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Maryland Analyses of Control Technology Optimization for Coal-Fired Electric Generation Units in 29 Eastern States and Other related Information

Part I – Overview of Maryland's Analysis and Proposed Remedy

Data readily available from the Environmental Protection Agency's Clean Air Markets Division (CAMD) indicates that many electric generating units in PA, WV, OH, KY, and IN are operating without running their post-combustion controls, including large coal fired EGUs with SCR and SNCR control technology. An analysis of CAMD data show NOx emission rates well above what is considered representative of an EGU running its post combustion controls efficiently. While these units have taken advantage of the very low NOx allowance prices to achieve compliance, the failure to operate SCR and SNCR control technologies during the ozone season has significantly increased emissions and exacerbated the transport of ozone and ozone precursors into Maryland during the time of year that our monitors are recording the highest ozone levels.

An analysis of 2015 and 2016 CAMD data, summarized in parts IV and V of this appendix, respectively, shows that many EGUs have not been running their post combustion controls as efficiently as they have in the past during the ozone season. Comparing emission rates since post combustion controls have been installed on the EGUs shows that many units' emission rates have increased significantly since the installation and initial testing, indicating that these EGUs are not operating the post combustion controls or operating them at a significantly reduced efficiency. Analysis of CAMD data for the 36 units included in this petition shows that the failure to run post combustion controls or operating them at reduced efficiency during the 2015 ozone season increased NOx emissions by up to 300 tons/day into the regional air shed just up-wind of some of Maryland's highest reading monitoring locations. The methodology for identifying these units and calculating increased NOx emissions can be found in part II of this appendix. Maryland asks EPA to use two methods to ensure that controls are operated during the 2017 ozone season:

1. **INCLUDE A GENERIC REQUIREMENT OR PERMIT CONDITION REQUIRING EACH OF THE 36 NAMED EGUS TO MINIMIZE EMISSIONS BY OPTIMIZING EXISTING CONTROL TECHNOOGIES DURING THE OZONE SEASON**

   An example of language that should be included in federal and state EGU regulations or operating permits, requiring the summertime minimization of NOx emissions and optimization of NOx controls, is provided below. The language was built from federal consent orders and is consistent with the technological limitations, manufacturer's specifications, good engineering and maintenance practices, and good air pollution control practices. In Maryland regulations, this language can be found in the Code of Maryland Regulations, Title 26, Subtitle 11, Chapter 38 Control of NOx Emissions from Coal-Fired Electric Generating Units. COMAR 26.11.38.03.A(2):

   > "Beginning on May 1, 2016, for each operating day during the ozone season, the owner or operator of an affected electric generating unit shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations,

> manufacturers' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal."

The full text of the regulation may be found in Appendix B.

2. USE 30-DAY ROLLING AVERAGE RATES TO ENFORCE OPTIMIZATION OF CONTROLS THROUGHOUT THE OZONE SEASON

MDE determined that the rate representative of a well controlled unit should be the maximum 30-day rolling average from the unit's best/lowest reported ozone year. This rate is not only effective; it is also achievable and makes common sense. This judgment was based on having selected the best or lowest ozone season NOx emission rate, but also selecting the maximum 30-day rolling average, the combination being considered a good, but also readily achievable NOx emission rate. Part III of this appendix provides a full discussion of the methodology used in computing the 30-day rolling average for each EGU with post combustion control technology in states that significantly impact Maryland.

While it is imperative that EPA enforce these 30-day rates for the 36 identified units in order to achieve the majority of NOx reductions, it is also necessary to ensure that units that are currently running their controls consistently well continue to do so. Maryland recommends that EPA enforce 30-day rates for all units to ensure that their emissions do not surpass 2015 or 2016 levels.

Part II – Methodology for Identifying Coal-Fired EGUs with non-Optimized Controls and Calculation of Potential NOx Reductions

The Maryland Department of the Environment (MDE) has developed a methodology to analyze the optimization of Selective Catalytic Reduction (SCR) and Selective non-Catalytic Reduction (SNCR) controls at coal-fired electric generating units (EGUs) in the Eastern U.S. MDE has used this methodology to analyze unit-level NOx emissions of over 470 EGUs for the 2015 and 2016 ozone season.

MDE assessed SCR/SNCR control optimization for a specific year by comparing ozone season data for that year to a series of rates reflecting various levels of optimization for each unit. These optimized rates are derived from the unit's 2005-2015 ozone season data (adjusted if controls were installed after 2005), available in the U.S. EPA's Air Market Programs Database. For initial screening, the lowest ozone season average emission rate was selected for each unit. If the unit installed a SCR or SNCR in 2005 or a later year, the data collection period was narrowed to the first ozone season in the year following the installation to 2015.

A deviation percentage was then calculated for each unit by dividing the current ozone season average emission rate by the identified best ozone season average emission rate. Units are then subdivided into three categories, or bins, to assess optimization efforts. Units where the deviation is less than 0% are in Bin 1 and are assumed to have fully optimized controls; their current ozone season average emission rate is better than their past best demonstrated emission rate. Units where the deviation is greater than 0% but less than 100% are in Bin2 and are assumed to have questionable levels of optimization, but are considered a low priority; their current ozone season rate is higher than (but not double) their past best demonstrated emission rate. Units where the deviation is greater than 100% are in Bin 3 and are assumed to likely have not optimized controls. Their current ozone season average emission rate has at least doubled their past best demonstrated emission rate; these are the highest priority units. The units in Bin 3 are further subdivided into units with (A) current ozone season average emission rates less than 0.1 lb/mmBtu, (B) current ozone season average emission rates greater than 0.1 but less than 0.2 lb/mmBtu, and (C) current ozone season average emission rates greater than 0.2 lb/mmBtu.

Next, for each unit the NOx mass was calculated if the unit had met its best historical ozone season NOx rate. This was calculated using the following equation:

$$NOx\ Mass\ at\ Best\ Performance\ (Tons) = \frac{Best\ OS\ NOx\ Rate\ \left(\frac{lb}{mmBtu}\right)}{2000\,\frac{lbs}{ton}} * Ozone\ Season\ Heat\ Input\ (mmBtu)$$

Potential NOx reductions were also calculated for each unit using the following equation:

$$Additional\ NOx\ Savings\ (Tons) = OS\ NOx\ Mass\ (Tons) - NOx\ Mass\ at\ Best\ Performance\ (Tons)$$

For the purposes of this Section 126 Petition, the units of interest are classified as Bin 3C units in either the 2015 or 2016[1] ozone season and were identified as significant contributors to

[1] Based on May and June 2016 data only. Full 2016 ozone season data was not available at the time of this study.

