Final Special Report:

Analysis of New England Electric Generators' NO_x Emissions on 25 Peak-load Days in 2005-2009

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Introduction

Annually, ISO New England (ISO-NE) produces the Electric Generator Air Emissions Report (formerly known as the Marginal Emissions Rate Analysis (MEA) Report). That report calculates the prior year's total emissions, and average and marginal emissions rates for NEPOOL generators.[1] At the request of the Environmental Advisory Group (EAG), an advisory group of the ISO's Planning Advisory Committee, ISO-NE conducted a special analysis of marginal NO_x emissions from NEPOOL generators for the five annual highest peak-load days for the years 2005 to 2009.[2] This special report provides the results of this analysis. The report is a one-time supplement to the Electric Generator Air Emissions Report and is intended to serve as a resource for ISO stakeholders.

The analysis determined two sets of results for the 25 peak-load days: 1) total hourly and daily system NO_x emissions and 2) system NO_x emission rates for the top (highest costs) 500 MW block of generators dispatched by ISO-NE to meet peak-demand and that would vary with load (herein referred to as the 500 MW decrement). The analysis also used an alternate method to calculate marginal peak NO_x rates based on the generator(s) that set the energy market's hourly Locational Marginal Price (LMP).[3] The details of this peak NO_x analysis were presented at EAG meetings from June 2009 to December 2010.[4]

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[1] Marginal emission rates are typically the emission rates of the generators that operate at the "margin" or very-end of the system load profile. Various methodologies have been used to determine marginal emissions.

[2] NO_x emissions contribute to ozone formation which tends to be greater on peak electric demand days.

[3] LMP is the energy bid price of the generator(s) that serves the last (highest) MW of the system load in a given time increment usually 5 minutes.

[4] See the EAG meeting materials at this link: http://www.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/eag/index.html.

Peak-Load Days and Generator Emission Rates

The twenty-five peak-demand days used in this analysis are shown in Table 1. The Table shows the following:

- Peak-load for each of the 25 days
- System generation at the peak-load hour
- Peak-load hour
- Temperature at Bradley Airport at the peak-load hour
- ISO generators' NO_x emissions at the peak-load hour
- Hourly peak NO_x emissions for the day if occurring at a different hour than the peak load

The all-time New England peak-demand of 28,130 MW occurred on August 2, 2006, which corresponded to the highest recorded temperature (99°F) at the peak-load hour over the 25 days. The lowest peak daily demand of the 25 days was 23,822 MW. It occurred on August 20, 2009, the lowest recorded temperature (87°F) of all twenty-five days. The highest hourly NO_x emissions of the twenty-five days (13.2 tons[5]) occurred July 27, 2005 at Hour 15[6], a different hour than the all-time peak-load hour (August 2, 2006, Hour 16). The lowest NO_x emissions at peak-load hour were 5.3 tons and occurred on the lowest peak-load day of the 25 peak days, also at Hour 15.

[5] A ton is equivalent to a U.S. short ton, or 2,000 lb.
[6] All numbers given for hours in this report are hour ending.

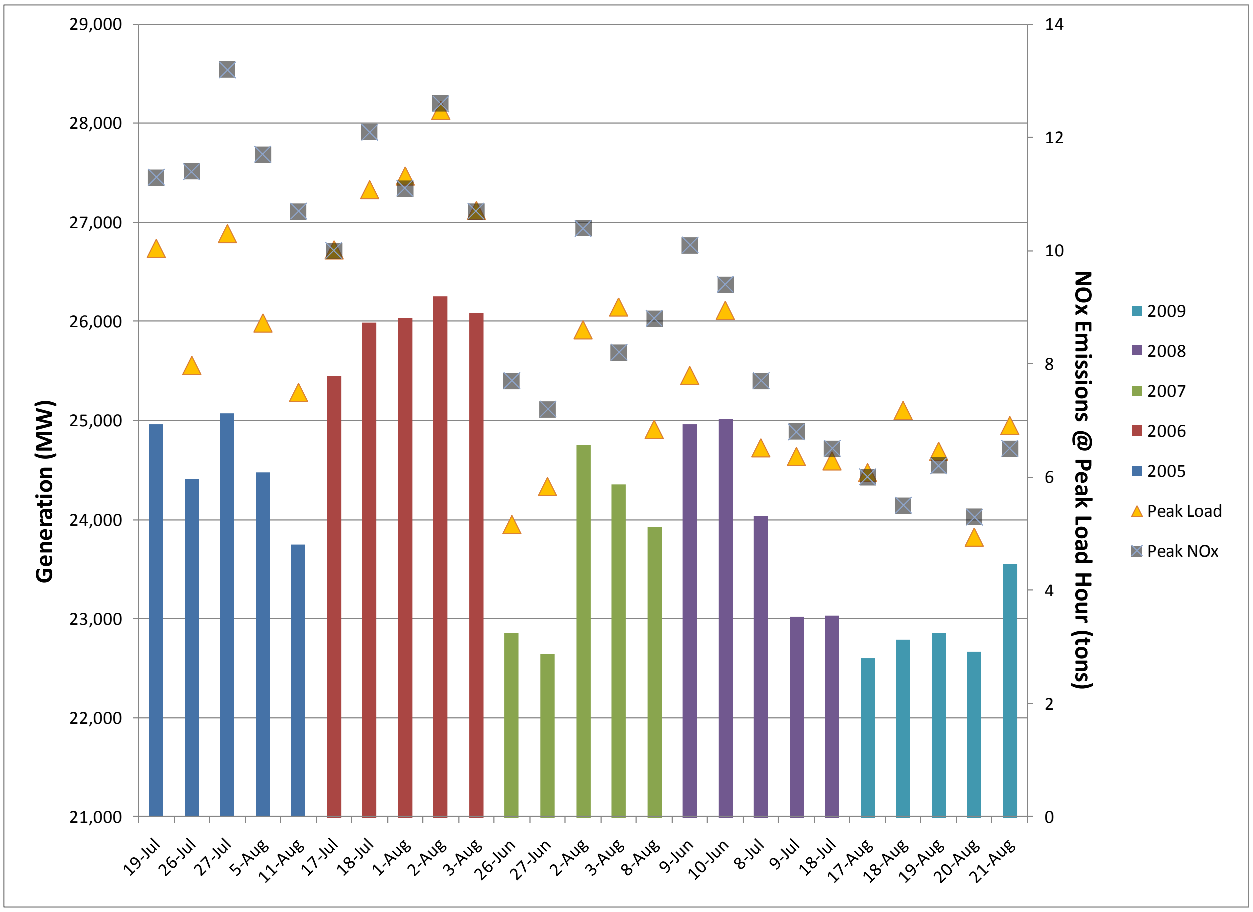
Table 1 – 25 New England Electric Peak-demand Days, Peak Hour Generation and NO_x Emissions

Year	Peak Day	System Peak-demand (MW)	ISO Generation at Peak (MW)	Peak-demand Hour Ending	Temp °F @ Bradley Airport @ Peak-demand	NO_x Emissions @ Peak-load Hour (Tons)	Peak NO_x Emissions* (Tons@Hr)
2005	July 19	26,736	24,966	15	90	11.3*	11.5@17
	July 26	25,555	24,407	17	92	11.4	
	July 27	26,885	25,071	15	94	13.2*	
	August 5	25,983	24,475	15	93	11.7	11.8@16
	August 11	25,282	23,747	16	91	10.7*	
2006	July 17	26,721	25,453	17	94	10.0*	10.1@16
	July 18	27,329	25,988	15	95	12.1*	12.2@16
	August 1	27,467	26,029	17	95	11.1*	11.7@20
	August 2	28,130(highest)	26,251	15	99	12.6*	12.9@17
	August 3	27,118	26,091	14	95	10.7*	11.8@15
2007	July 26	23,948	22,853	17	95	7.7	
	July 27	24,332	22,639	15	94	7.2	7.4@16&17
	August 2	25,914	24,756	17	93	10.4*	10.4@18
	August 3	26,145	24,351	15	93	8.2	9.2@14
	August 8	24,910	23,922	17	94	8.8*	9.3@18
2008	June 9	25,453	24,961	17	94	10.1*	
	June 10	26,111	25,019	17	98	9.4	
	July 8	24,723	24,029	17	89	7.7	7.8@15
	July 9	24,635	23,021	15	88	6.8	
	July 18	24,591	23,027	16	91	6.5*	6.7@17
2009	August 17	24,473	22,596	14	89	6.0*	6.1@16
	August 18	25,100	22,785	15	91	5.5*	5.8@14
	August 19	24,688	22,850	15	88	6.2	
	August 20	23,822(lowest)	22,667	15	87	5.3	
	August 21	24,948	23,551	15	91	6.5	

Note: The difference between the generation at system peak and the system peak-demand is the net imports and settlement-only generation. The latter are typically small generators not dispatched by the ISO but whose energy payments are administered by the ISO.
*Omitted if same hour as peak-load.

Figure 1 shows similar data as in Table 1: the 25 peak-day peak-hour loads (triangles), the corresponding ISO generation (bars) and the system NO_x emissions (squares) at the time of the peak-load hour. The figure shows that the generation at peak-load varies similarly as the peak-load varies. The system NO_x emissions generally show some correlation with the peak generation pattern, but not for all of the days. On June 10, 2008 and August 18, 2009 comparison with the previous peak day (which is also the previous calendar day) shows generation following a different trend than emissions.

