hurdle rate to simulate market inefficiencies, and a single economic dispatch case. A metric of adjusted production cost is used to determine the cost savings between the cases. The adjusted production cost captures the actual production cost used to serve the load. The production cost used to serve the purchase/sale to the outside world needs to be adjusted from the total production cost; and, three options to calculate the adjusted production cost are evaluated.

The results of the 2006 analysis indicated a range of savings from $34 million to $66 million for the PROMOD simulations. The benefits in various scenarios accrue to different market participants. In general benefits tend to be greater in PJM. In some scenarios net benefits in the MISO region are negative. Fuel price sensitivity studies are also performed. The results of the simulation and sensitivity runs are detailed in the following section. Study Assumptions and benchmark results are given in the Appendix.

It is important to note that the base case on which the production cost savings are based is benchmarked against the actual market conditions experienced over the last year. Therefore, the production cost savings that result from the analysis are inclusive of the benefits that will be achieved via implementation of the various Joint and Common Market (JCM) initiatives already under development or investigation. Specifically, the following JCM initiatives are expected to increase the convergence of the two markets and achieve a significant portion of these savings:

- PJM implementation of marginal losses;
- Alignment of PJM Operating Reserve and MISO Revenue Sufficient Guarantee products;
- Moving Joint-Owned Units between markets;
- Alternative border pricing point mechanisms.

Other potential JCM initiatives are also being considered that could further enhance the convergence of the two markets. In addition, PJM and MISO are and will be continuously analyzing and improving the operation of the Market-to-Market coordination that was implemented as Phase 2 of the Joint Operating Agreement. The initiatives described above are expected to achieve a significant portion of the production cost savings estimated in the simulations, at substantially less cost than a single unit commitment and dispatch. Once the above initiatives have been incorporated into the operations of the two RTOs for a time period significant enough over which to judge their effectiveness, an analysis could be conducted that would indicate more definitively the remaining benefits that might be achieved through a single economic dispatch.

2 Study Results

2.1 Different options for Adjusted Production Cost calculation

The benefit of single economic dispatch is measured by the savings in production cost to serve load in the combined region. In reality, each entity has purchases and/or sales with other entities, including entities outside the combined region. If an entity is a net seller its production cost is based on serving its own load plus serving outside load. Therefore, the production cost associated with serving the outside load must be removed from the total production cost for the entity being studied. On the other hand, if an entity is a net purchaser then its outside purchased energy must be added to its production cost.

Production cost models such as PROMOD are based on a single economic dispatch of the entire model region, in this case the Eastern Interconnection. All generation in the model is dispatched on an economic basis to serve aggregate load. As such, there is no model derived value of net purchases or sales for a sub region. The value of such transactions must be estimated. In this study the following three options for calculating the Adjusted Production Cost accounting for purchases and sales are investigated:

- Option 1: *CA* level calculation - CA's transactions within pool and outside pool are priced separately based on the sign of each transaction. Figure 1 shows the detail of Option 1.
- Option 2: Pool level calculation - Pool transaction is priced based on the pool-wide load or generation weighted LMP. Figure 2 shows the detail of Option 2.

- Option 3: Pool level calculation - Captures the transaction from each CA to outside pools, and prices this transaction with CA's load or generation weighted LMP. Internal transactions between CAs are not priced. Figure 3 shows the detail of Option 3.

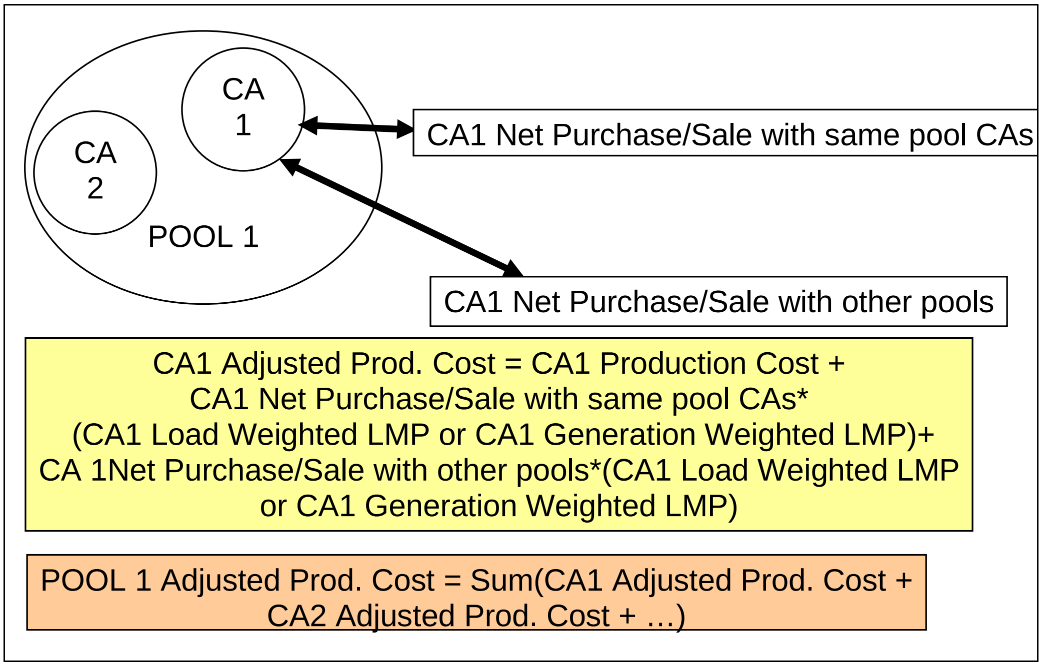

Figure 1: Option 1

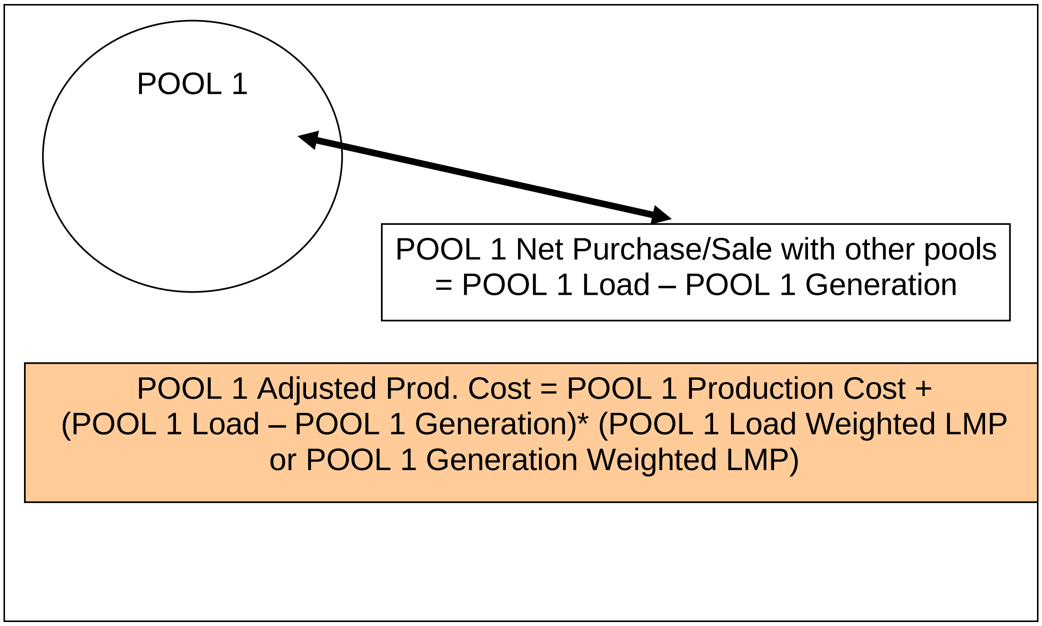

Figure 2: Option 2

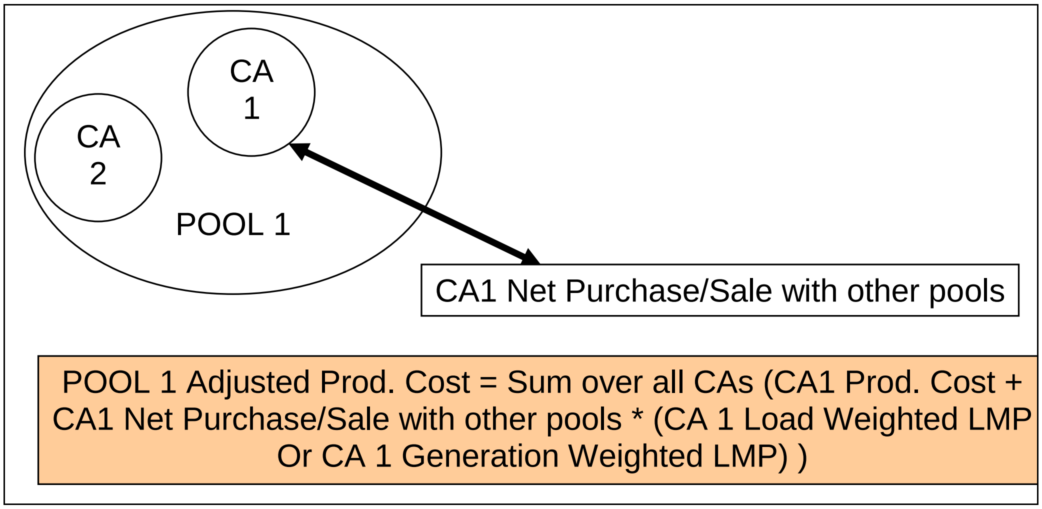

Figure 3: Option 3

Difference between Option 1 vs. (2 and 3) is:

- Transactions between CAs within the same pool are not included in Options 2 and 3.
- Options 2 and 3 can only be used for pool level comparison, while Option 1 can be used for both pool and Control Area level comparison.