Maryland through EPA's significant contribution assessments. Table A.1 shows analysis results for each of the units of interest for this petition. Parts IV and V of this appendix provide summary reports of analyses for the 2015 and 2016 ozone season, respectively. Data for all units in the eastern modeling domain can be provided upon request.

MDE has also automated this process into an Excel tool. Users enter the unit level emissions data for the desired ozone season into the tool and the tool automatically performs an ozone season analysis. This analysis includes a comparison for the unit's performance for the selected ozone season year to the unit's best demonstrated rate and its maximum 30-day rolling average rate (from that unit's best year), calculation of potential lost NOx reductions, and state level summaries. The tool also produces unit-level and state-level summary reports showing deviations from the optimized rates and lost NOx benefits as well as unit-level and state-level summary charts. The tool also bins units into various levels of optimization, allowing users to prioritize which units to focus on when assessing the optimization of controls. Tools can be provided upon request.

Table A-1: 2015 Ozone Season Deviation from Best Demonstrated Rate and Lost NOx Savings for Units in Section 126 Petition

Unit Level Data for Units with SCR and SNCR							2015 OS Data				Historical Emissions Data (2005-2014)		Deviation from Best Historical Performance				
Plant ID	State	Facility Name	Unit ID	Post Combustion Control Type	Control Installation Year	Notes	2015 OS NOx Mass	2015 OS NOx Rate	2015 OS Heat Input	2015 OS Capacity Factor	Best Performing OS Emission Rate	Best Performing OS Emission Rate Year	Deviation from Best Historical Performance	NOx Mass if Exceeding Units Met Best Historical Performance	Additional Savings if Exceeding Units Met Historical Best Performance	Daily Lost NOx Benefit	Bin
(ORISPL)					(Year)		(tons)	(lb/mmBtu)	(mmBtu)	(%)	(lb/mmBtu)	(Year)	(%)	(tons)	(tons)	(tons)	
ERTAC	ERTAC	ERTAC	ERTAC	CAMD/ERTAC	CAMD/ERTAC	CAMD/ERTAC	CAMD	CAMD	CAMD	Calculated	CAMD	CAMD	Calculated	Calculated	Calculated	Calculated	Calculated
6705	IN	Alcoa Allowance Management Inc	4	SCR	2004	0	1,306.95	0.2826	9,132,100	72.93%	0.0948	2007	198.10%	432.86	-874.09	-6.65	3
983	IN	Clifty Creek	1	SCR	2003	0	474.83	0.2276	4,634,125	67.12%	0.0735	2005	209.66%	170.30	-304.52	-2.27	3
983	IN	Clifty Creek	2	SCR	2003	0	497.83	0.2290	4,837,826	70.22%	0.0750	2005	205.33%	181.42	-316.41	-2.27	3
983	IN	Clifty Creek	3	SCR	2003	0	418.94	0.2287	4,047,900	58.48%	0.0742	2005	208.22%	150.18	-268.76	-2.21	3
6113	IN	Gibson	3	SCR	2002	0	911.58	0.2006	10,486,751	44.81%	0.0659	2005	204.40%	345.54	-566.04	-5.28	3
6113	IN	Gibson	5	SCR	2004	0	1,678.35	0.3409	9,726,977	46.85%	0.0597	2007	471.02%	290.35	-1,388.00	-12.46	3
994	IN	Petersburg	2	SCR	2004	0	1,256.30	0.2047	12,210,481	61.65%	0.0510	2005	301.37%	311.37	-944.93	-6.96	3
994	IN	Petersburg	3	SCR	2004	0	996.46	0.2692	7,105,947	28.42%	0.0466	2005	477.68%	165.57	-830.89	-9.52	3
6018	KY	East Bend	2	SCR	2002	0	2,151.49	0.2156	19,808,040	78.16%	0.0518	2006	316.22%	513.03	-1,638.46	-11.56	3
1374	KY	Elmer Smith	1	SCR	2003	0	610.71	0.3564	3,414,643	64.13%	0.1229	2006	189.99%	209.83	-400.88	-3.35	3
1378	KY	Paradise	3	SCR	2004	0	1,749.43	0.1544	24,979,798	64.58%	0.1001	2005	54.25%	1,250.24	-499.19	-3.94	2
6031	OH	Killen Station	2	SCR	2003	0	2,124.32	0.2411	18,199,876	78.93%	0.0885	2005	172.43%	805.34	-1,318.97	-9.23	3
2876	OH	Kyger Creek	1	SCR	2003	0	381.02	0.2130	3,922,236	50.81%	0.0788	2005	170.30%	154.54	-226.49	-2.11	3
2876	OH	Kyger Creek	2	SCR	2003	0	340.09	0.2016	3,617,082	46.55%	0.0792	2005	154.55%	143.24	-196.85	-1.97	3
2876	OH	Kyger Creek	3	SCR	2003	0	457.80	0.2557	3,876,711	48.99%	0.0787	2005	224.90%	152.55	-305.25	-2.86	3
2876	OH	Kyger Creek	4	SCR	2003	0	410.00	0.2815	3,142,591	39.83%	0.0786	2005	258.14%	123.50	-286.50	-3.13	3
2876	OH	Kyger Creek	5	SCR	2003	0	419.25	0.2952	3,074,554	38.38%	0.0785	2005	276.05%	120.68	-298.58	-3.25	3
6019	OH	W H Zimmer Generating Station	1	SCR	2004	0	3,160.04	0.2281	27,848,588	61.68%	0.0562	2006	305.87%	782.55	-2,377.50	-21.15	3
6094	PA	Bruce Mansfield	1	SCR	2003	0	2,408.67	0.2421	19,257,533	64.89%	0.0820	2008	195.24%	789.56	-1,619.11	-11.37	3
10641	PA	Cambria Cogen	1	SNCR	1999	0	139.52	0.1699	1,617,997	0.00%	0.0945	2005	79.79%	76.45	-63.06	-0.48	2
10641	PA	Cambria Cogen	2	SNCR	1999	0	137.94	0.1664	1,623,672	0.00%	0.0949	2006	75.34%	77.04	-60.89	-0.46	2
8226	PA	Cheswick	1	SCR	2003	0	1,346.92	0.2535	11,037,901	45.32%	0.0901	2006	181.35%	497.26	-849.66	-7.64	3
3122	PA	Homer City	1	SCR	2001	0	2,623.59	0.3505	14,943,755	63.15%	0.0667	2006	425.49%	498.37	-2,125.22	-14.88	3
3122	PA	Homer City	2	SCR	2000	0	1,612.18	0.3509	9,059,918	38.37%	0.0826	2006	324.82%	374.17	-1,238.01	-12.95	3
3122	PA	Homer City	3	SCR	2001	0	2,131.38	0.2819	14,758,744	59.33%	0.0872	2005	223.28%	643.48	-1,487.90	-11.19	3
3136	PA	Keystone	1	SCR	2003	0	2,198.27	0.2320	22,040,908	66.61%	0.0431	2006	438.28%	474.98	-1,723.29	-11.76	3
3136	PA	Keystone	2	SCR	2003	0	1,907.22	0.2425	18,137,676	53.93%	0.0433	2008	460.05%	392.68	-1,514.54	-12.74	3
3149	PA	Montour	1	SCR	2001	0	2,245.84	0.3092	15,205,020	56.12%	0.0581	2006	432.19%	441.71	-1,804.13	-13.33	3
3149	PA	Montour	2	SCR	2000	0	2,203.23	0.3362	13,350,369	52.18%	0.0578	2006	481.66%	385.83	-1,817.40	-14.53	3
10151	WV	Grant Town Power Plant	1A	SNCR	2003	0	285.03	0.3425	1,660,875	0.00%	0.0721	2005	375.03%	59.87	-225.16	-1.95	3
10151	WV	Grant Town Power Plant	1B	SNCR	2003	0	338.59	0.3397	1,985,069	0.00%	0.0722	2005	370.50%	71.66	-266.93	-1.93	3
3944	WV	Harrison Power Station	1	SCR	2001	0	2,155.48	0.3176	13,622,732	63.92%	0.0634	2005	400.95%	431.84	-1,723.64	-13.58	3
3944	WV	Harrison Power Station	2	SCR	2003	0	2,854.85	0.3643	15,908,614	72.27%	0.0662	2005	450.30%	526.58	-2,328.28	-16.38	3
3944	WV	Harrison Power Station	3	SCR	2003	0	2,965.19	0.3424	17,510,991	74.15%	0.0658	2005	420.36%	576.11	-2,389.08	-16.72	3
6004	WV	Pleasants Power Station	1	SCR	2003	0	1,889.22	0.2185	16,562,512	75.94%	0.0394	2005	454.57%	326.28	-1,562.94	-11.08	3
6004	WV	Pleasants Power Station	2	SCR	2003	0	3,190.54	0.3706	16,298,974	74.80%	0.0390	2005	850.26%	317.83	-2,872.70	-20.80	3
							51,979.03	0.2608	398,649,486	58.86%			306.61%	13,264.78	-38,714.25	-303.95	3
							2015 OS Data						2015 OS At Best Historical Rates				