Figure 1 – ISO New England 25 Peak-loads (triangles), ISO Generation (bars) and Peak Hour NO_x (squares)



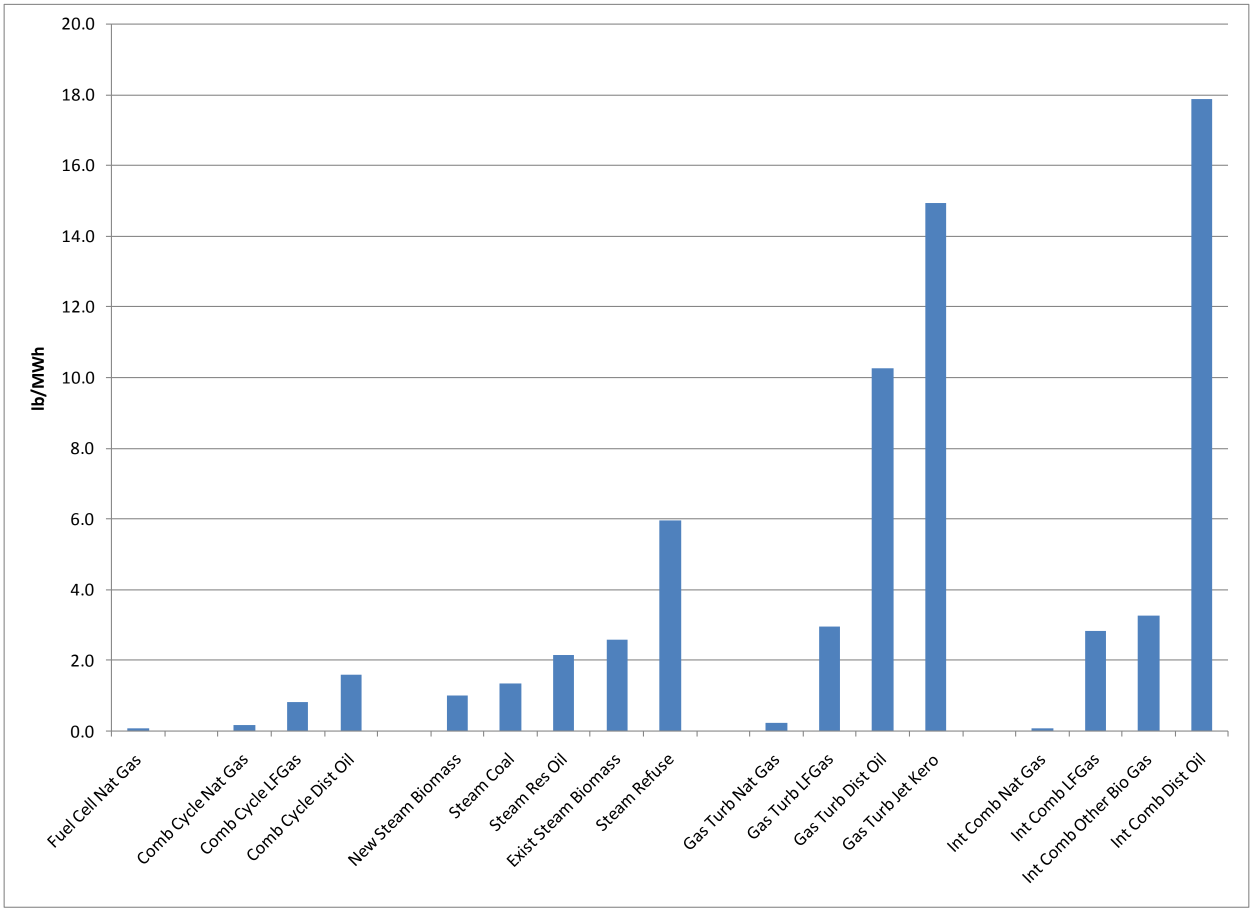
For the first set of results, which are system NO_x emissions on the 25 peak-demand days, the analysis used the hourly emissions data from EPA's Clean Air Markets Database for the generators greater than 25 MW.[7] Supplementing this data, ISO approximated emissions for smaller generators using the product of ISO proprietary emissions rates and hourly MW output. The second set of results, NO_x emissions for the 500 MW decrement, used output (MW) based on generators' hourly ISO Energy Market bid data on the peak days and ISO proprietary emission rates. Both sets of results used ISO hourly generation data for all generators.

To illustrate general differences among types of fuel and generator technologies, Figure 2 shows the ISO generators' emission rates used in the analysis aggregated into combinations of fuels and technologies.

[7] "Clean Air Markets- Data and Maps," US EPA, http://camddataandmaps.epa.gov/gdm/index.cfm?fuseaction=emissions.wizard.

The rates are a MW-weighted average of all the generators within a given fuel and technology combination, e.g. combined cycle natural gas.[8] The fuel and technology combinations with the highest NO_x emission rates were internal combustion engines fueled with distillate oil, gas turbines using jet fuel or kerosene and distillate oil, and steam refuse plants. The graph suggests these generation-fuel combinations with higher emission rates likely contribute to the marginal emissions on peak-load days.

Figure 2 – ISO-NE MW Weighted-Average NO_x Emissions Rates by Generator Fuel Types

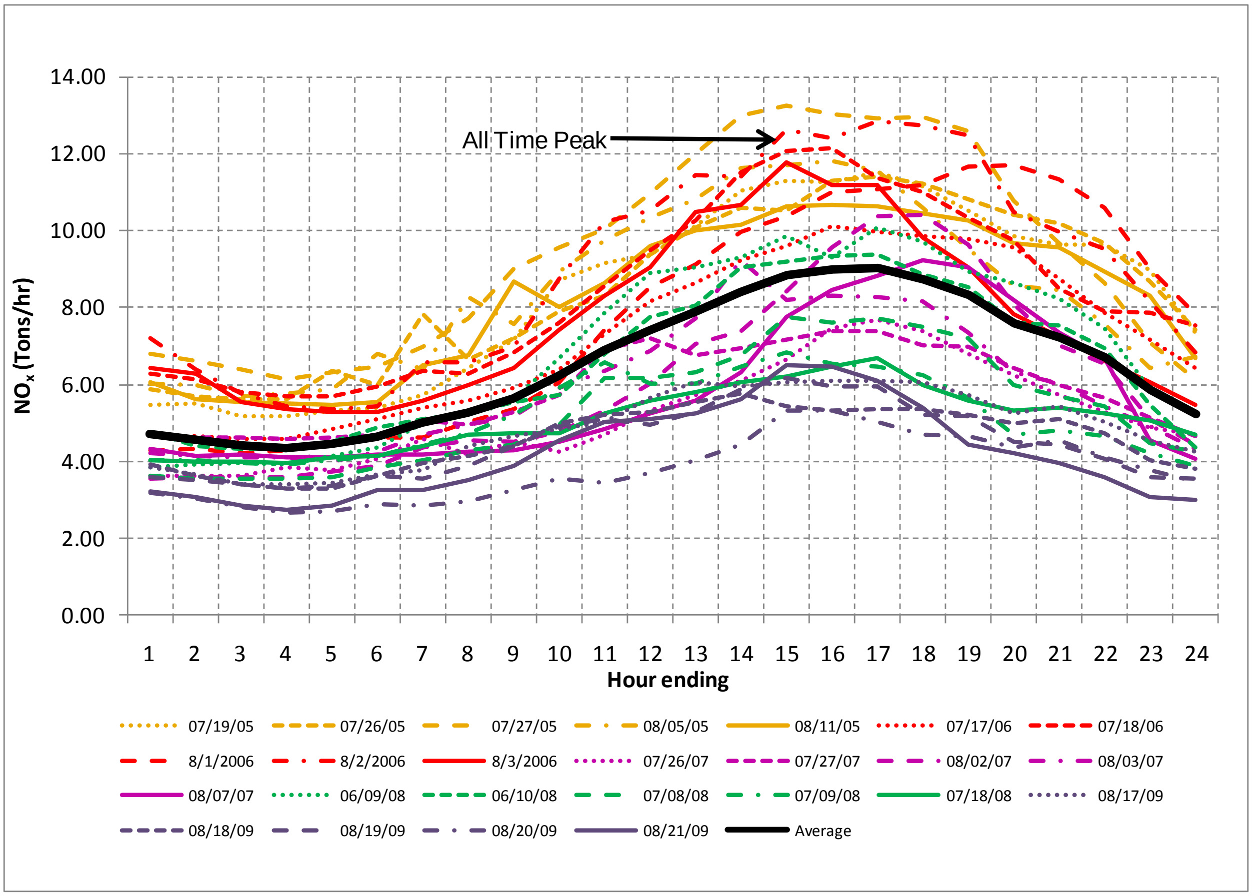


[8] The weighted average rates are the sum of the NO_x rates times the MW of each generator within a combination of fuel and technology, divided by the total MW of the generation in that combination.

System NO_x Emissions on Peak Days

ISO developed the total system hourly NO_x emissions for the ISO administered New England (NEPOOL) generators for the 25 peak-load days. These emissions are shown graphically in Figure 3. These NO_x emission profiles were developed using generator air emissions data from the U.S. EPA Clean Air Markets Division database and ISO sources.[9] Using these two sources, ISO-NE calculated hourly system generators NO_x emission profiles (in tons/hour) for the twenty-five peak-demand days (2005 - 2009) shown in the figure. The highest system peak hourly NO_x emissions were 13.2 tons, which occurred on July 27, 2005 at hour 15. On the all time peak-load day of August 2, 2006, the highest hourly system NO_x emissions were 12.9 tons at hour 17, while at the peak-demand hour 15 they were 12.6 tons. The average curve shows the result of averaging emissions for each hour over the twenty-five days.

Figure 3 – New England Generation Hourly NO_x Emissions on the Five Highest Yearly Peak-load Days (2005-2009)



[9] A comparison of results using an ISO emissions rate only method and using the combined ISO and EPA data method used in this report may be found in EAG meeting materials for October 16, 2009 at http://www.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/eag/mtrls/2009/oct162009/index.html.