Difference between Option 2 and Option 3 is:

- Option 2 uses pool level generation or load weighted LMP to price the pool to pool transaction.
- Option 3 captures CAs transaction from/to outside pool, and uses CAs load or generation weighted LMP to price this transaction.

2.2 Results

For current market, we have run 3 cases. The difference between these cases is the dispatch hurdle rate between MISO and PJM. The hurdle rates evaluated are $1.5/MWH, $2.5/MWH and $5/MWH respectively for the three cases. The adjusted production costs of these three cases are calculated and compared to the adjusted production cost from the single economic dispatch case. The results are shown in Table 1.

Table 1: Adjusted Production Cost Savings ($ million)

	Option 1			Option 2			Option 3		
	MISO	PJM	Total	MISO	PJM	Total	MISO	PJM	Total
$1.5 Hurdle	$ (3.12)	$46.80	$43.68	$ 8.71	$25.67	$34.38	$(7.63)	$22.43	$14.80
$2.5 Hurdle	$ 9.83	$55.56	$65.39	$18.42	$34.40	$52.82	$ 2.57	$31.02	$33.59
$5 Hurdle	$18.55	$80.12	$98.67	$24.36	$45.72	$70.08	$ 9.33	$42.59	$51.92

For Option 1, the total saving is in the range of $44 – $99 million. For Option 2, the total saving is in the range of $34 – $79 million. For Option 3, the total saving is in the range of $15 – $52 million.

In benchmark, it is shown that $2.5/MWH hurdle rate case gives the best benchmark of MISO/PJM scheduled interchange. In $2.5/MWH hurdle rate case, three options give the adjusted production cost saving range of $34 million and $65 million.

Different options gave out different results, but they are consistent in range of saving, and these savings are very small compared to the total production cost value (less than 0.2% of the total production cost).

2.3 Sensitivity Studies

The following fuel price sensitivity runs were performed on the $2.5/MWh dispatch/$10/MWh commitment hurdle rate case and single market dispatch case:

- Lower Gas Price (40% lower than original case in all east interconnection)
- Lower Gas Price (10% lower than original case in all east interconnection)
- Higher Gas Price (10% higher than original case in all east interconnection)
- Higher Gas Price (50% higher than original case in all east interconnection)
- Higher Coal Price in MISO area (10% higher than original case)
- Higher Coal Price in PJM area (10% higher than original case)

The results of these sensitivity runs are shown in Table 2.

Table 2: Sensitivity Run Results

	Adjusted Production Cost Savings ($ million)								
	Option 1			Option 2			Option 3		
Gas Sensitivity	**MISO**	**PJM**	**Total**	**MISO**	**PJM**	**Total**	**MISO**	**PJM**	**Total**
40% Lower Gas Price	$27.55	$16.78	$44.33	$35.86	$ (2.19)	$ 33.67	$24.06	$ (3.82)	$20.24
10% Lower Gas Price	$ 0.50	$48.02	$48.52	$14.34	$27.25	$ 41.60	$ (1.82)	$24.39	$22.57
Base Case	$ 9.83	$55.56	$65.39	$18.42	$34.40	$ 52.82	$ 2.57	$31.02	$33.59
10% Higher Gas Price	$ 7.95	$51.58	$59.53	$14.69	$30.82	$ 45.51	$ 2.62	$29.28	$31.89
50% Higher Gas Price	$25.79	$38.69	$64.48	$32.28	$ 9.05	$ 41.33	$28.37	$ 5.57	$33.94
Coal Sensitivity	**MISO**	**PJM**	**Total**	**MISO**	**PJM**	**Total**	**MISO**	**PJM**	**Total**
10% Higher MISO Coal	$13.64	$78.26	$91.90	$25.58	$44.44	$ 70.03	$ 7.92	$36.44	$44.36
Base Case	$ 9.83	$55.56	$65.39	$18.42	$34.40	$ 52.82	$ 2.57	$31.02	$33.59
10% Higher PJM Coal	$12.96	$40.25	$53.21	$20.41	$20.88	$ 41.30	$ 8.79	$22.93	$31.72

Figure 4 shows the adjusted production cost savings for each of the three options with different gas prices. Between the three options, the gas price change causes the same change pattern of adjusted production cost savings. In the gas sensitivity cases, all gas within the Eastern Interconnection is increased or decreased by the same percentage. The gas sensitivity cases show a small decrease in savings attributed to gas price fluctuations. In the coal case sensitivities, only one RTO's coal prices were raised while keeping the coal prices in the other RTO at the original price level.