Part III – Development of 30-Day Rolling Averages for Coal-Fired EGUs Equipped with SCR and SNCR

In early 2015 Tad Aburn requested options for determining what NOx rates would be acceptable for a well-controlled unit equipped with SCR or SNCR post-combustion controls.

Previous analyses of upwind states (IL, IN, KY, MI, NC, OH, TN, VA and WV – also including MD and PA) for determining well-controlled NOx rates focused on single ozone season average emission rates. This data (from CAMD) was analyzed from 2005-2012 (or for one ozone season after the control was installed if the control was installed after 2005); the lowest ozone season average emission rate was selected, per unit, from that dataset. This value was used in two data packages (dated 5/13/2014 and 9/18/2014) to show the potential reductions in NOx mass if the units with SCR or SNCR had optimized their post-combustion controls to the lowest reported ozone season average emission rate. This potential NOx savings was also modeled using the identified lowest ozone season average emission rate by the University of Maryland using two photochemical model platforms – the 2007/2018 MARAMA 7C platform with ERTAC EGU and the 2011/2018 EPA platform with IPM. For these analyses the lowest ozone season average NOx emission rate was considered representative of a well-controlled unit.

There has been a recent effort to update the dataset examining well controlled units best reported emission rates due to internal discussion, feedback from upwind states and as part of the shift to the new photochemical modeling platform MARAMA Alpha 2 2011/2018 with ERTAC EGU. Tad also requested an examination of 30-day rolling averages as representative of a well-controlled unit, and that information has also been folded into the updated dataset. From the identified lowest ozone season year (as reported to CAMD 2005-2014, or for one ozone season after the control was installed if the control was installed after 2005), daily ozone season NOx values (rate, mass and heat input) were downloaded and used to calculate a series of 30-day rolling averages spanning that identified ozone season, beginning on the 30th day of operation during ozone season. 30-day rolling averages were calculated by summing the total tons of NOx emitted for that day and the previous 29 days and dividing by the sum of the heat input for that day and the previous 29 days. From those rolling averages, three averages were identified: the minimum 30-day rolling average, the median 30-day rolling average, and the maximum 30-day rolling average.

It was decided, based on internal discussion, that the rate representative of a well controlled unit should be the maximum 30-day rolling average from the best/lowest reported ozone year. This judgment was based on having selected the best or lowest ozone season NOx emission rate, but also selecting the maximum 30-day rolling average, the combination being considered a good, but also readily achievable, NOx emission rate. In order to ensure that the maximum 30-day rolling average is representative of a well-controlled unit, the maximum 30-day rolling average for each unit was compared to the median 30-day rolling average. For units with a maximum 30-day rolling average deviating more than 75% from the median 30-day rolling average, the maximum 30-day rolling was considered inappropriate and the median 30-day rolling average was prescribed instead. Calculated deviation values are included in the appendix. For a small subset of units, where the maximum 30-day rolling average or median 30-day rolling average is significantly higher than the minimum 301-day rolling average and/or the lowest ozone season average rate, or for where a 30-day rolling rate cannot be calculated, the lowest ozone season average rate was prescribed instead. 30-day rolling averages were also provided for units slated to receive SCR or SNCR controls where the units have demonstrated that they can achieve a rate lower than the predicted controlled rate.