Figure 4 – New England Generation Cumulative Daily NO_x Emissions on the Five Highest Yearly Peak-load Days for Years 2005 – 2009

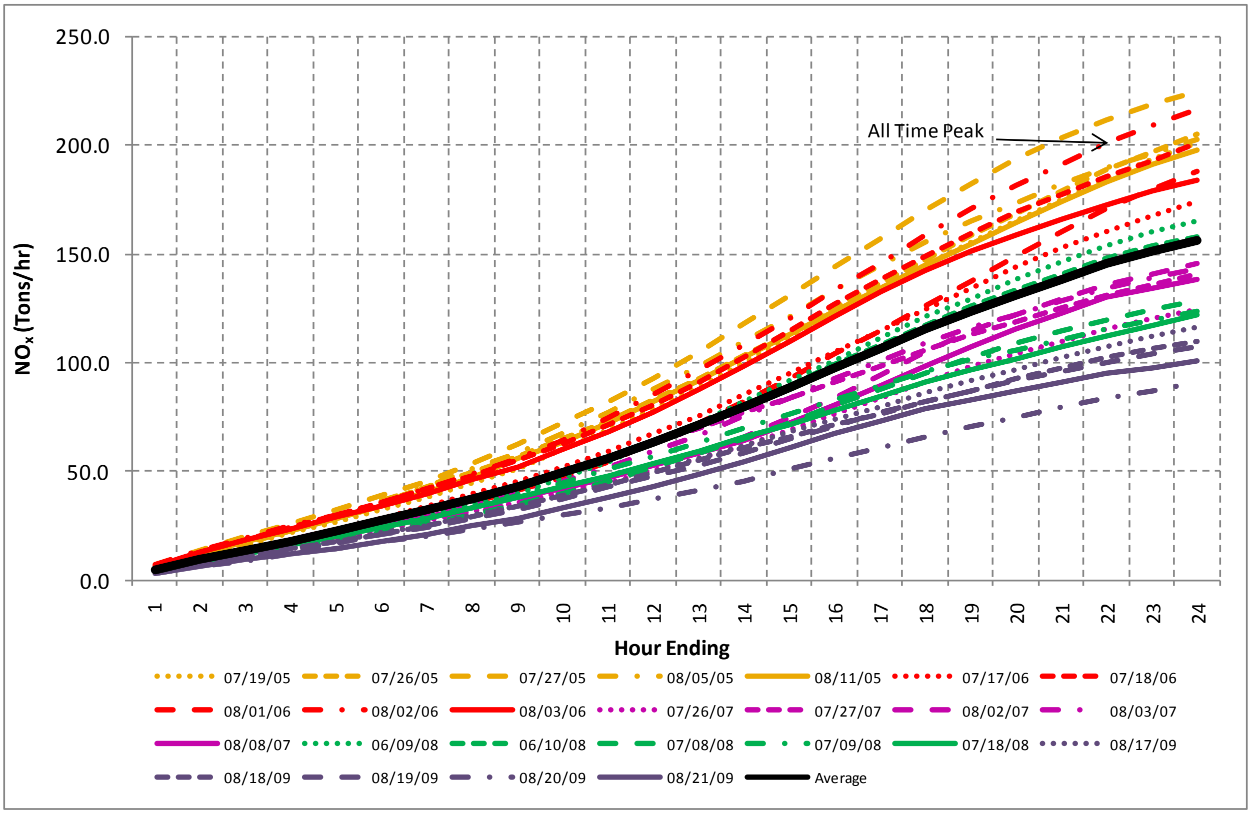


Figure 4 shows the 24-hour system cumulative NO_x emissions for each of the 25 peak-load days. The total daily NO_x emissions ranged from 90 tons on August 20, 2009 to 225 tons on July 27, 2005. On the all time peak-load day (August 2, 2006) the daily NO_x emissions were 216 tons[10].

[10] If the NO_x air emissions from regional emergency generating resources, which ran only on the all-time peak day of August 2, 2006, were also included, ISO estimated that they would add approximately 3 tons during the peak hour and approximately 12 tons to the total daily NO_x emissions for that day.

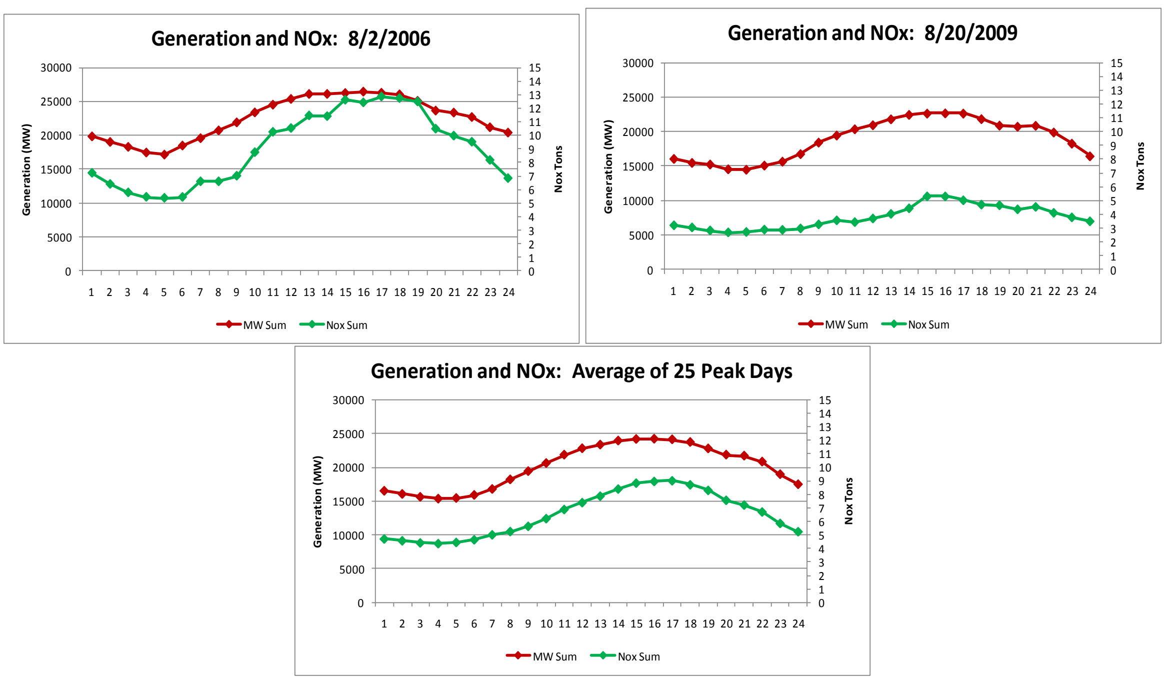
Hourly System Generation and NO_x Emissions on Selected Peak Days

This section shows the relationship between NO_x emissions and generation on specific peak days that is suggested by the preceding peak-day hourly emissions curves (Figure 3) and the fuel types contributing to both. This relationship is best seen when emissions and generation are graphed together over the course of the day.

Figure 6 presents the system hourly NO_x emissions and generation curves for the highest and lowest peak-load days of the 25-day sample. These are August 2, 2006 and August 20, 2009 respectively. The figure also presents the hourly average for all twenty-five days.

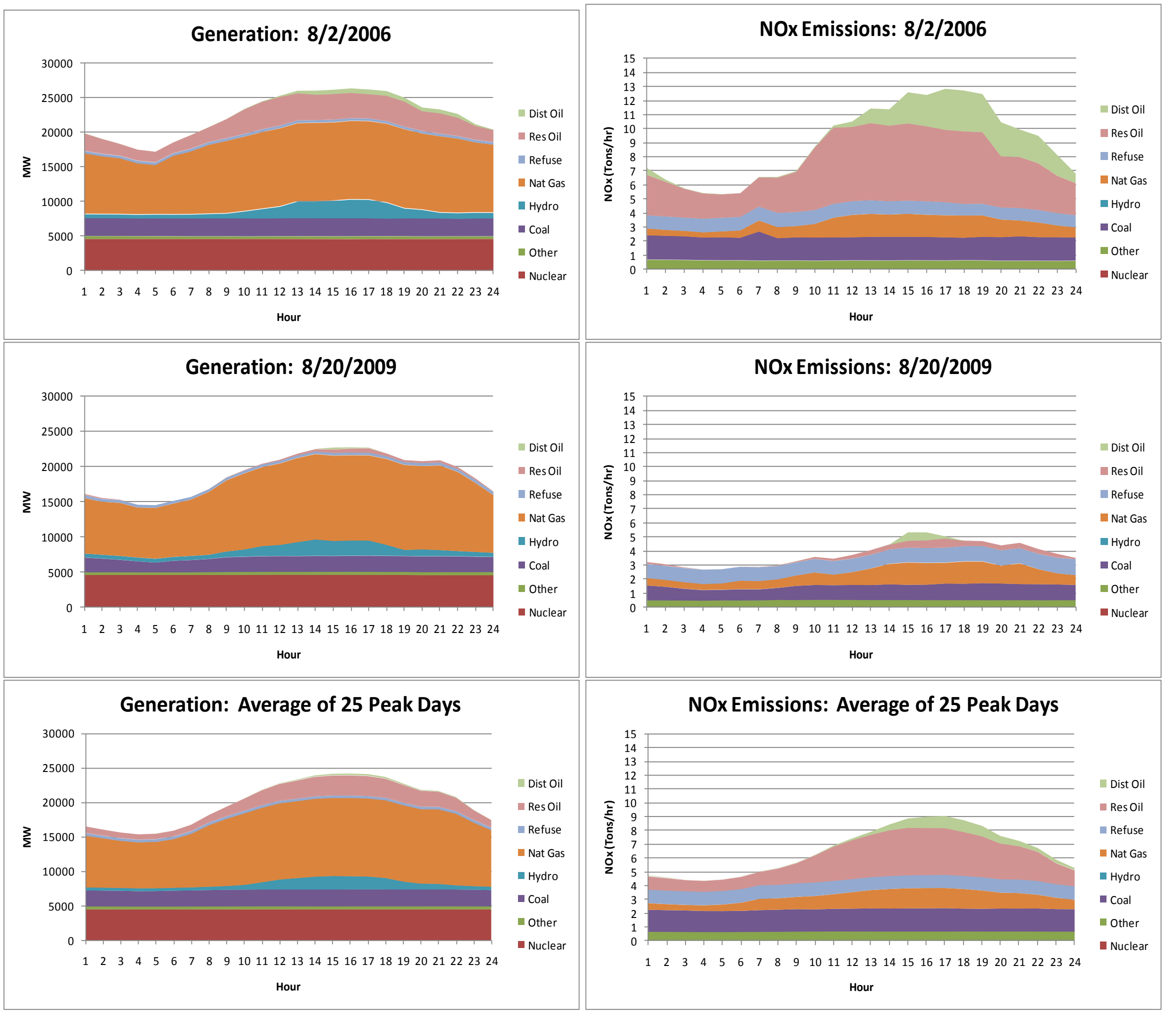
These profiles show a fairly clear correlation of how NO_x emissions vary with the level of generation. On the all-time peak day (August 2, 2006), the graph shows that the hourly NO_x increased more rapidly approaching the peak hour than did the increase in generation.