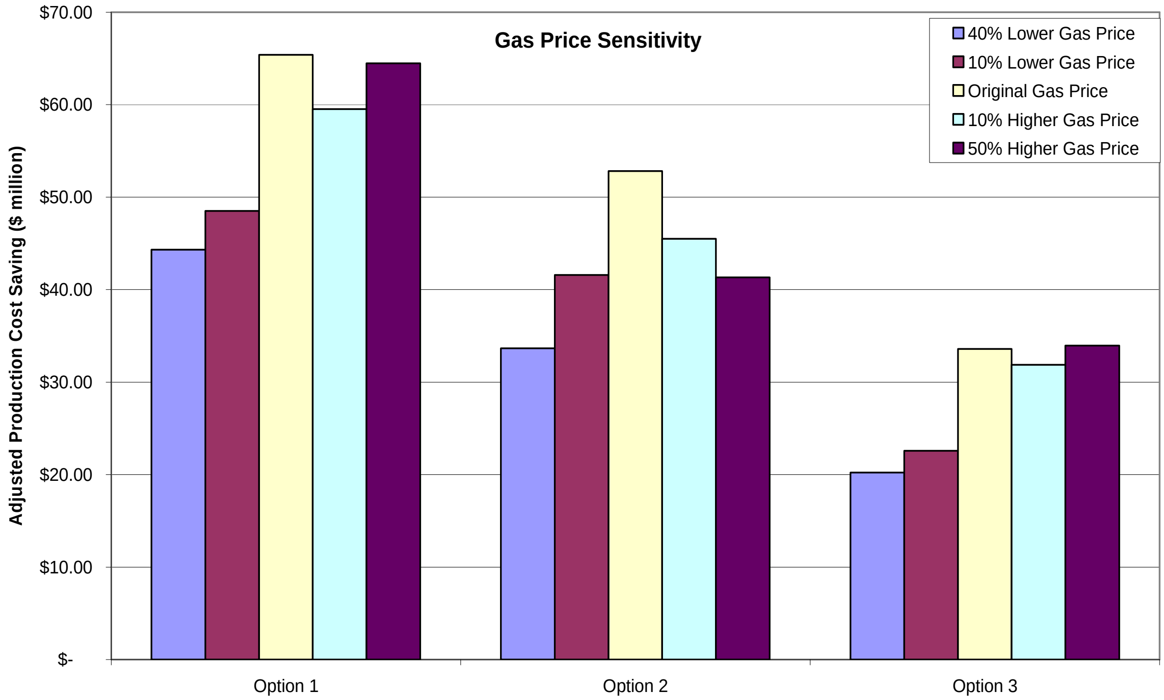

Figure 4: Gas Price Sensitivity Results

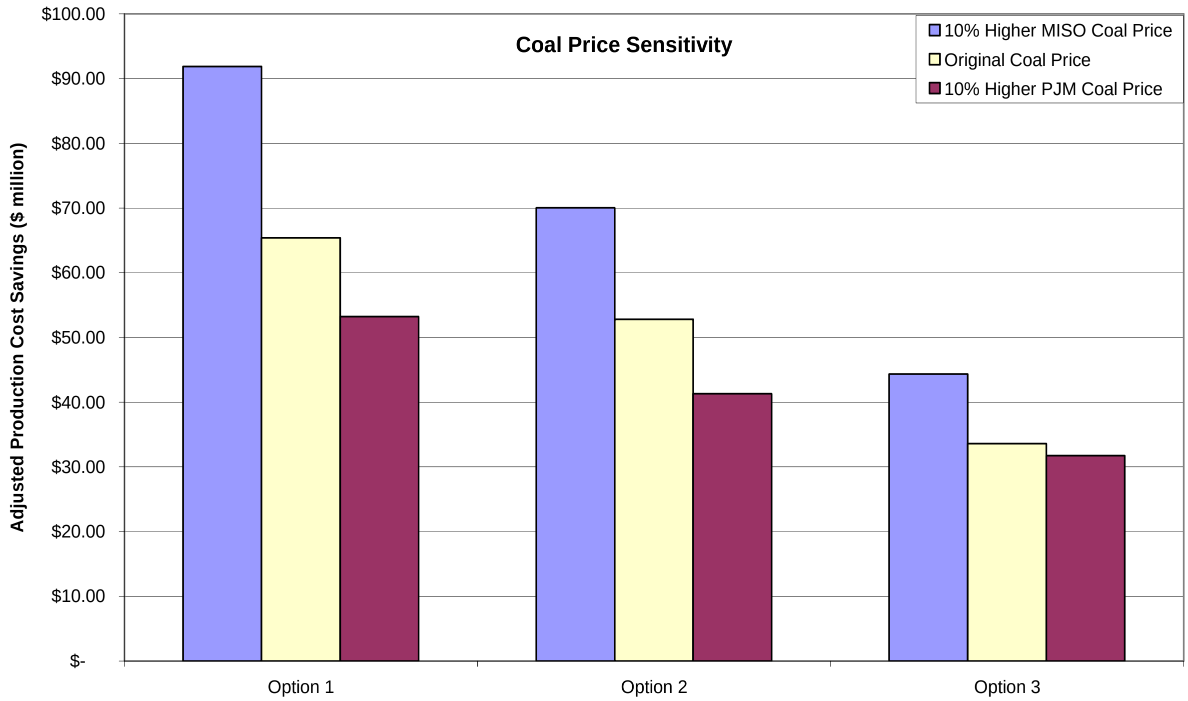

Figure 5: Coal Price Sensitivity Results

Appendix

1 Study Assumptions

Various assumptions related to PROMOD studies are discussed in this section. Some of the assumptions are generic for all PROMOD studies undertaken by the MISO; while some are specific to the Single Economic Dispatch study.

The underlying source of PROMOD data is contained in Powerbase. Powerbase is a separately licensed tool from New Energy Associates that contains much of the data necessary to create and run PROMOD data files. The data in Powerbase can be replaced in whole or in part with user specified data. For example, MISO adjusts Powerbase data for generators in the interconnection queue and specific generator parameters (e.g. must run status), but does not normally update Powerbase economic data for our members due to confidentiality concerns.

The primary assumptions discussed here are: fuel price forecasts, load forecasts, generating units and parameters, power flow case, commitment and dispatch hurdle rates, and case description. Detailed assumptions regarding existing units, retired units, variable operations and maintenance (O & M) values, penalty factors, must run units, unit maintenance and forced outage rates (EFOR) are discussed in the generating units and parameters topic.

1.1 Fuel Forecast[1]

The source for the fuel forecasts in the Powerbase database is the Platt's database, Henry Hub forecasts and EIA forecasts. NewEnergy Associates (NEA) contracts with Platts for various fuel price forecasts. NEA starts with Platt's forecasts for natural gas and then uses the basis differential inherent in Platt's forecast for Natural Gas combined with NYMEX Henry Hub futures prices for the first 18 months of the forecast. For the forecast beyond 18 months, the Energy Information Administration (EIA) natural gas forecast for the Henry Hub serves as the base index. The basis differential to each area is then applied against the EIA forecast of the Henry Hub prices.

Figure A.1 illustrates the fuel price forecasts. For a detailed listing of the fuel forecasts, please refer to the Appendices. NEA December 2005 release data was utilized for this study purposes.

The oil price forecasts are based on futures contracts with no basis differential. Heavy Oil forecasts in this PROMOD study are adjusted based on Crude Oil prices and Light Oil price forecasts are adjusted based of Heating Oil prices from NYMEX. The coal price forecasts are from Platts directly. The coal price forecasts include transportation costs. NEA updates the fuel price forecasts every quarter.

[1] Platts Fuel Forecasting methodology, found on NEA PowerBase support web site

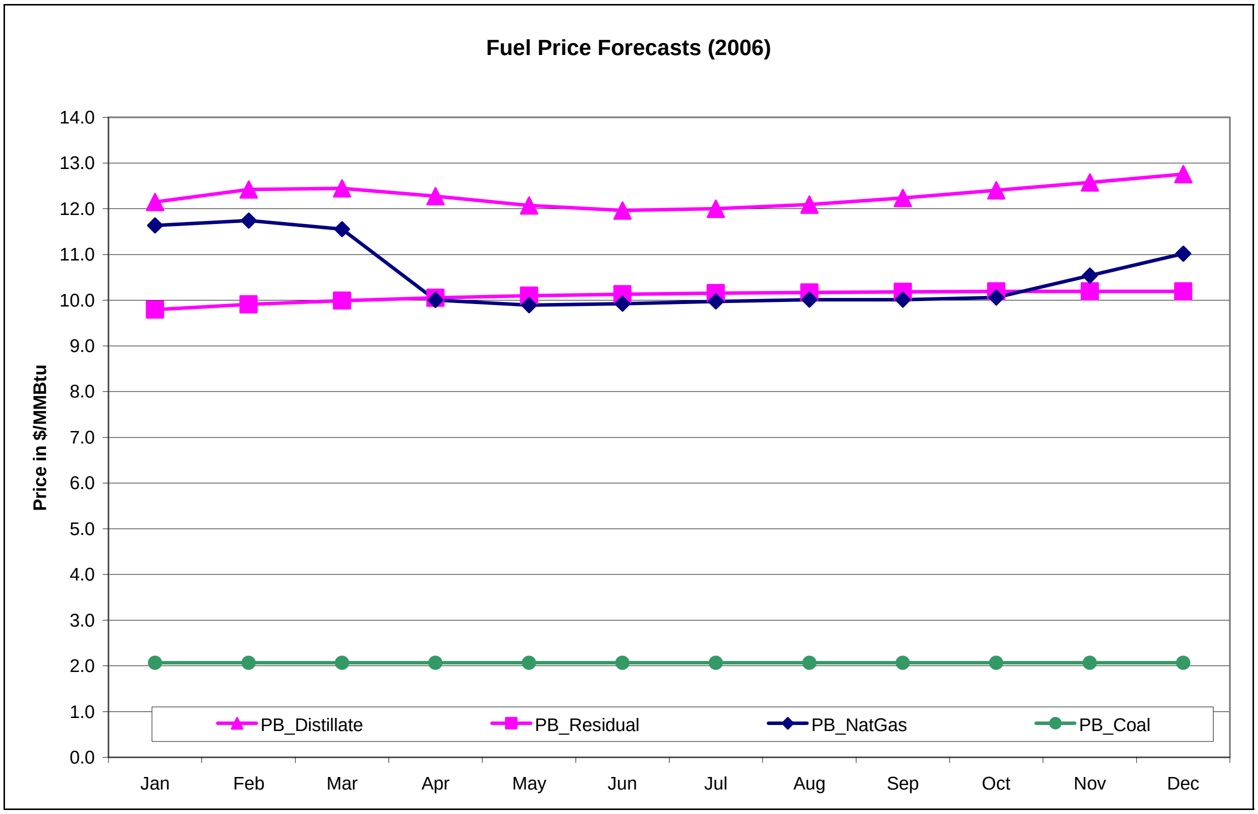

Figure A. 1: Fuel Forecasts for 2006

Coal starts at $ 2.0 per MMBtu in Jan 2006 as seen in figure 2. Natural gas starts at $11.7 per MMBtu, oil distillate at $12 per MMBtu and residual at $10 per MMBtu.

1.2 Load Forecast and Losses

The load forecasts in the Powerbase database come from FERC 714 filings. NEA scales these values to match the sub regional totals to the NERC Electricity and Supply Demand (ES &D) database. These values are verified by MISO against load flow data for a specific year for some studies. MISO members submit load forecasts to MISO as a part of Module E process, but this data is only for the near-term and less than 18 months. For the purposes of this single economic dispatch study, hourly load data for Jan 2006 was requested from the Data Management Team (DMT) department of MISO. These values were given by control area and did contain transmission losses. (Note to the reader: PROMOD requires losses in its load data)

1.2.1 Treatment of Losses in PROMOD

There are 3 options to treat losses in PROMOD. They are:

- Option 1: Load in PROMOD load file is equal to actual load plus the loss. Losses and LMP loss component are not calculated by PROMOD.