30 day rolling average calculations include days during which the units were determined to not have optimized SCR or SNCR controls, giving each unit some leeway to realistically achieve the maximum 30-day rolling average given. For units with SCR, controls were determined not to be optimized on days where the daily NOx rate was more than twice the median 30-day rolling average. For SNCR units, the threshold was set as two standard deviations higher than the median calculated daily NOx rate. Additional analysis of daily ozone season data include the number of days in the unit's best performing ozone season during which the daily NOx rate exceeded the maximum 30-day rolling average and the ozone season operating percentage (see appendix).

For the purposes of this Section 126 petition, the table and appendix only includes data pertaining to the units identified in the petition. Data for all units in the eastern modeling domain can be provided upon request.

Table A.2. 30-Day Rolling Average Ozone Season NOx Rates for Selected Coal-Fired Units with SCR or SNCR Controls

Plant ID (ORISPL)	State	Facility Name	Unit ID	Post-Combustion Control Type	Best Performing Ozone Season Emission Rate Year (Year)	Best Performing Ozone Season Emission Rate (lb/mmBtu)	Max 30-Day Rolling Average (lb/mmBtu)
ERTAC	ERTAC	ERTAC	ERTAC	CAMD	CAMD 2005-2014		Calculated
6705	IN	Alcoa Allowance Management	4	SCR	2007	0.0948	0.1035
983	IN	Clifty Creek	1	SCR	2005	0.0735	0.0895
983	IN	Clifty Creek	2	SCR	2005	0.0750	0.0896
983	IN	Clifty Creek	3	SCR	2005	0.0742	0.0836
6113	IN	Gibson	3	SCR	2005	0.0659	0.0883
6113	IN	Gibson	5	SCR	2007	0.0597	0.0837
994	IN	Petersburg	2	SCR	2005	0.0510	0.0618
994	IN	Petersburg	3	SCR	2005	0.0466	0.0605
6018	KY	East Bend	2	SCR	2006	0.0518	0.0671
1374	KY	Elmer Smith	1	SCR	2006	0.1229	0.1594
1378	KY	Paradise	3	SCR	2005	0.1001	0.1201
6031	OH	Killen Station	2	SCR	2005	0.0885	0.0965
2876	OH	Kyger Creek	1	SCR	2005	0.0788	0.0854
2876	OH	Kyger Creek	2	SCR	2005	0.0792	0.0841
2876	OH	Kyger Creek	3	SCR	2005	0.0787	0.0841
2876	OH	Kyger Creek	4	SCR	2005	0.0786	0.0843

2876	OH	Kyger Creek	5	SCR	2005	0.0785	0.0841	
6019	OH	W H Zimmer Generating Station	1	SCR	2006	0.0562	0.0944	*
6094	PA	Bruce Mansfield	1	SCR	2008	0.0820	0.0887	
10641	PA	Cambria Cogen	1	SNCR	2005	0.0945	0.1150	
10641	PA	Cambria Cogen	2	SNCR	2006	0.0949	0.1153	
8226	PA	Cheswick	1	SCR	2006	0.0901	0.0970	
3122	PA	Homer City	1	SCR	2006	0.0667	0.0722	
3122	PA	Homer City	2	SCR	2006	0.0826	0.0930	*
3122	PA	Homer City	3	SCR	2005	0.0872	0.1049	
3136	PA	Keystone	1	SCR	2006	0.0431	0.0479	
3136	PA	Keystone	2	SCR	2008	0.0433	0.0459	
3149	PA	Montour	1	SCR	2006	0.0581	0.0995	*
3149	PA	Montour	2	SCR	2006	0.0578	0.0876	
10151	WV	Grant Town Power Plant	1A	SNCR	2005	0.0721	0.0773	*
10151	WV	Grant Town Power Plant	1B	SNCR	2005	0.0722	0.0773	*
3944	WV	Harrison Power Station	1	SCR	2005	0.0634	0.0657	
3944	WV	Harrison Power Station	2	SCR	2005	0.0662	0.0845	
3944	WV	Harrison Power Station	3	SCR	2005	0.0658	0.0831	
6004	WV	Pleasants Power Station	1	SCR	2005	0.0394	0.0461	
6004	WV	Pleasants Power Station	2	SCR	2005	0.0390	0.0448	

*	Max 30-Day Rolling Average Rate is not appropriate. The 90th percentile 30-Day Rolling Average Rate has been substituted.

Table A.3. 30-Day Rolling Average Ozone Season NOx Rates and calculated values for selected coal-fired units with SCR or SNCR post-combustion controls

Unit Level Data					Ozone Season Emissions Data		30-Day Rolling Average Options			Analysis			
Plant ID (ORISPL)	State	Facility Name	Unit ID	Post-Combustion Control Type	Best Performing Ozone Season Emission Rate Year (Year)	Best Performing Ozone Season Emission Rate (lb/mmBtu)	Min 30-Day Rolling Average (lb/mmBtu)	Median 30-Day Rolling Average (lb/mmBtu)	Max 30-Day Rolling Average (lb/mmBtu)	Days With SCR or SNCR Not Optimized (Days)	Days Over Max 30-day Rolling (Days)	Ozone Season Operating Time (%)	Deviation of Max 30-Day from Median 30-Day Rolling (%)
ERTAC	ERTAC	ERTAC	ERTAC	CAMD	(CAMD 2005-2014)		Calculated	Calculated	Calculated	Calculated	Calculated	Calculated	Calculated
6705	IN	Alcoa Allowance Management Inc	4	SCR	2007	0.0948	0.0892	0.0923	0.1035	0	24	82.20%	12.13%
983	IN	Clifty Creek	1	SCR	2005	0.0735	0.0588	0.0696	0.0895	8	26	89.40%	28.59%
983	IN	Clifty Creek	2	SCR	2005	0.0750	0.0600	0.0712	0.0896	10	28	92.80%	25.84%
983	IN	Clifty Creek	3	SCR	2005	0.0742	0.0598	0.0712	0.0836	8	32	97.90%	17.42%
6113	IN	Gibson	3	SCR	2005	0.0659	0.0528	0.0621	0.0883	1	16	100.00%	42.19%
6113	IN	Gibson	5	SCR	2007	0.0597	0.0392	0.0531	0.0837	12	22	92.70%	57.63%
994	IN	Petersburg	2	SCR	2005	0.0510	0.0409	0.0489	0.0618	6	17	97.30%	26.38%
994	IN	Petersburg	3	SCR	2005	0.0466	0.0279	0.0389	0.0605	13	17	94.71%	55.48%
6018	KY	East Bend	2	SCR	2006	0.0518	0.0445	0.0494	0.0671	2	11	100.00%	35.83%
1374	KY	Elmer Smith	1	SCR	2006	0.1229	0.0939	0.1085	0.1594	10	23	90.30%	46.91%
1378	KY	Paradise	3	SCR	2005	0.1001	0.0542	0.0803	0.1201	16	18	85.60%	49.56%
6031	OH	Killen Station	2	SCR	2005	0.0885	0.0762	0.0840	0.0965	4	24	95.30%	14.88%
2876	OH	Kyger Creek	1	SCR	2005	0.0788	0.0721	0.0757	0.0854	0	24	94.30%	12.81%
2876	OH	Kyger Creek	2	SCR	2005	0.0792	0.0724	0.0764	0.0841	0	29	93.40%	10.08%
2876	OH	Kyger Creek	3	SCR	2005	0.0787	0.0721	0.0755	0.0841	0	30	93.70%	11.39%
2876	OH	Kyger Creek	4	SCR	2005	0.0786	0.0722	0.0756	0.0843	0	26	96.00%	11.51%