Figure 5 – Generation and Emissions Curves for Highest, Lowest, and Average Peak-load Days



To see better the relationship between emissions and fuel types in use in the system, the graphs in Figure 5 have been modified to show the types of fuel used by the generators and their associated emissions. For the figures in this section, the fuel types have been developed by grouping the primary fuel category recorded for each asset in the CELT report into more general types.[11] The resulting graphs for the highest, lowest, and average peak-days are presented in Figure 6.[12]

Figure 6 – Generation and NO_x Emissions by Fuel Type: Highest, Lowest, and Average Peak-load Days



The results reflect the wide variations in emission rates among the various types of fuels and generators (see Figure 2). The graphs show clearly the dominant role that residual and distillate oil generation have in NO_x emissions on peak-load days compared to their energy contribution. During the all-time peak hour, natural gas provided 11,349 MWh of energy and emitted 1.65 tons of NO_x, while distillate oil generated only 637 MWh but emitted 2.22 tons. Similarly, on the lowest peak-load day, natural gas

[11] *2011-2020 Forecast Report of Capacity, Energy, Loads, and Transmission*, (Holyoke, MA: ISO New England, April 2011), http://www.iso-ne.com/trans/celt/report/index.html. Earlier reports, archived at the same site, were consulted for assets no longer listed in the CELT. Three fuel types in the following figures represent multiple CELT categories: "other" includes solar, wood, wood waste, tire-derived fuels, biomass gas, wind, and black liquor, "refuse" includes both municipal solid waste and landfill gas, and "dist oil" combines kerosene, jet fuel, #2 fuel oil, and distillate fuel oil.

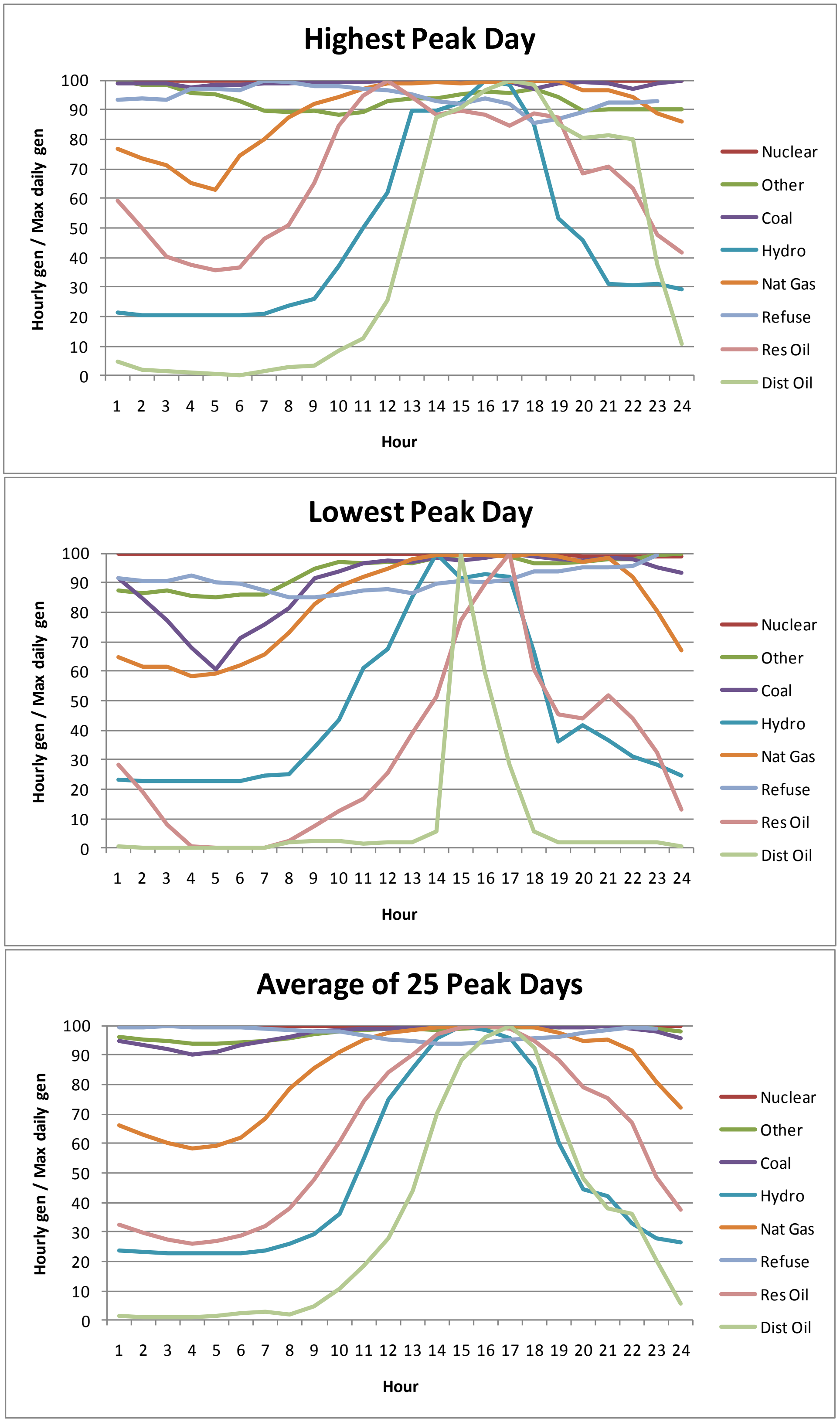
[12] The graphs for all the 25 days are posted at: http://www.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/eag/usr_sprdshts/index.html

generation provided 12,112 MWh and emitted 1.61 tons of NO_x, while distillate oil generation provided 252 MWh and emitted 0.61 tons of NO_x.

To examine loading of generation types over the day, Figure 7 shows the generator output in each hour divided by the maximum hourly generation output for that type in the day. The figure shows how the fuel types varied in their output over the 24 hours of the day, normalized to their maximum output during the day. Natural gas showed some reduced generation during non-peak hours, but typically continued to provide at least 50% as much output as in the peak hour. On the all-time peak day, hydroelectric generation fell below 50% at hour 20 and distillate and residual oil at hour 23. On the lowest peak day, hydroelectric fell below 50% in hour 19, distillate oil in hour 16, and, similarly, residual oil in hour 19.[13]

[13] On the low-peak day, residual oil returned to 52% of its maximum output for the day in hour 21 after two hours around 45%.

Figure 7 – Generation by Fuel Type as a Percentage of its Maximum Hourly Output



Creation and Analysis of the 500 MW Decrement of Peak Generation

The second set of results in this peak NO_x analysis was based on determining the NO_x emissions associated with the generation dispatched to meet the highest 500 MW system load decrement. This decrement was analyzed each hour of the 25 peak-demand days examined in this analysis.

Within any hourly 500 MW generation decrement, there can be generators that do not vary with changes in system demand. These may include hydro, generators running for transmission constraints, and self scheduled generators. Given that the objective of this analysis was to determine incremental system NO_x emissions from generators that serve load changes, four sequential adjustments were made to obtain a truly variable 500 MW dispatch block (within the highest cost portion of the hourly bid stack). The adjustments consisted of removing, one category at a time, this non-varying generation until all the non-varying MW were removed. This required going down the bid stack of the marginal generation until an approximately 500 MW decrement was obtained that reflected *only* generation that would vary with load. If system load increased or decreased, this resulting 500 MW is the generation that would increase or decrease with load changes. It would consist of thermal generation that has this capability, typically fueled by oil or gas. Then a marginal NO_x emissions rate could be calculated from the generators within this "adjusted" decrement. The Appendix provides a more detailed description of the creation of the 500 MW decrement.