- Option 2: Load in PROMOD load file is equal to actual load plus the loss. Losses are not calculated by PROMOD. LMP loss component is calculated by PROMOD in an approximation method. (this option is used in PROMOD analysis by MISO staff)
- Option 3: Load in PROMOD load file is equal to actual load. PROMOD calculates losses and the LMP loss component, this is sometimes called “marginal loss” calculation method

1.3 Generating Units and parameters

Detailed assumptions regarding existing units, retired units, variable operations and maintenance (O & M) values, penalty factors, must run units, unit maintenance and forced outage rates (EFOR) are discussed in this section.

1.3.1 Existing Units

The Appendices contains specific generating unit information of the type used in this study. Typically as part of the PROMOD model development process, MISO verifies generators in the default Powerbase database against the MISO load flow models. Stakeholders are involved in this process. The Expansion Planning Working Group (reporting to Planning Sub-Committee) is sent a list of generators mapped to load flow models and member comments are solicited. A list of the existing units in the database is given in Appendix A of this document.

Table A.1 below shows a summary of several operating characteristics, by class, for existing units in the Eastern Interconnect. These are average values for that class/type of existing units from the Powerbase database. Only heat rates, forced outage rates, start up costs, ramp up date and ramp down rates are shown.

Table A. 1: Summary of Operating Characteristics

	Average				
FuelType	Heat Rate (MMBtu/MWh)	Forced Outage Rate (%)	Startup Cost Adder ($000)	Ramp Up Rate (MW/hr)	Ramp Down Rate (MW/hr)
Combined Cycle	7.2	4.1	9.3	122.4	147.8
Combustion Turbine <= 100	12.4	7.8	3.1	509.5	510.0
Combustion Turbine > 100	12.3	5.1	4.8	159.0	186.7
ST Coal <=100	12.1	6.1	5.8	26.4	28.9
ST Coal >100, <=200	10.4	6.6	9.4	55.9	59.5
ST Coal >200	9.8	7.5	22.1	154.5	167.3
ST Gas <=100	12.8	6.3	3.5	27.3	28.9
ST Gas >100, <=200	11.0	7.6	7.2	61.3	62.8
ST Gas >200	10.2	10.0	19.3	173.3	174.4
ST Oil <=100	12.9	3.6	3.7	27.7	31.8
ST Oil >100, <=200	10.5	6.8	7.6	62.9	68.4
ST Oil >200	10.1	9.1	19.7	186.9	199.3

1.3.2 Retired Units

Units are retired in the database based on public announcements, various ISO web sites and from Platt's database, by NEA. In addition to the retirements found in the default database, MISO also makes sure that the units retired in the load flow model are retired in the PROMOD model. This is done as a part of the PROMOD model development process.

1.3.3 Variable O & M

Variable Operations and Maintenance (O&M) values are included in the Powerbase database. The source for these values is the FERC Form 1 data and EIA Form 412. Generator data in the Appendices also shows the variable O & M costs modeled for each unit in the PROMOD database.

1.3.4 Penalty Factors

Penalty factors are factors assigned to generators in the PROMOD to mimic certain sensitivities. In this particular PROMOD run we did not assign any penalty factors.

1.3.5 Unit Maintenance

In PROMOD, maintenance is automatically scheduled for all units except for nuclear. Nuclear unit maintenance is well known from the NRC (Nuclear Regulatory Commission) web site. Hence these units' maintenance schedules are input in the Powerbase database by NEA. The remaining units are scheduled in PROMOD using the automatic maintenance scheduler; whereby, PROMOD schedules maintenance according to the overall system reliability as a target.

1.3.6 Forced outage rates

NEA updates Forced Outage rate (FOR) information from NERC GADS (Generator Availability Data System) data in the default database. These are based of historical 5-year average values by class of generators. These values are not changed by MISO in this particular PROMOD study.

1.3.7 Environmental parameters

The Powerbase database has emissions cost associated with some of the units in the Eastern Interconnect. This data comes from the Continuous Emission Monitoring System (CEMS) data source of the Environmental Protection Agency (EPA) web site. The effluents modeled in the database include: Carbon dioxide (CO_2), Nitrous oxide (NO_x), Ontario Nitrous oxide (ONTARIO NO_x), State Implementation Plan Nitrous oxide (SIP NO_x) and Sulfur oxides (SO_x). The allowance costs for each pollutant are as follows:

- ONTARIO NO_x - $ 2,687.5 per ton (May to September),
- SIP NO_x - $ 2,687.5 per ton (May to September), and

- SO_x - $1,565.5 per ton.

NewEnergy Associates updates these costs every quarter based on the CEMS web site.

1.4 Power flow case

Generators in this PROMOD model were mapped to the 2005 series MISO 2006 power flow case. The transmission topology reflects transmission projects verified with “Appendix A” from the MISO MTEP (not to be confused with the listing of Appendices in this report) and SPP Transmission planning projects listing. Inserts from SPP load flow models were added on top of the MISO topology.

1.5 Commitment and Dispatch hurdle rates

PROMOD performs the transmission constrained unit commitment and economic dispatch, therefore its solution includes two steps. The first step is unit commitment, and the second step is economic dispatch. For each step, the user can define its own hurdle rate. The hurdle rate defined for the unit commitment step is called the commitment hurdle rate, and the hurdle rate defined for the economic dispatch step is called the dispatch hurdle rate.

The hurdle rate will influence the capability of a pool to obtain support or sell energy to other pools. A pool is defined in PROMOD as a set of companies that have no hurdle rates between them and their generators will be committed and dispatched together to meet their total load. Separate pools will exchange energy when the difference between dispatch cost in the buying and selling pools is greater than the hurdle rate between them.

Normally, users will set the commitment hurdle rate to be more expensive than the dispatch hurdle rate such that the pool units will be dispatched against its own pool load first in order to get the commitment order right and then allow pool interchange during the final dispatch via the dispatch hurdle rate.

In this study, for current market cases, the commitment hurdle rates are set as $10/MWH between all pools. Exception was MISO to MH, where we set the commitment hurdle rate as $0/MWH. The dispatch hurdle rates between pools are set as shown in Table A.2. The MISO/PJM dispatch hurdle rates are set as $1.5/MWH, $2.5/MWH and $5/MWH for three market cases.

For the single economic dispatch case, the dispatch and commitment hurdle rates are set the same as in current market case, except that the dispatch and commitment hurdle rates between MISO and PJM are set to $0/MWH.

Table A. 2: Dispatch Hurdle Rates modeled

	DISPATCH HURDLE RATES								
	TO /FROM ->	on-peak/off-peak							
FROM /TO	MISO	PJM	SPP	SETRANS	IMO	MH	NYISO	TVA	NONMISO
MISO	*	2.5/2.5	7.5/5.3	7.5/5.3	7.5/5.3	0/0	N/a	7.5/5.3	7.5/5.3
PJM	2.5/2.5	*	n/a	4.8/4.8	N/A	n/a	7.0/7.0	N/a	4.8/4.8
SPP	5.0/5.0	n/a	*	5.0/5.0	N/A	n/a	N/a	N/a	5.0/5.0
SETRANS	8.3/8.3	6.5/4.5	8.3/8.3	*	N/A	n/a	N/a	N/a	8.3/8.3
IMO	10.5/8.5	n/a	n/a	n/a	*	10.5/8.5	6.5/4.5	N/a	n/a
MH	n/a	n/a	n/a	n/a	7.0/5.0	*	N/a	N/a	11.6/7.3
NYISO	n/a	5.0/5.0	n/a	n/a	7.0/5.0	n/a	*	N/a	n/a
TVA	N/a							*	n/a
NONMISO	4.2/3.7	4.2/3.7	6.8/6.8	4.2/3.7	N/A	6.5/4.5	N/a	N/a	*

1.6 Event File

The event file in PROMOD contains the list of contingencies and monitored elements. For this analysis there were 492 contingencies and 1307 monitored elements. The actual event file is confidential; however, an excel spreadsheet that contains the event file information is included in the Appendices.

Monitored flowgates in PROMOD constitute an “event file”. The source for this event file is the MISO Book of flowgates and NERC Book of flowgates. Certain flowgates may have operating guides associated with them in real time operations. Hence the “event file” is scrubbed to remove any flowgates that might have an operating guide associated with them. For a detailed listing of flowgates modeled in the Single Economic Dispatch study, please refer to the spreadsheet in the Appendices.

2 PROMOD Benchmark

An integral part of the single economic dispatch study effort is the benchmarking of PROMOD results to actual MISO and PJM Day-ahead market data in Jan 2006. The followings are the variables that we used to perform the benchmark:

- Scheduled interchange between MISO and PJM
- LMPs at Hubs
- Capacity Factor of generating units

For the benchmark purpose, we collected the following information:

- Hub LMP in MISO and PJM day-ahead market (January 2006)
- Hourly generations of all units in MISO market (January 2006)
- The hourly scheduled interchange between MISO and PJM in year 2005

We also collected the MISO companies' hourly load data from MISO market of January 2006, and used them to replace the original January 2006 load data from PowerBase.