2876	OH	Kyger Creek	5	SCR	2005	0.0785	0.0721	0.0752	0.0841	0	28	98.10%	11.84%
6019	OH	W H Zimmer Generating Station	1	SCR	2006	0.0562	0.0395	0.0500	0.1225*	8	7	85.23%	145.09%
6094	PA	Bruce Mansfield	1	SCR	2008	0.0820	0.0650	0.0721	0.0887	8	11	72.30%	23.02%
10641	PA	Cambria Cogen	1	SNCR	2005	0.0945	0.0820	0.0892	0.1150	10	11	97.60%	28.92%
10641	PA	Cambria Cogen	2	SNCR	2006	0.0949	0.0831	0.0886	0.1153	9	10	98.10%	30.14%
8226	PA	Cheswick	1	SCR	2006	0.0901	0.0667	0.0706	0.0970	6	21	59.80%	37.39%
3122	PA	Homer City	1	SCR	2006	0.0667	0.0601	0.0662	0.0722	3	13	96.70%	9.06%
3122	PA	Homer City	2	SCR	2006	0.0826	0.0623	0.0695	0.1224*	12	13	88.08%	76.03%
3122	PA	Homer City	3	SCR	2005	0.0872	0.0608	0.0723	0.1049	8	17	76.60%	45.09%
3136	PA	Keystone	1	SCR	2006	0.0431	0.0398	0.0422	0.0479	4	8	97.40%	13.51%
3136	PA	Keystone	2	SCR	2008	0.0433	0.0398	0.0422	0.0459	2	9	99.70%	8.77%
3149	PA	Montour	1	SCR	2006	0.0581	0.0454	0.0477	0.1044*	7	7	93.30%	118.87%
3149	PA	Montour	2	SCR	2006	0.0578	0.0382	0.0532	0.0876	13	14	94.80%	64.66%
10151	WV	Grant Town Power Plant	1A	SNCR	2005	0.0721	0.0591	0.0622	0.1120*	8	9	98.00%	80.06%
10151	WV	Grant Town Power Plant	1B	SNCR	2005	0.0722	0.0593	0.0622	0.1119*	7	8	99.10%	79.90%
3944	WV	Harrison Power Station	1	SCR	2005	0.0634	0.0570	0.0599	0.0657	5	21	74.60%	9.68%
3944	WV	Harrison Power Station	2	SCR	2005	0.0662	0.0573	0.0607	0.0845	9	17	92.30%	39.21%
3944	WV	Harrison Power Station	3	SCR	2005	0.0658	0.0573	0.0613	0.0831	8	18	97.30%	35.56%
6004	WV	Pleasants Power Station	1	SCR	2005	0.0394	0.0320	0.0380	0.0461	9	17	98.80%	21.32%
6004	WV	Pleasants Power Station	2	SCR	2005	0.0390	0.0307	0.0365	0.0448	12	21	92.30%	22.74%

* Max 30-Day Rolling Average Rate is not appropriate. The 90th percentile 30-Day Rolling Average Rate should be used instead.

Key:

CAMD Avg O.S. NOx rate (lb/MMBtu): Average ozone season NOx rate reported by CAMD during the unit's best performing ozone season

Min 30-Day Rolling (lb/MMBtu): Minimum of 30-day rolling average NOx rates during the unit's best performing ozone season. Rolling averages were calculated for each day by summing the NOx emissions for that day and the previous 29 days, and dividing by the sum of the heat inputs for that day and the previous 29 days.

Median 30-Day Rolling (lb/MMBtu): Median of 30-day rolling average NOx rates during the unit's best performing ozone season

Max 30-Day Rolling (lb/MMBtu): Maximum of 30-day rolling average NOx rates during the unit's best performing ozone season

Days with SCR Not Optimized: Number of days during the unit's best ozone season during which the unit was determined to not be running SCR or SNCR

SCR units: Threshold daily NOx rate for not optimized SCR was set as twice the median 30-day rolling average rate

SNCR units: Threshold daily NOx rate for no SNCR was set as two standard deviations higher than the median calculated daily NOx rate

Days Over Max 30-day Rolling: Number of days during the unit's best ozone season during which the calculated daily NOx rate was greater than the max 30-day rolling average NOx rate

Ozone Season Operating Time (%): The percentage of time that the unit was operating during its best performing ozone season

Deviation of Max 30-Day from Median 30-Day Rolling: Percent difference of max 30-day rolling average from median 30-day rolling average. Deviation above 75% indicates that max-30 day rolling average is not an appropriate indicator rate for the unit. Median 30-day rolling was used instead

Sources

1. ERTAC-EGU Unit Availability File and Controls File (Version 2.3, updated 10/2014)
   * Plant ID, State, Facility Name and Unit ID
   * Activation Date and Retirement Date
   * ERTAC Future NOx Controls and Control Year
2. CAMD data pull, all programs, "Facility Attribute Report, 2005-2014"
   * Existing Controls for NOx.

Notes

* Plant ID, State, Facility Name, Unit ID, Activation Date and Retirement Date, ERTAC Future NOx Controls and Control Year are all from the ERTAC-EGU Unit Availability File and Controls File (Version 2.3, updated 10/2014) and feedback from the States. State representatives are responsible for updating the ERTAC data multiple times throughout the year. This data has been QA/QC'd by the states and represents a quality such that the state would include said data in their SIP submissions.