After making the adjustments, ISO's analysis of this 500 MW "adjusted" decrement revealed that the average peak-load hour NO_x emission rate for the twenty-five peak-demand days was 1.15 tons per hour, or 4.4[14] lbs per MWh. These peak NO_x emission rates occurred during the peak-demand-day hours 15 to 18. Similarly, the lowest load hours occurred during the peak-demand day hours 3 to 5. The analysis of NO_x emissions during the low-load hours yielded an emissions rate of 0.14 tons per hour, or 0.47 lbs per MWh. Summing over twenty-four hours, the total NO_x emissions for the 500 MW decrements ranged from 3.6 tons to 27.2 tons for the twenty-five peak-demand days.[15]

To show emission behavior of the 500 MW decrement over the course of a typical day, the average hourly NO_x emission rates for the 500 MW decrement for each of the five years are shown in Figure 8, as well as the average for all five years together.

[14] The lb/MWh rate is roughly four times the tons/hour rate (2000tons/lbs x 1/500 MW), but may differ due to the actual size of the 500 MW decrement. The rate calculations in lb/MWh throughout this report use the actual size of the decrement.

[15] See Table 2 and hourly data on the spreadsheet posted on EAG site at http://www.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/eag/usr_sprdshts/index.html for further information.

Figure 8 – New England Generation Hourly NO_x Emission Rates for a 500 MW Decrement of Thermal Generation Averaged Yearly for the Five Peak-load Days

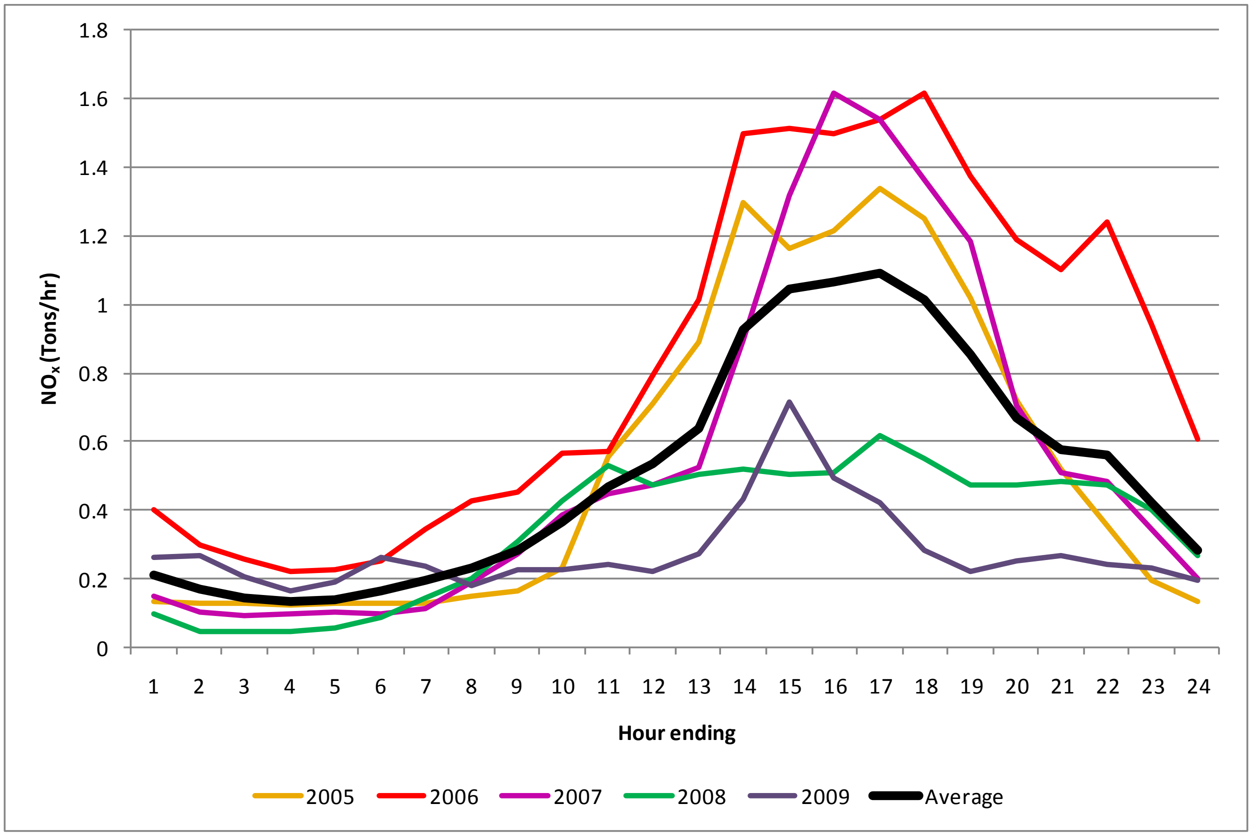


Figure 9 is similar to Figure 8 but shows the hourly NO_x emissions for all 25 peak-demand days. One can see the high variability in the NO_x emission rates over the 25 days: i.e., 0.14 to 2.8 tons per hour (or 0.45 to 11.0 lb/MWh) during the peak hours. This was caused by the varying peak loads and, correspondingly, varying generation levels as seen in Table 1. Also, differences in the specific generation running on a given peak day and hour (see Figure 2) due to economics and system conditions could contribute to this variation in NO_x rates. The difference in total system generation among the 25 peak-load days from the lowest to highest day was about 3,684 MW (see Table 1).

Figure 9 – New England Generation Hourly NO_x Emission Rates for a 500 MW Decrement of Thermal Generation for the 25 Peak-Load Days

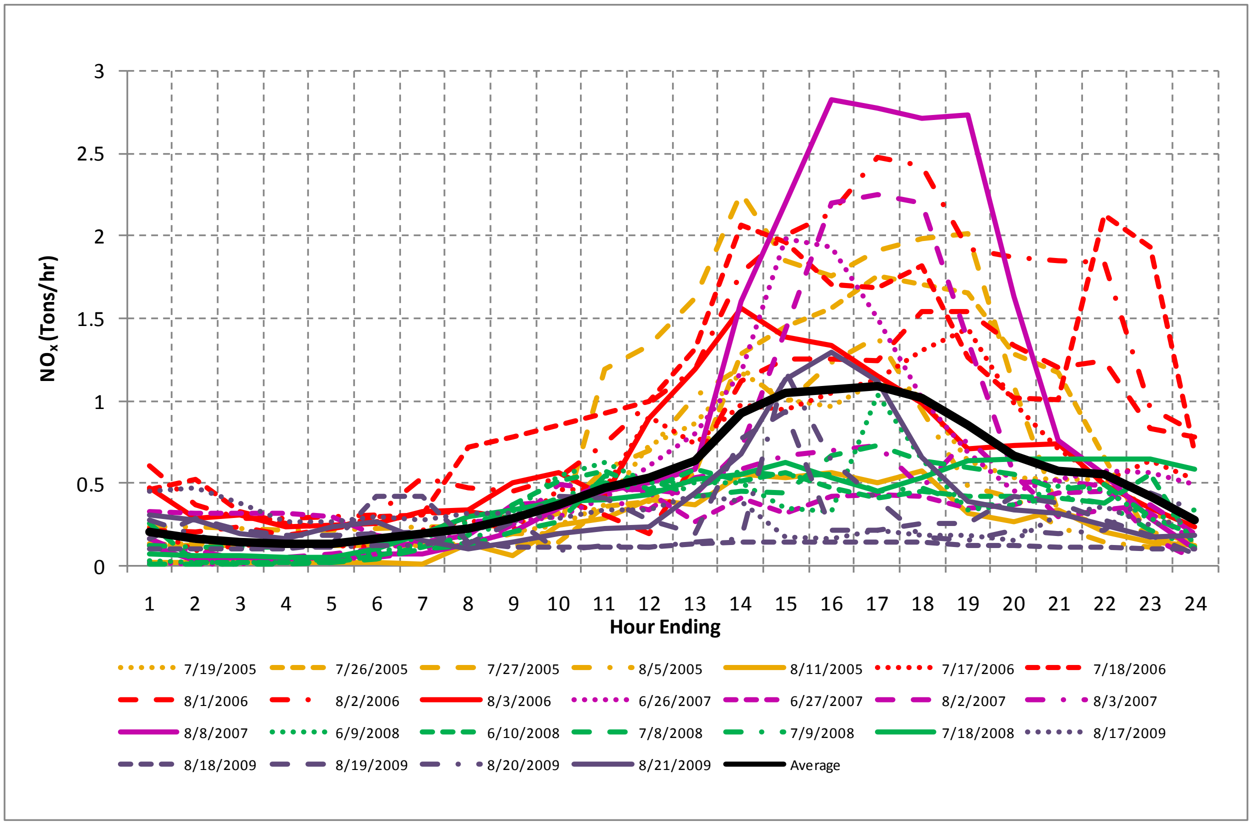
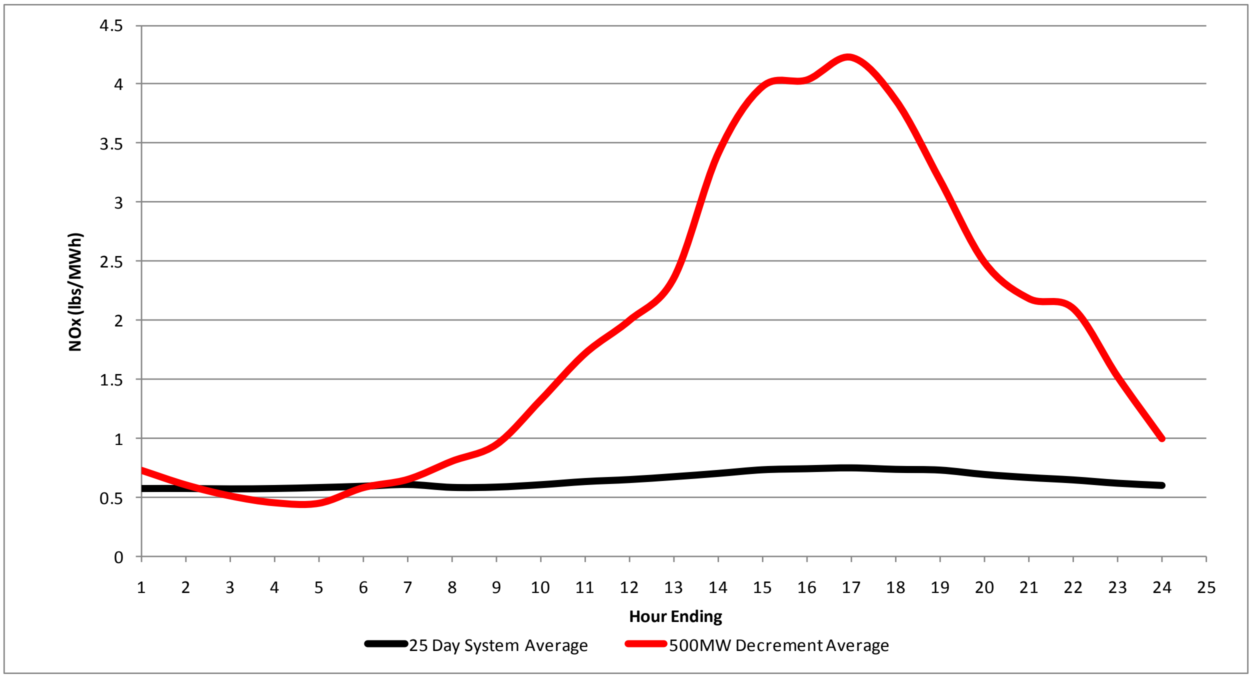