Following sections discuss in detail the PROMOD benchmark with market data.

2.1 MISO to PJM Scheduled Interchange Benchmark

The scheduled interchange benchmark served as the primary metric to determine the hurdle rate to be applied for the case used for LMP and capacity factor benchmark.

We have run the following hurdle rate cases:

1) $1.5/MWH dispatch hurdle, $10/MWH commitment hurdle between MISO and PJM.
2) $2.5/MWH dispatch hurdle, $10/MWH commitment hurdle between MISO and PJM.
3) $5/MWH dispatch hurdle, $10/MWH commitment hurdle between MISO and PJM.

From each case run, we get the hourly interchange between MISO and PJM. The duration curves of these hourly interchanges are shown in Figure A.3. The duration curve of Year 2005 MISO/PJM scheduled interchange data from market is also shown in the same figure.

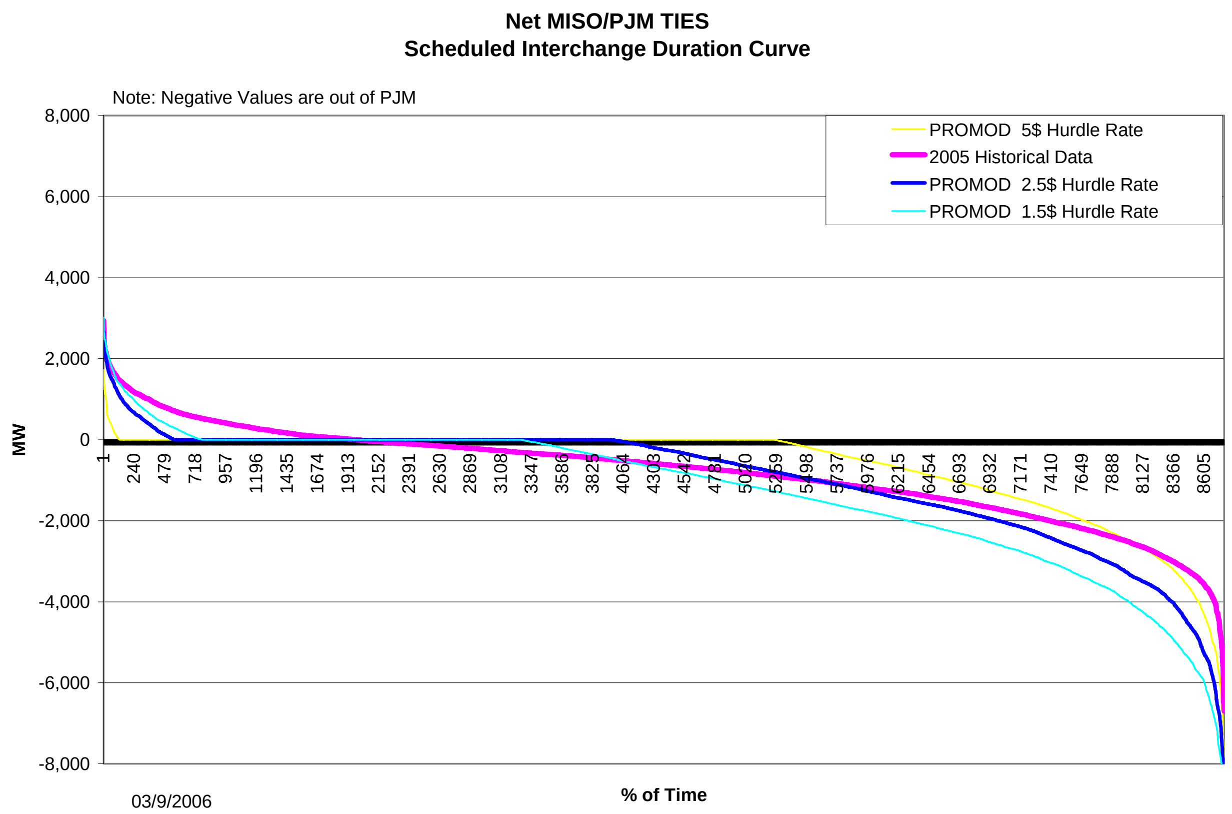

Figure A. 2: MISO/PJM Scheduled Interchange Benchmark

The figure shows that the $ 2.5/MWH hurdle rate case is closer to the historical data. So in LMP and capacity factor benchmark, we will use the $ 2.5/MWH hurdle rate case results.

2.2 Hub LMP Benchmark

Hub LMPs from PROMOD case with $ 2.5/MWh PJM/MISO dispatch hurdle rate and $10/MWh commitment hurdle rate is used to benchmark the Day Ahead ("DA") market data (Jan 2006). The following hub LMPs were collected from the MISO and PJM DA market:

1) Cinergy
2) FirstEnergy
3) Illinois
4) Michigan
5) Minnesota
6) AEP Gen
7) Chicago
8) PJM Western
9) PJM Western Interface.

To evaluate the PROMOD LMPs against the actual DA market results, the following statistic indices are used:

- **Correlation –** The single number that describes the degree of relationship between two variables. For benchmark purpose, the two variables are PROMOD LMP and DA market LMP. The closer the number to 1, the closer the relationship of these two variables has.
    - Significance of correlation: Determines if the probability of correlation is a real one and not a chance occurrence. If we assume correlation of a chance occurrence is not greater than 1%, then the critical value of correlation is 0.188. Therefore if the correlation of the hub LMPs is larger than 0.188, we conclude the correlation is "statistically significant".
- **Average Error –** This is an index widely used to check the quality of forecasted values compared to the true values. For a certain hub, the PROMOD hub LMPs are: P1, P2, …, P744, the DA market hub LMPs are: M1, M2, …, M744, then the Average Error for these LMPs is:

$$AvergeError = \frac{\sum_{i=1}^{744} abs(P_i - M_i)/M_i}{744}$$

The hub LMP benchmarks for these hubs are shown in Figure A.4 – Figure A.12.