Part IV – 2015 Ozone Season Analysis of Optimization of SCR/SNCR Controls at Coal-Fired EGUs

The following presentation provides a summary of the results of the 2015 ozone season analysis for all 29 states in the eastern modeling domain, using the methodologies discussed in Part II of this appendix.

MARYLAND

Department of the Environment

The SCOOT 2015 Voluntary Control Effort

An effort to optimize the use of existing control technologies

An Assessment of Optimization of Controls At Coal-Fired Units in the Eastern Modeling Domain
November 12, 2015

MDE

Last SCOOT Meeting

Newport RI - August 30, 2015

- This is an updated version of the briefing provided at the August 30th SCOOT meeting in Newport, RI
- Now covers the entire 2015 ozone season - not just May and June
- Includes analyses of coal-fired EGUs in many more states in the East
  - Now 29 eastern states - not just 11 states

MARYLAND

What We Did

- Analyzed the emissions data submitted by sources for 2015 Ozone Season in the Eastern Modeling Domain
  - AL, AR, DE, FL, GA, IA, IL, IN, KS, KY, LA, MA, MD, MI, MN, MO, NC, NE, NH, NJ, NY, OH, PA, SC, TN, TX, VA, WI & WV
- Looked at 2015 ozone season average emission rates at 385 individual units
  - 3 Units Did Not Report
- Compared those rates to the lowest demonstrated ozone season average emission rate from the past
- Placed individual units into three bins based upon the above rate comparisons
  - **BIN 1** - Review not needed - Equal or better performance compared to past - optimization underway (58 units)
  - **BIN 2** - Review needed but lower priority - Slightly poorer performance compared to past (241 units)
  - **BIN 3** - High priority for review - Noticeably poorer performance compared to past (73 units)
  - 10 units did not operate, retired or switched fuels
- Calculated potential lost NOx reductions

BIN Number 1

… units with 2015 rates better than … or close to … best historical rates

State	Facility	Unit	2015 OS Rate (lb/mmBtu)	Best OS Rate (lb/mmBtu)	Deviation	State	Facility	Unit	2015 OS Rate (lb/mmBtu)	Best OS Rate (lb/mmBtu)	Deviation
AL	Barry	1	0.05	0.26	-82%	MD	Wagner	3	0.06	0.06	-9%
AL	Barry	2	0.05	0.26	-81%	MD	Dickerson	1	0.22	0.24	-7%
FL	Crist	5	0.12	0.14	-12%	MD	Dickerson	2	0.22	0.24	-7%
FL	C H. Stanton	2	0.10	0.15	-30%	MD	Dickerson	3	0.22	0.24	-7%
IA	Lansing	4	0.05	0.10	-43%	MI	Dan E Karn	1	0.05	0.06	-24%
IL	E D Edwards	3	0.07	0.08	-14%	MI	Campbell	2	0.04	0.14	-73%
IL	Joliet 29	71	0.09	0.10	-7%	MI	Campbell	3	0.04	0.07	-40%
IL	Joliet 29	72	0.09	0.10	-7%	MO	Thomas Hill	MB2	0.12	0.42	-73%
IL	Marion	4	0.08	0.10	-19%	NC	Wstmrln'd II	2	0.13	0.16	-20%
IL	Powerton	62	0.09	0.10	-9%	NE	NE Cty	2	0.06	0.06	-8%
IN	Bailly	8	0.11	0.12	-7%	NJ	Logan	1001	0.10	0.11	-11%
IN	F B Culley	3	0.09	0.10	-8%	NJ	Mercer	2	0.05	0.08	-28%
KS	Jeffrey	3	0.12	0.12	-7%	PA	Shawville	1	0.31	0.37	-16%
KY	H L Spurlock	3	0.06	0.06	-11%	PA	Shawville	2	0.30	0.39	-24%
KY	J S. Cooper	2	0.12	0.13	-10%	WI	Edgewater	4	0.13	0.14	-9%
KY	Trimble	2	0.04	0.05	-25%	WI	Manitowoc	9	0.04	0.05	-23%
MD	B Shores	2	0.07	0.08	-11%	WI	N Dewey	1	0.23	0.25	-7%
MD	C P Crane	1	0.28	0.35	-20%	WI	N Dewey	2	0.23	0.25	-8%
MD	C P Crane	2	0.24	0.26	-9%	WI	South Oak	7	0.06	0.07	-14%
MD	Wagner	2	0.22	0.27	-18%	WI	South Oak	8	0.06	0.07	-7%

Top 40 – out of 58

BIN Number 2

… Units with 2015 rates that are worse than (but not more than double) best historical rates and an emission rate greater than 0.1 lb/mmBtu for SCR and 0.2 lb/mmBtu for SNCR

State	Facility	Unit	2015 OS Rate (lb/mmBtu)	Best OS Rate (lb/mmBtu)	Deviation	State	Facility	Unit	2015 OS Rate (lb/mmBtu)	Best OS Rate (lb/mmBtu)	Deviation
AL	Barry	4	0.35	0.23	53%	NC	G G Allen	5	0.31	0.19	60%
AL	C R Lowman	2	0.24	0.16	45%	NC	Marshall	3	0.13	0.07	93%
AL	E C Gaston	5	0.12	0.08	55%	NC	Marshall	4	0.27	0.20	38%
DE	Indian River	4	0.10	0.07	52%	NC	Roxboro	1	0.16	0.08	87%
GA	Hammond	4	0.10	0.06	86%	NC	Roxboro	4A	0.16	0.08	97%
IL	Dallman	32	0.12	0.08	47%	NC	Roxboro	4B	0.16	0.08	98%
IL	Duck Creek	1	0.10	0.07	39%	NY	Somerset	1	0.23	0.14	72%
IN	Gibson	4	0.11	0.06	80%	OH	Avon Lake	12	0.40	0.28	39%
IN	Harding St	70	0.10	0.07	55%	PA	B Mansfield	3	0.14	0.07	90%
IN	Tanners Crk	U2	0.38	0.28	39%	PA	New Castle	3	0.28	0.20	45%
IN	Tanners Crk	U3	0.44	0.27	64%	PA	New Castle	4	0.32	0.16	99%
KY	Paradise	3	0.15	0.10	54%	SC	Cope	COP1	0.11	0.08	43%
MO	New Madrid	1	0.13	0.09	45%	SC	Williams	WIL1	0.11	0.06	90%
MO	New Madrid	2	0.16	0.09	72%	VA	Clinch River	1	0.35	0.19	85%
MO	Sibley	2	0.65	0.42	57%	VA	Clinch River	2	0.33	0.19	73%
MO	Thomas Hill	MB1	0.16	0.10	65%	VA	Clinch River	3	0.26	0.17	51%
NC	G G Allen	1	0.29	0.16	79%	VA	Yorktown	1	0.37	0.22	64%
NC	G G Allen	2	0.28	0.16	78%	VA	Yorktown	2	0.37	0.22	67%
NC	G G Allen	3	0.32	0.17	87%	WI	Bay Front	2	0.22	0.14	55%
NC	G G Allen	4	0.33	0.18	83%	WV	J E Amos	3	0.11	0.06	85%

Top 40 – out of 85. There are a total of 254 units in this Bin – 85 have rates above 0.1 or 0.2 lb/mmBtu.