Figure 10 shows a lb/MWh based comparison of the average hourly NO_x rate for the total system generation over the 25 peak days, versus the average NO_x rate for the 500 MW decrement also over the 25 peak days. These curves are generated from the average emissions at each hour over the twenty-five days for total generation and for the top 500 MW of generation. The figure shows that the average historical NO_x emission rate for the 500 MW decrement is about six times the average total system NO_x emissions rate at the same peak average hour (17).

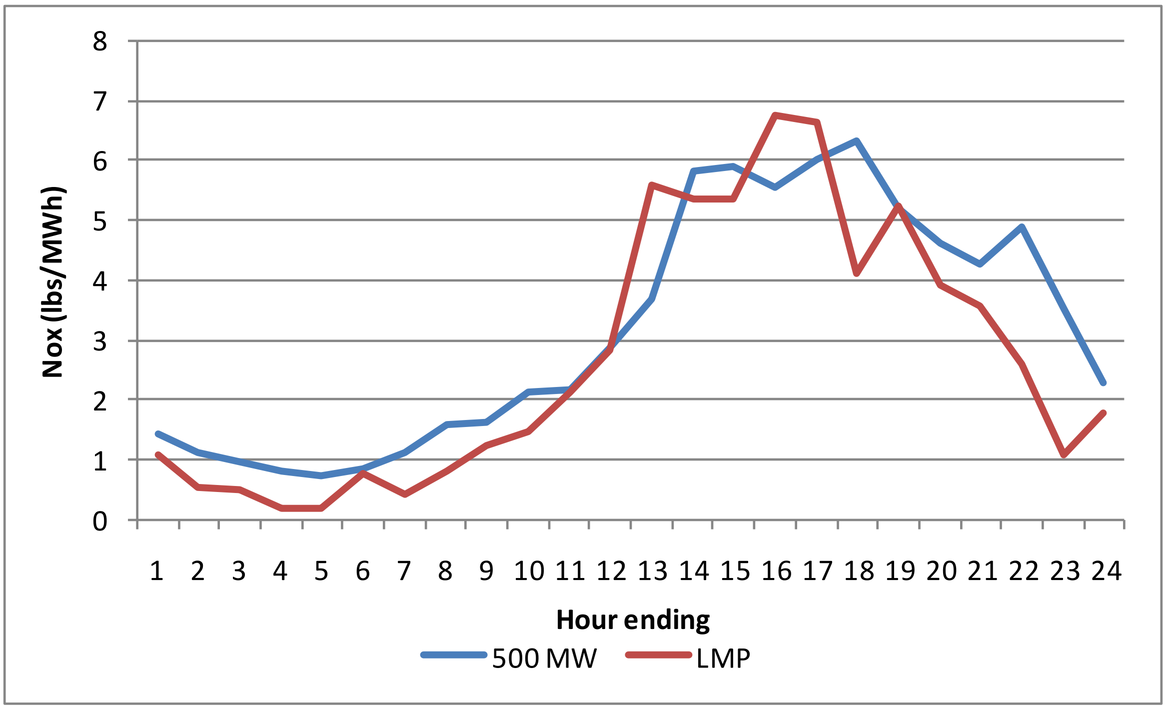
Figure 10 – Comparison of Average Hourly NO_x Emission Rates: Total System vs. 500 MW Decrement



An LMP Calculation Method of Peak Day NO_x Marginal Emission Rates

ISO-NE also performed an alternative marginal emissions calculation using a method based on the LMP generation. The results of this method were compared to those of the 500 MW decrement method discussed above. The LMP calculation determined the NO_x emission rates for a one (1) MW reduction of the generator(s) identified as setting the hourly LMP. The calculation was performed for the five peak-demand days for 2006 and the results are shown in Figure 11. The figure compares the average LMP marginal method results to the results of the 500 MW decrement method for 2006. While the results of the LMP marginal methodology appear to be similar to the results of the 500 MW decrement methodology, the LMP produced slightly lower NO_x rates for all but three hours.

Figure 11 – Comparison of the LMP and the 500 MW Decrement Marginal Calculation Methods for the Average Hourly NO_x Rates of the Five Peak-Demand Days in 2006



Summary

The peak-demand day NO_x emissions analysis provides a number of results for the New England generators' NO_x air emissions during twenty-five summer peak-demand days from 2005 to 2009. These results included analyzing NO_x emissions for: 1) the total New England system generation, 2) a 500 MW generation decrement over all hours on the 25 peak days, and 3) using the LMP price for a 1 MW decrement on the five peak days of 2006. To facilitate comparison of the results from these methods, a summary of some key values calculated from the hourly data[16] used for the previous graphs is given in Table 2. The table also includes NO_x rates calculated in ISO's 2009 Electric Generation Air Emissions Report (EGAER) for reference.

For the peak-day results, average peak-demand hour NO_x emissions have been calculated from the emissions at each of the daily peak-demand hours during the period, as listed in Table 1. The average hourly value is for all hours in the twenty-five days, while Low and High Demand Hours represent average hours three to five and 15 to 18 only. The conversion from tons/hr to lbs/MWh uses the actual size of the 500 MW decrement, and thus varies slightly from the expected conversion factor of four (See footnote 14). The LMP calculation explored as an alternative method for peak day emissions calculation included only 2006 peak days, so for comparison the 2006 data for the 500 MW decrement is presented.

Table 2 – Summary of Key Results of ISO-NE's Peak-demand Day NO_x Analysis

NO_x Emissions on 25 Peak Days: 2005-2009 (Tons/hr)			
	EGAER- Annual Average[17]	Peak Days- All Generators	Peak Days- 500 MW Decrement
Average Peak-demand Hour		9.07	1.15
Average Hour	4.47	6.52	0.51
Average (Low Demand Hrs)[18]		4.4	0.14
Average (High Demand Hrs)[19]		8.9	1.05

NO_x Emissions on 25 Peak Days: 2005-2009 (Lbs/MWh)			
	EGAER- 2009 Ozone Season Marginal[20]	Peak Days- All Generators	Peak Days- 500 MW Decrement
Average Peak-demand Hour		0.75	4.4
Average Hour		0.64	1.88
Average (Low Demand Hrs)[21]	0.13	0.58	0.47
Average (High Demand Hrs)[22]	0.17	0.74	4.02

[16] Spreadsheet posted on EAG site: http://www.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/eag/usr_sprdshts/index.html.
[17] This value has been calculated from Table 5.2 of the *2009 ISO New England Electric Generation Air Emissions Report* by dividing the sum of NO_x emissions during the five-year period by the number of hours in the period.
[18] For the calculation of the peak-demand averages, hours 3 to 5 were used as the low demand hours.
[19] For the calculation of the peak-demand averages, hours 15 to 18 were used as the high demand hours.
[20] See Table 1.2 of the *2009 ISO New England Electric Generation Air Emissions Report*.
[21] For the EGAER figures, the low demand figure is that for off-peak hours (10 P.M. to 8 A.M.)
[22] For the EGAER figures, the high demand figure is that for on-peak hours (8 A.M. to 10 P.M.)

Comparison of LMP to Decremental Emissions for2006 (Lbs/MWh)		
	2006 Peak Days- LMP Method	2006 Peak Days- 500 MW Decrement
Average Peak-demand Hour	8.37	6.05
Average Hour	2.67	3.13
Average (Low Demand Hrs)	0.29	0.83
Average (High Demand Hrs)	5.72	5.94

The following summarizes the key results of ISO's calculations for the ISO's generation's system NO_x emissions for the 25 peak-demand days:

- Total system NO_x emissions during the hours 14 to 18 for the peak 25 days ranged from 6 tons to 13 tons per hour (see Figure 3) and the average for the peak load hours was around 9 tons (Table 2). The system NO_x emissions on the all-time peak-demand day (August 2, 2006) at the peak-demand hour were approximately 12 tons. However, another peak day, July 27, 2005, had slightly higher NO_x emissions during its peak-demand hour.
- Over 24 hours the cumulative system NO_x emissions varied from 90 tons to 225 tons (Figure 4) for the 25 peak days.
- The average peak-load hour NO_x rate over the five years (for the 25 peak-load days) for a 500 MW generation decrement was 4.4 lbs/MWh. This average NO_x emission rate is over twenty-five times higher than the 2009 average New England generation on-peak ozone season NO_x rate of 0.17 lbs/MWh, calculated in the 2009 ISO-NE Electric Generator Air Emissions Report. This latter rate averages all NO_x emissions for weekday hours between 8 A.M. and 10 P.M. over the five months of the summer ozone season (May through September).
- The 24 hour average of the 25 peak days for the 500 MW decrement was 1.9 lbs/MWh (Figure 10 vs. 0.64 lb/MWh for the total system NO_x rate for the 25 days.
- Compared to the total system average NO_x emissions rate at the peak hour, the 4.4 lbs/MWh for the 500 MW decrement at the peak hour is about six times higher.