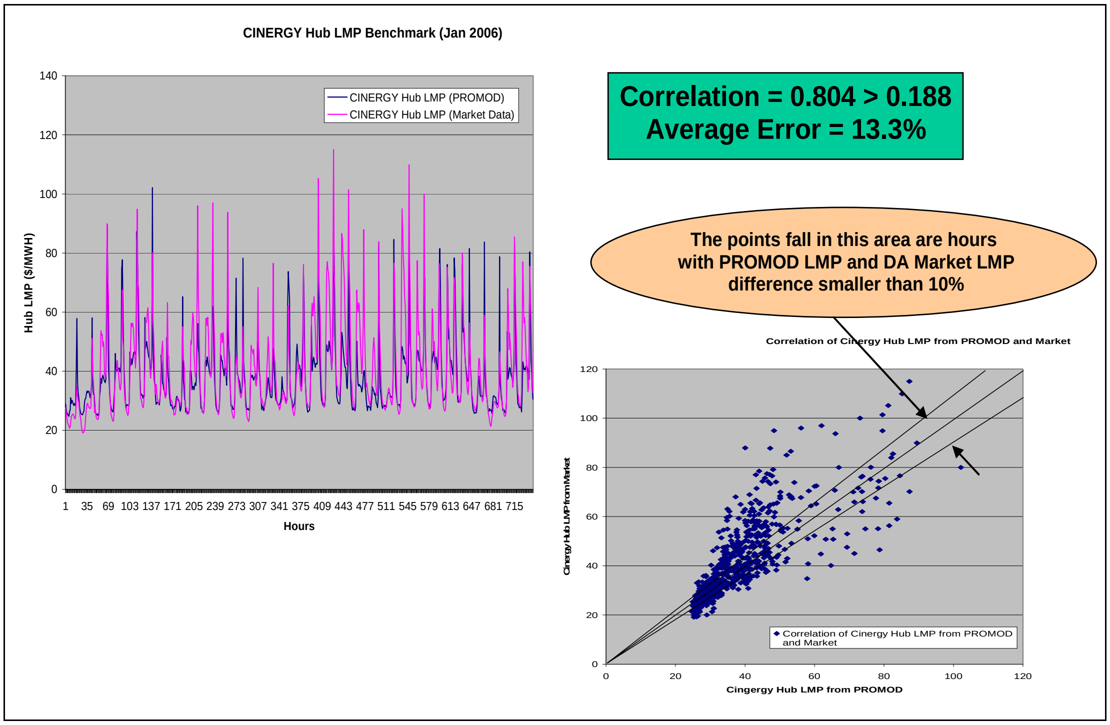

Figure A. 3: Cinergy Hub Benchmark

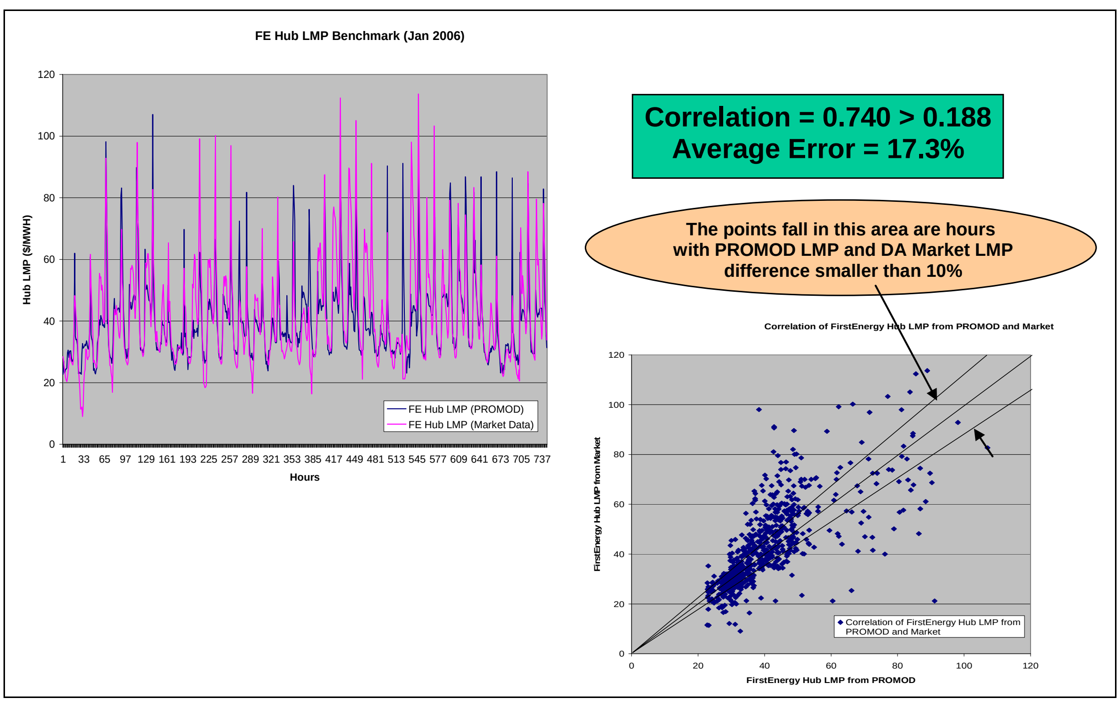

Figure A. 4: FirstEnergy Hub Benchmark

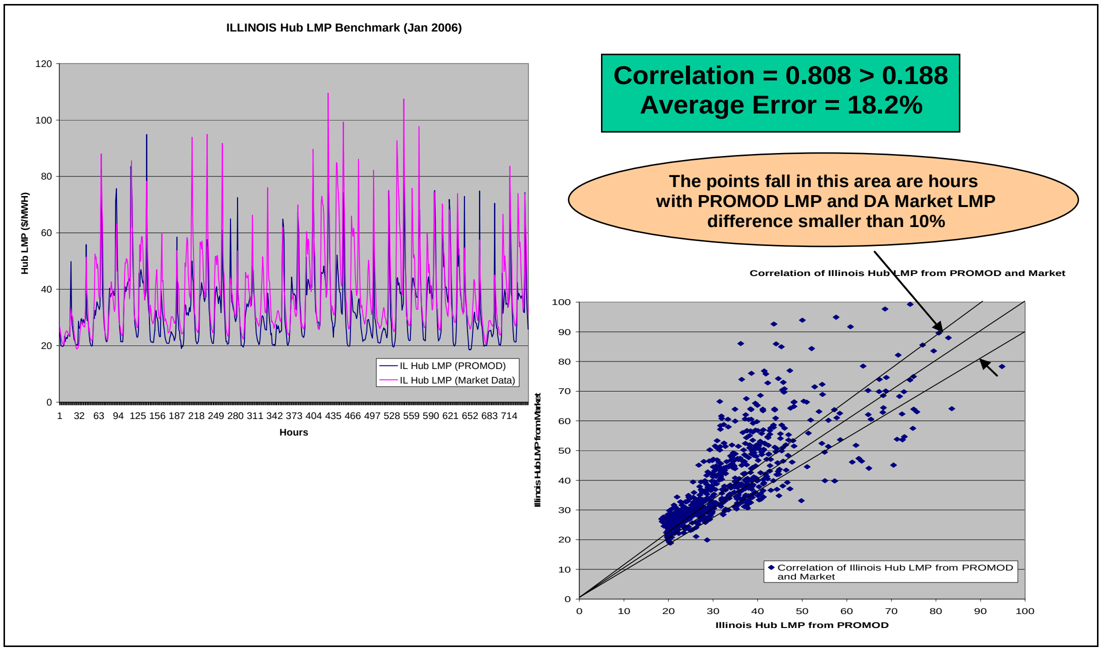

Figure A. 5: Illinois Hub Benchmark

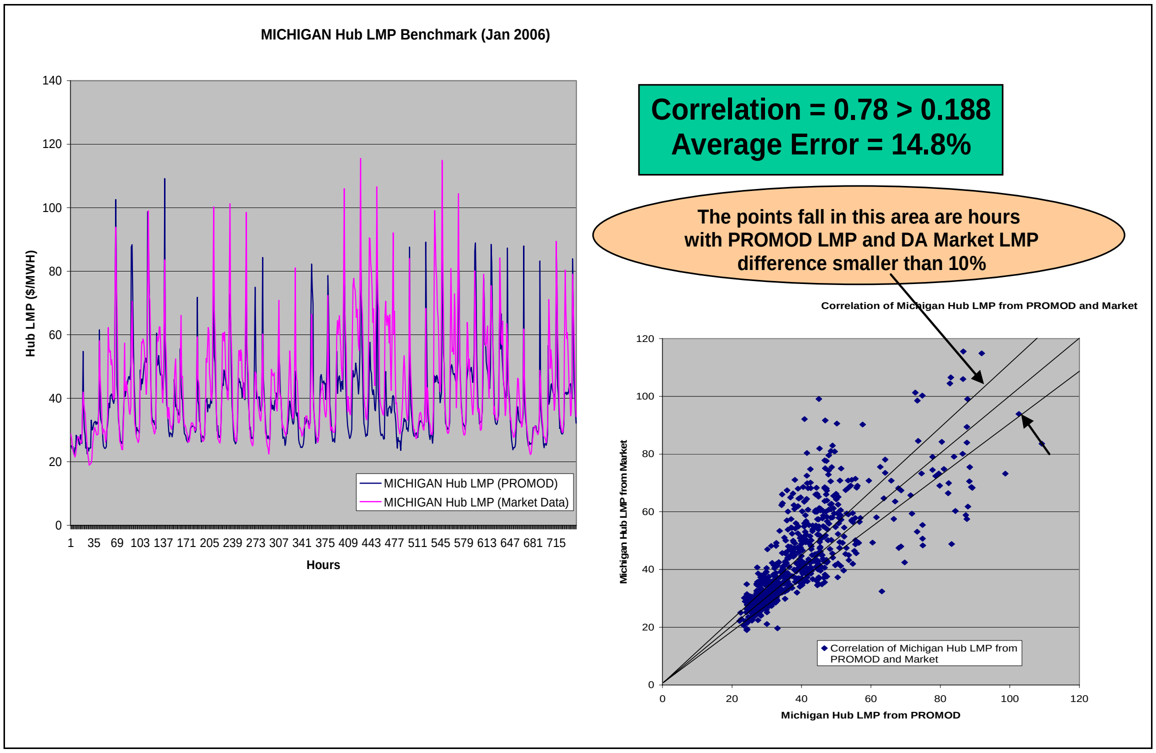

Figure A. 6: Michigan Hub Benchmark

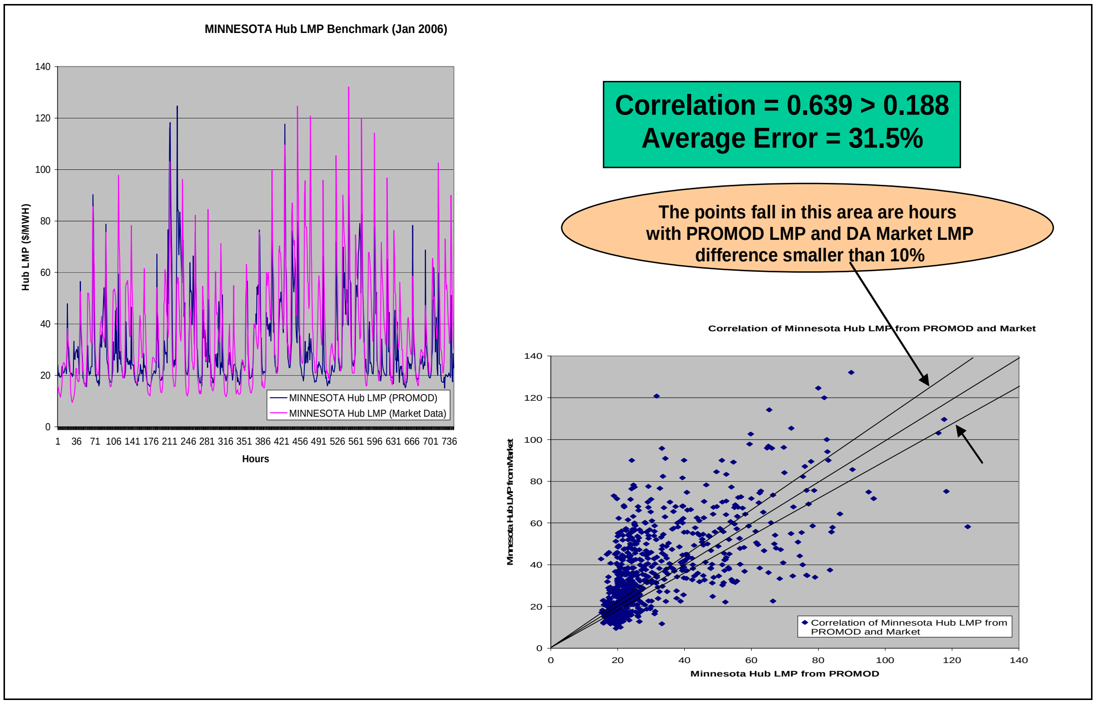

Figure A. 7: Minnesota Hub Benchmark

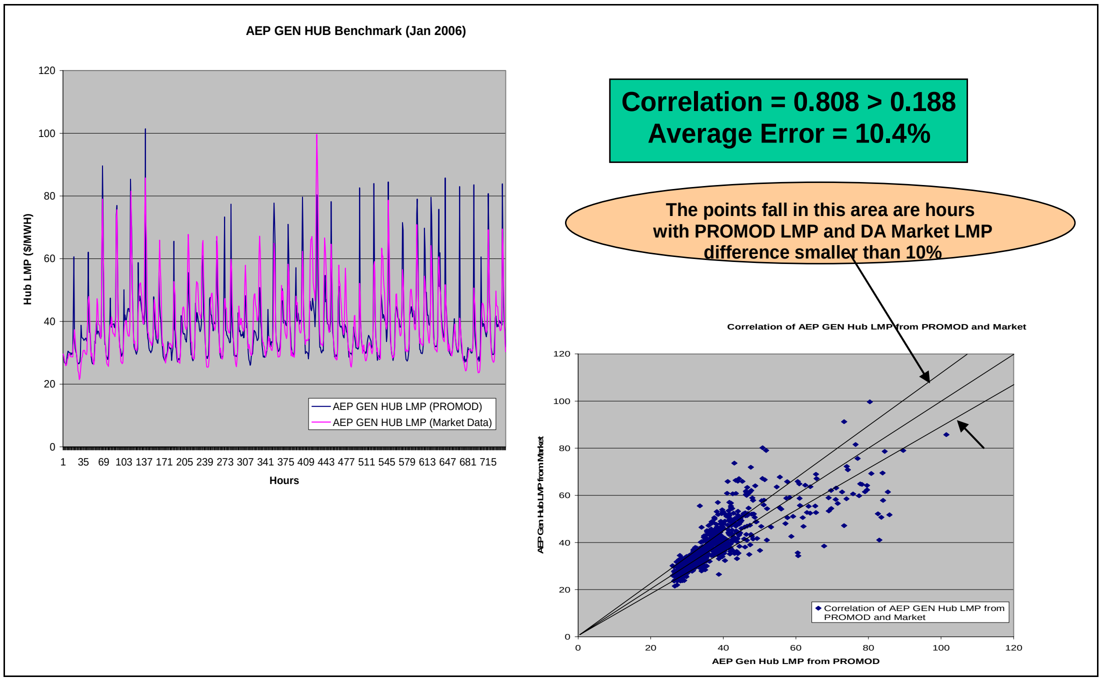

Figure A. 8: AEP Gen Hub Benchmark

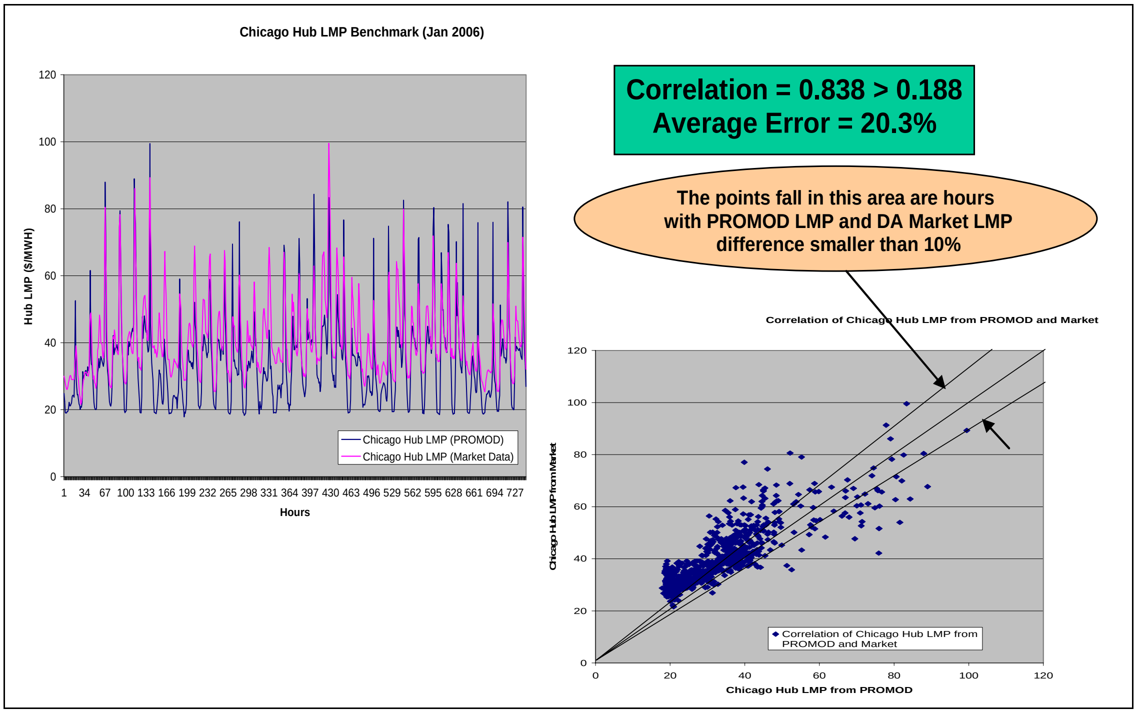

Figure A. 9: Chicago Hub Benchmark

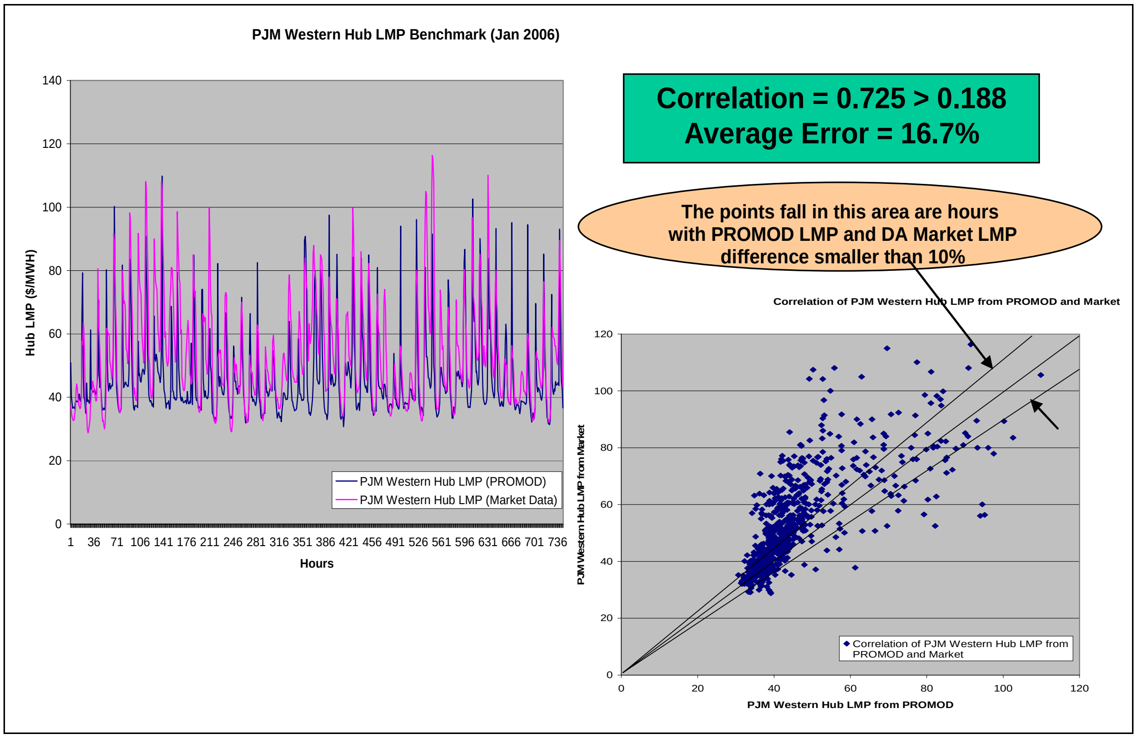

Figure A. 10: PJM Western Hub Benchmark

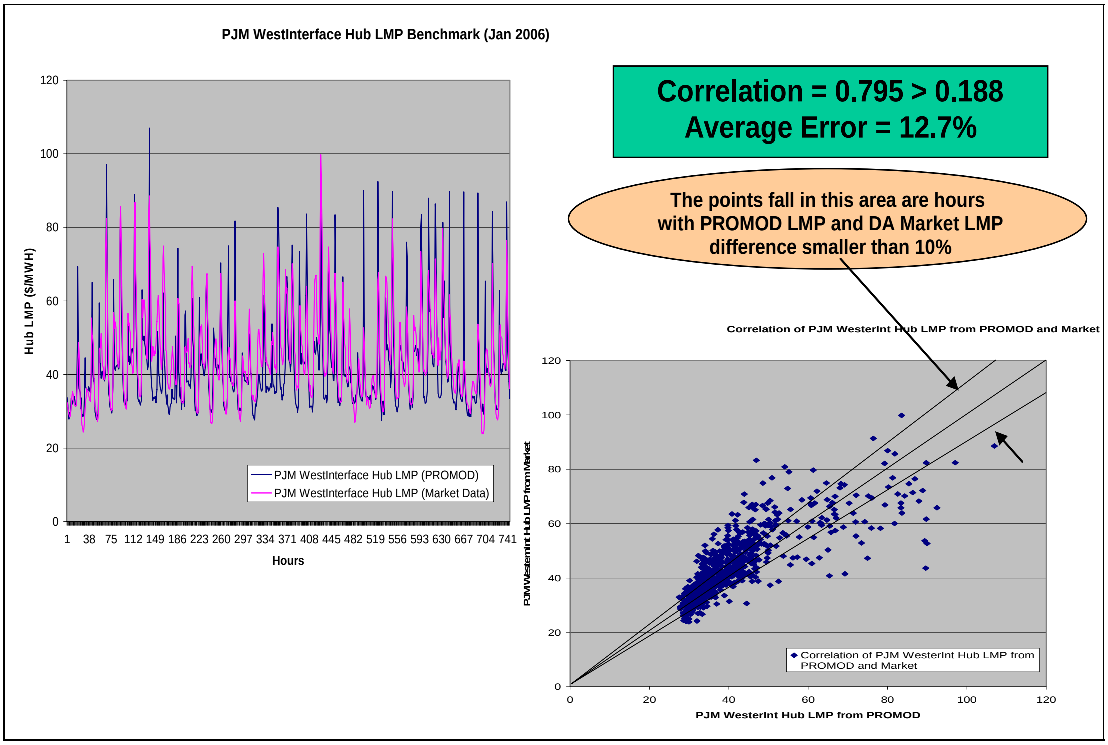

Figure A. 11: PJM Western Interface Hub Benchmark

From these figures and the statistic indices, we can see PROMOD hub LMPs benchmarked well to DA Market LMPs.

2.3 Capacity factors on generator classes

- Nuclear units: Comparing market data with initial PROMOD runs, PROMOD benchmarks well with market data. However, we did not change the outage schedule for nuclear units in PROMOD so that nuclear units were dispatched in more or less the same manner in both market data and PROMOD data, as in quarterly Cost Benefit studies.
- Combined cycle (CC's) units: We found that PROMOD dispatched combined cycle units less when compared to the market data.
- Combustion Turbines (CT's): Consistent with the quarterly Cost Benefit studies, we found that PROMOD did not dispatch CT's to the level found in the market.