BIN Number 3

- BIN Number 3 includes 73 units that warrant the most significant review.
- It has been subdivided into three categories - All units in BIN 3 have rates that are more than double best historical rates:
  - 6 units have 2015 rates less than 0.1 lb/mmBtu
  - 26 units have 2015 rates between 0.1 and 0.2 lb/mmBtu
  - 41 units have 2015 rates greater than 0.2 lb/mmBtu

*Units with 2015 rates that are **more than double** best historical rates and 2015 NOx rates **between 0.1 and 0.2 lb/mmBtu***

State	Facility	Unit	2015 OS Rate (lb/mmBtu)	Best OS Rate (lb/mmBtu)	Deviation	State	Facility	Unit	2015 OS Rate (lb/mmBtu)	Best OS Rate (lb/mmBtu)	Deviation
AL	Gorgas	10	0.17	0.07	151%	NC	Mayo	1A	0.17	0.06	179%
IN	A B Brown	1	0.15	0.08	104%	NC	Mayo	1B	0.17	0.06	177%
IN	Gibson	1	0.11	0.03	235%	NC	Roxboro	2	0.14	0.06	146%
IN	Gibson	2	0.14	0.07	110%	NC	Roxboro	3A	0.19	0.07	155%
KY	Big Sandy	BSU2	0.20	0.10	106%	NC	Roxboro	3B	0.19	0.08	153%
KY	Ghent	3	0.17	0.03	533%	OH	Gavin	1	0.17	0.07	151%
KY	Mill Creek	3	0.18	0.05	307%	OH	Gavin	2	0.15	0.06	164%
KY	Mill Creek	4	0.16	0.04	327%	OH	Miami	7	0.15	0.05	177%
KY	Trimble Cty	1	0.13	0.03	323%	OH	Miami	8	0.16	0.05	190%
MA	Brayton Pt	3	0.14	0.04	255%	PA	B Mansfield	2	0.17	0.08	106%
NC	Belews Crk	1	0.13	0.03	374%	PA	Scrubgrass	1	0.12	0.06	108%
NC	Belews Crk	2	0.11	0.04	193%	WV	J E Amos	2	0.10	0.03	233%
NC	Cliffside	5	0.13	0.06	137%	WV	Mtn'eer	1	0.11	0.04	180%

* All but 1 with SCR

BIN Number 3

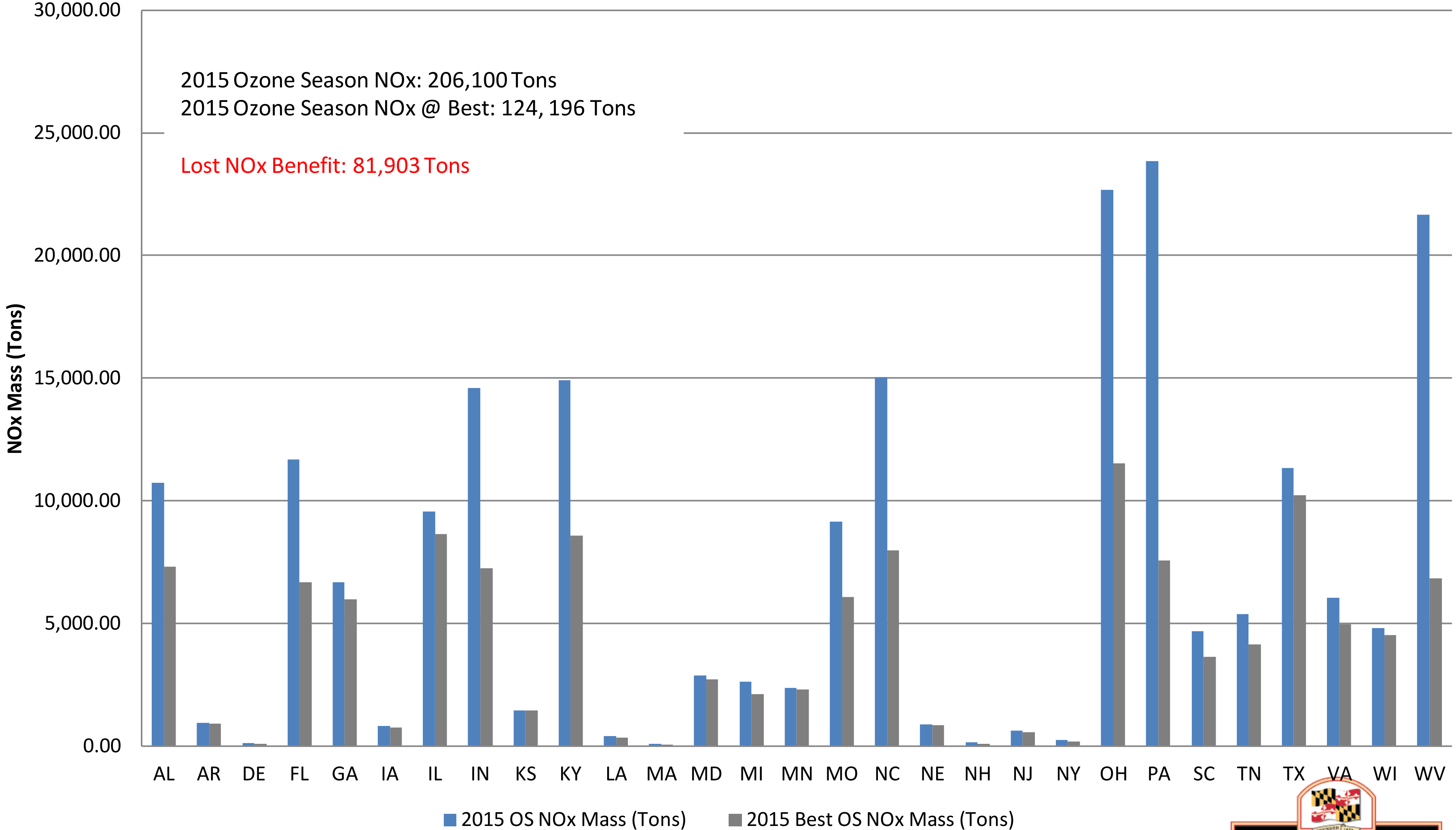
*… units with 2015 rates that are **more than double** best historical rates and 2015 NOx rates **above 0.2 lb/mmBtu***