Appendix: Development of the 500 MW Decrement Used in the Calculations

This appendix explains in more detail how the 500 MW generation decrement with the highest energy bids was adjusted to obtain only the highest bid 500 MW decrement of thermal generation that would vary with load changes.

Since the ISO generators are dispatched in blocks of five-minute increments, these *"dispatch blocks"* were integrated into hourly averages to correspond with their associated hourly bid prices. These *"generation bid blocks"* were then sorted from lowest to highest based on their energy bid price. This (500 MW) size decrement was suggested by the EAG for the analysis and corresponds to the decrement used by ISO-NE in an earlier methodology used to calculate New England generation's *"marginal emissions."*

Generation within the 500 MW decrement that could not be categorized as *"incremental"* includes: 1) the energy-limited units hydro-electric and pumped storage plants, 2) generation that was dispatched and operating because of transmission constraints in the system, 3) self-scheduled (SS) generation, and 4) generation with its minimum block being held *"on-line"* for 24 hours (i.e., due to a required minimum down-time), so the unit would be available to serve the next day's peak-demand. ISO-NE then analytically removed each of these types of generators from the 500 MW decrement, one type at a time, to arrive at the 500 MW of highest-cost generation that would vary with changes in demand. Five groups of generators were defined to reflect this adjustment process and these are listed below:

Group 1: This was the initial "group" from which the subsequent adjustments were made. It included all the generation within the initial highest cost 500 MW dispatch decrement.

Group 2: This group excluded all hydro-electric and pumped storage stations from the Group 1 500 MW decrement. These types of generation were removed because the bids for limited energy generation (LEG) probably would not change or vary with system load levels. The LEG capacity (MW) removed was replaced with the next highest cost generation to aggregate back to a 500 MW decrement block.

Group 3: This group started with the Group 2 decrement and removed the generation operating due to transmission security needs. These generators were dispatched due to system transmission constraints, regardless of whether they were economically warranted. Similar to Group 2, after removal of this generation group, the next highest cost generation was added to aggregate the decrement back to 500 MW.

Group 4: Similarly, this group started with the Group 3 decrement and removed all self-scheduled units from the decrement and then, added the next highest bid generation to replace these units and aggregate back to 500 MW.

Group 5: Starting with the Group 4 decrement, Group 5 removed all of the minimum load (Block 1) dispatch bids from residual oil steam units within Group 4 and added the next highest bids to aggregate back to 500 MW. This resultant group was assumed to consist of only the generation with the highest bids that would vary with load.

The capacity (MW) removed from Group 2 through Group 4 is shown in Figure 12. To determine the true variable 500 MW of generation within the top of the system dispatch, the figure shows that on a number of peak days it was typically necessary to consider a much larger dispatch block than the top 500 MW economically dispatched, i.e. Group 1, in order to exclude the various groups of generation blocks that would not vary with changes in demand.

Figure 12 – Capacity Removed from the 500 MW Decrement for Groups 2 through 4

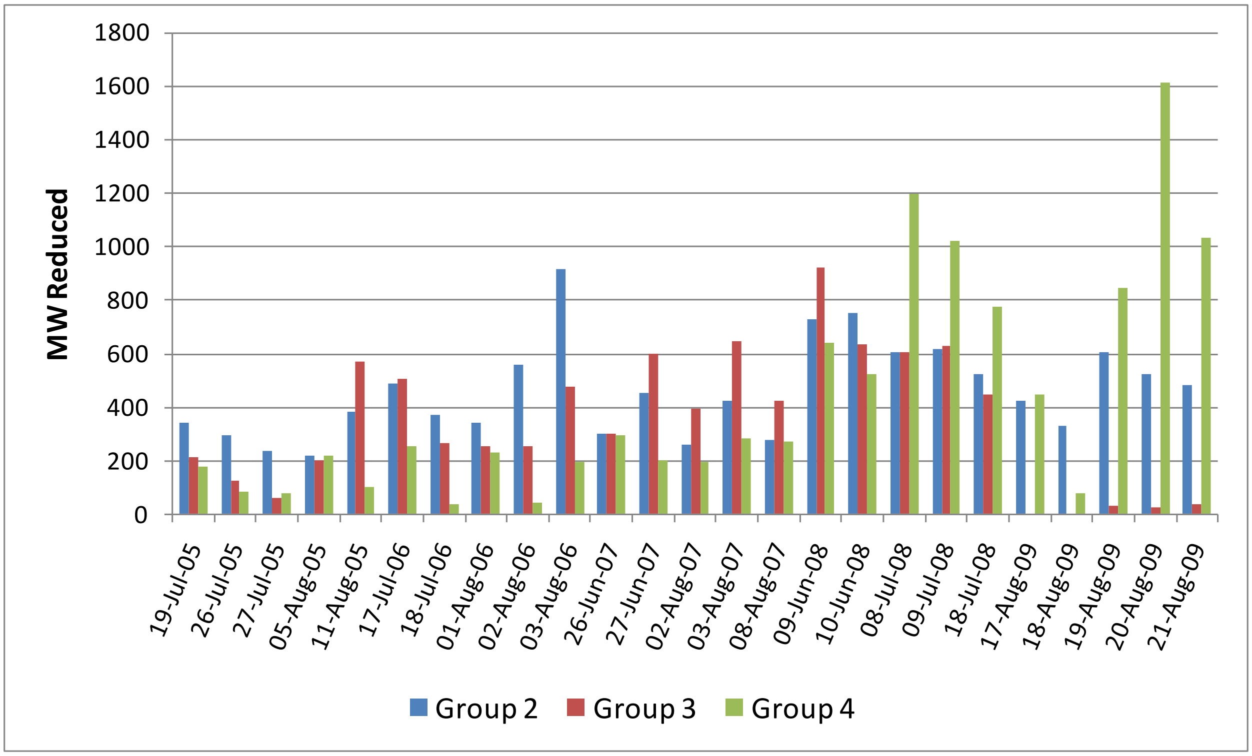


Figure 13 shows for Groups 1 through 4 the peak NO_x emissions rate, averaged hourly over the twenty-five peak-demand days. It illustrates how the peak NO_x emissions rate increases significantly from Group 1 to Groups 2 and 3. On-peak NO_x emission rates for Group 4 decrease slightly on the peak hours, but are similar to Group 1's off-peak rates.

Figure 13 – Average Hourly NO_x Rates for the Twenty-Five Peak-Demand Days

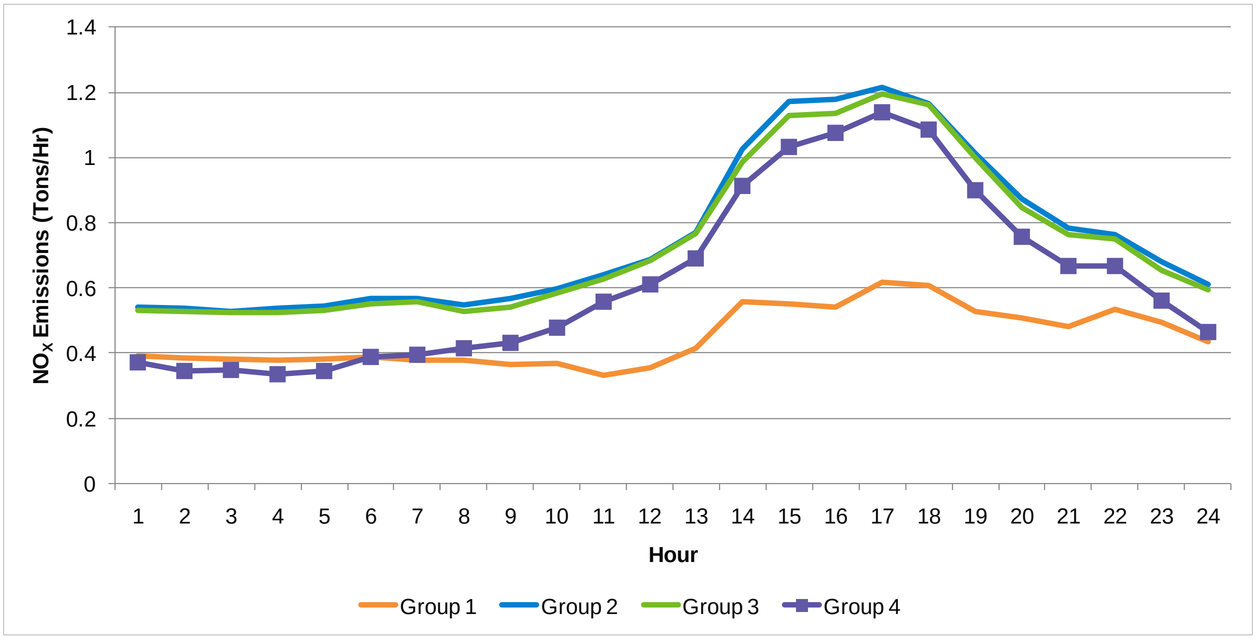


Figure 14, showing the averages previous presented in Figure 8, shows for Group 5 the average hourly NO_x emission rates (in tons per hour) for the five peak-demand days for each of the five years. It also shows the average of the five years hourly NO_x emission rates. Comparing the average for Group 4 (Figure 13) with the average for Group 5 (Figure 14), the results are similar for these two groups at the peak hours. However, the Group 5 emission rate is roughly half that of Group 4, for the hours 01 through 08 and for hour 24. This suggests that the dispatch Block 1 [i.e. the minimum load block] of the residual oil-steam units was indeed contributing to the off-peak emissions rate, but its removal in Group 5 did not principally affect the NO_x emissions rate during peak hours.