- Hydro units: Consistent with the quarterly Cost Benefit studies, we found that hydro units were dispatched more in PROMOD than in the MISO market data. Pumped storage, run-of-the-river and hydro storage constitute the hydro units in PROMOD data.
- Steam turbine Coal units (ST Coal): Steam turbine coal units were split into 2 classes based on their ratings, less than 300 MW class and greater than or equal to 300 MW class. We found that PROMOD over dispatched in at least one class.

Some of the possible reasons include:

1. Units may be assigned to different categories in PROMOD than in the market data. For example, if a unit with 400MW maximum capacity is split into 2 units (200MW, 200MW) in market data, it will be counted in category (<300MW) in DMT data, but be counted in category (>300MW) in PROMOD. Consequently, it is more appropriate to compare the total coal generation rather than by size category.
2. From the designation of jointly owned units (JOU's) in our market data, it was quite difficult to point out in which class of ST Coal units we should assign the market data. Hence we added 85% of JOU energy to ST Coal greater than or equal to 300 MW category, and 15% of them to ST Coal less than 300 MW category. Hence PROMOD and market data dispatches were consistent in that category.

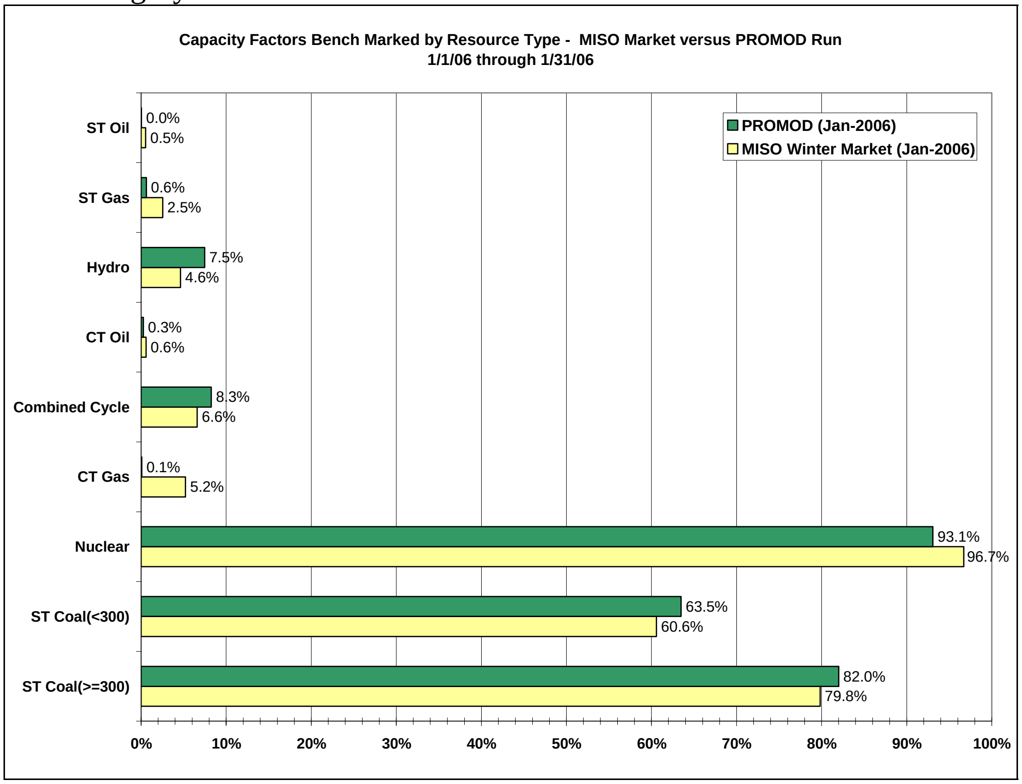

Figure A. 12: Capacity Factor comparison

Based on our quarterly Cost Benefit studies observations, ST Coal units and nuclear units constitute approximately 95% of the total energy in the fall 2005 MISO market. Hence achieving a good benchmark on these units is very important.

2.4 Additional options considered for benchmark

2.4.1 PROMOD "switches":

Couple of adjustments made to the PROMOD "switches" helped us to arrive at a better LMP benchmark. They are:

- Making sure the "bid logic" switch is ON: Bid Logic switch enables us to include start up and no load costs in the unit costs
- Designating that coal and nuclear units would provide spinning reserves, the default was: CT's can also provide spinning reserves (also see the section on "benchmark on units contributing to spinning reserves")

2.4.2 Transmission and Generation Outages

For benchmarking purposes a listing of transmission and generation outages for the period of January 2006 was obtained. There were 35 transmission outages for January 2006 with voltage levels above 138 kV. Incorporating these outages in PROMOD did not change the LMP benchmark and there was a significant increase in PROMOD run times. Hence this option was not used in our benchmark.

Additionally, there was 7,000 MW of coal unit capacity out of service in the January 2006 period. The coal units were either out on maintenance or being forced out. Incorporating these outages in PROMOD did not change the LMP benchmark.