Figure 14 – Hourly 500 MW Decrement NO_x Emission Rates for Group 5

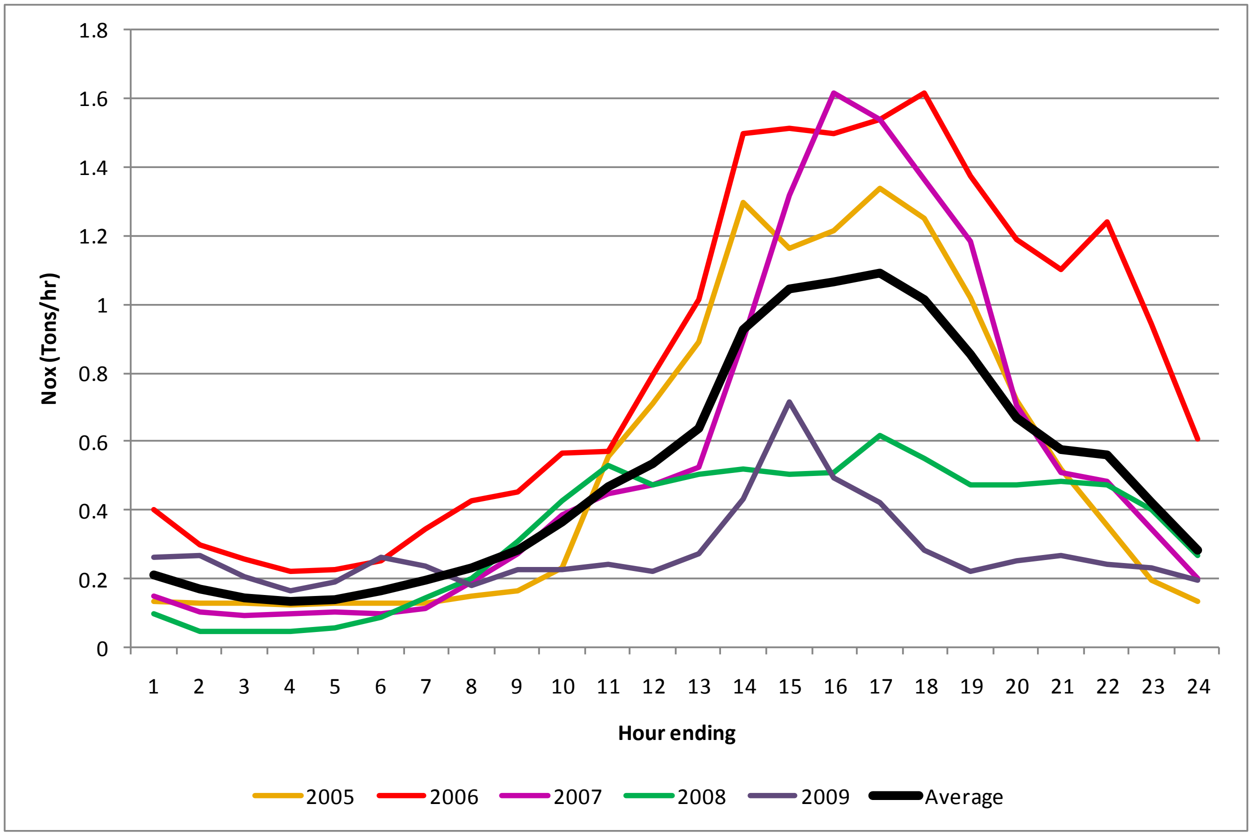


Figure 15 shows that for the 500 MW decrement, the daily NO_x emissions are lower when comparing Group 5 to Group 4 for the twenty-five peak-demand days. The NO_x emissions differences range from a less than a ton on July 18, 2006 to about seven tons reduction on August 11, 2005. Emissions from Group 5 were lower than Group 4 on every day, showing that the minimum load dispatch (Block 1) bids of the fossil-steam units contributed more NO_x air emissions on a daily basis than the next highest cost units on the bid stack, which replaced them in Group 5. The minimum load blocks of these units were not truly *"variable generation"* with respect to changes in system load and, therefore, should not be included.

Figure 15 – Total Daily NO_x in the 500 MW Decrement for 25 Peak-demand Days: Group 4 vs. Group 5

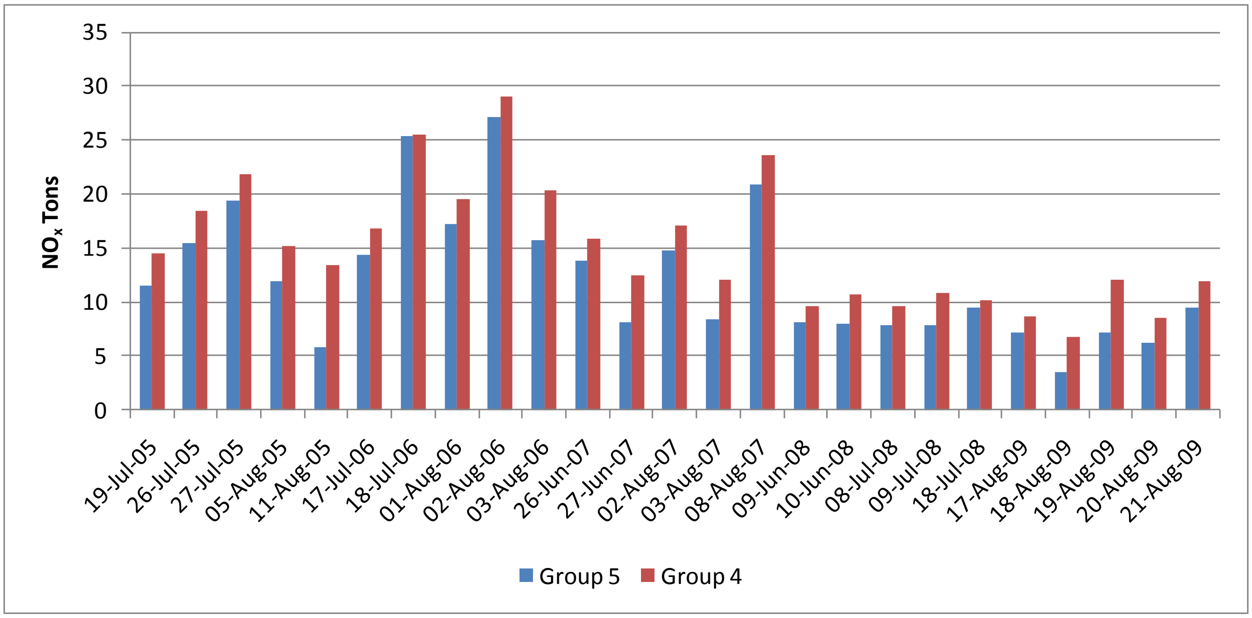
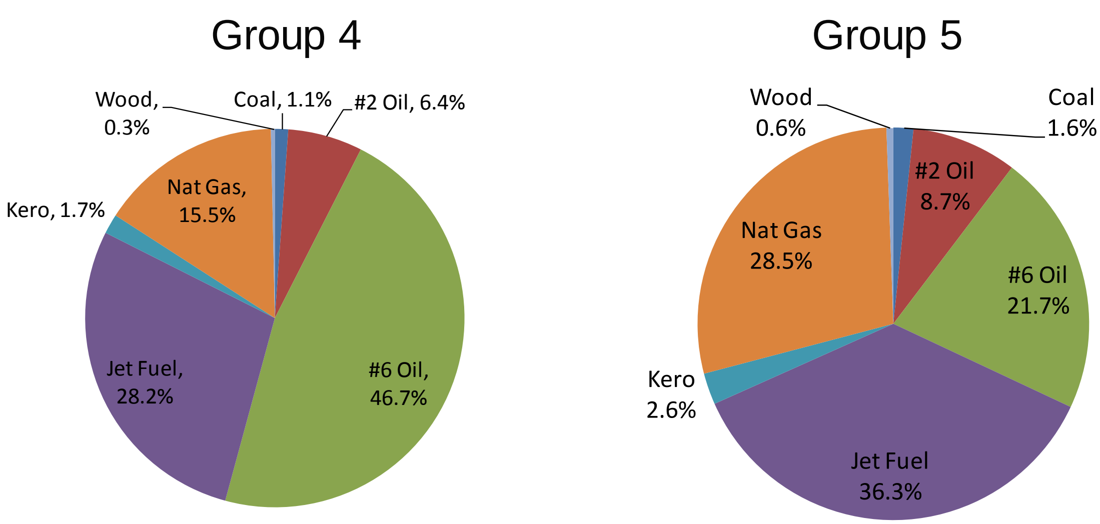


Figure 16 shows the fuel types in the 500 MW decrements for Group 4 versus Group 5 for the twenty-five peak-demand days. As might be expected, in Group 5, the residual oil portion dropped by more than 50%, the natural gas portion almost doubled and jet fuel increased from 28 to 36%.

Figure 16 – Fuel Types Comprising the 500 MW Block: Group 4 vs. Group 5



*Numbers may not add to 100% due to rounding