State	Facility	Unit	2015 OS Rate (lb/mmBtu)	Best OS Rate (lb/mmBtu)	Deviation
AL	C R Lowman	3	0.26	0.06	342%
FL	St. Johns Rvr	1	0.41	0.13	221%
FL	St. Johns Rvr	2	0.38	0.13	200%
IN	Alcoa	4	0.28	0.09	198%
IN	Clifty Creek	1	0.23	0.07	210%
IN	Clifty Creek	2	0.23	0.08	205%
IN	Clifty Creek	3	0.23	0.07	208%
IN	Gibson	3	0.20	0.07	204%
IN	Gibson	5	0.34	0.06	471%
IN	Petersburg	2	0.20	0.05	301%
IN	Petersburg	3	0.27	0.05	478%
KY	East Bend	2	0.22	0.05	316%
KY	Elmer Smith	1	0.36	0.12	190%
MO	Sibley	1	0.70	0.34	106%
MO	Sibley	3	0.24	0.08	203%
MO	Thomas Hill	MB3	0.23	0.10	138%
NH	Merrimack	1	0.52	0.16	224%
NH	Merrimack	2	0.44	0.16	175%
OH	Killen	2	0.24	0.09	172%
OH	Kyger Creek	1	0.21	0.08	170%
OH	Kyger Creek	2	0.20	0.08	155%
OH	Kyger Creek	3	0.26	0.08	225%
OH	Kyger Creek	4	0.28	0.08	258%
OH	Kyger Creek	5	0.30	0.08	276%
OH	W HZimmer	1	0.23	0.06	306%
PA	B Mansfield	1	0.24	0.08	195%
PA	Cheswick	1	0.25	0.09	181%
PA	Homer City	1	0.35	0.07	425%
PA	Homer City	2	0.35	0.08	325%
PA	Homer City	3	0.28	0.09	223%
PA	Keystone	1	0.23	0.04	438%
PA	Keystone	2	0.24	0.04	460%
PA	Montour	1	0.31	0.06	432%
PA	Montour	2	0.34	0.06	482%
WV	Grant Town	1A	0.34	0.07	375%
WV	Grant Town	1B	0.34	0.07	370%
WV	Harrison	1	0.32	0.06	401%
WV	Harrison	2	0.36	0.07	450%
WV	Harrison	3	0.34	0.07	420%
WV	Pleasants	1	0.22	0.04	455%
WV	Pleasants	2	0.37	0.04	850%

* All but 3 with SCR

Lost NOx Reductions - By State

2015 Ozone Season Total NOx Emissions - Actual and Best Rates from Past

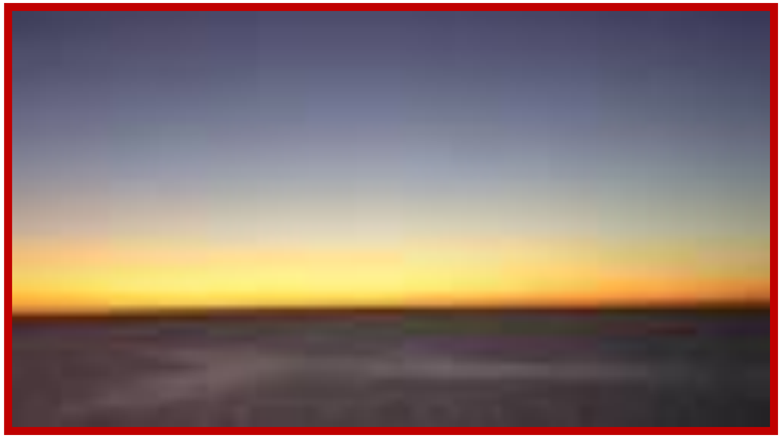


* Ongoing analyses are looking at how to adjust "best rates from the past" to account for operation at lower capacity and equipment age

Optimization Appears to be Underway

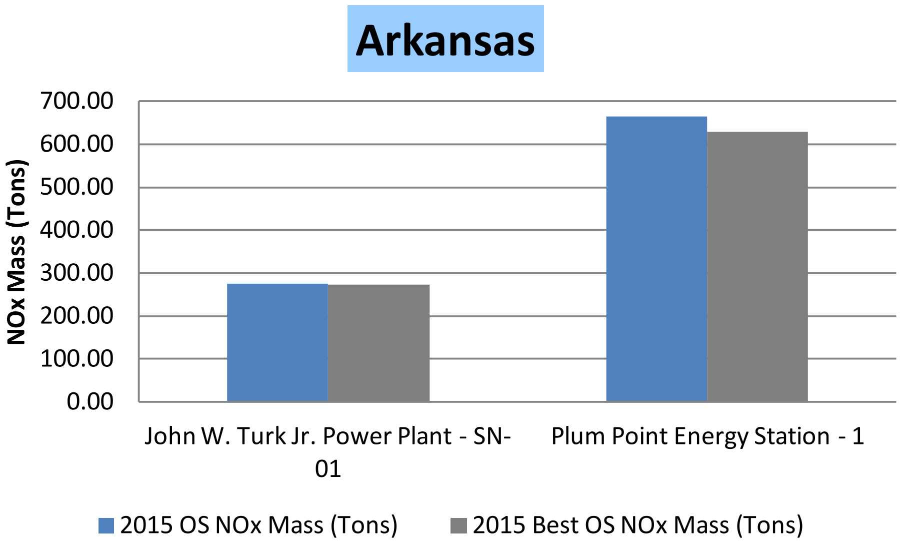
- States with the majority of their units meeting or out-performing best historical rates

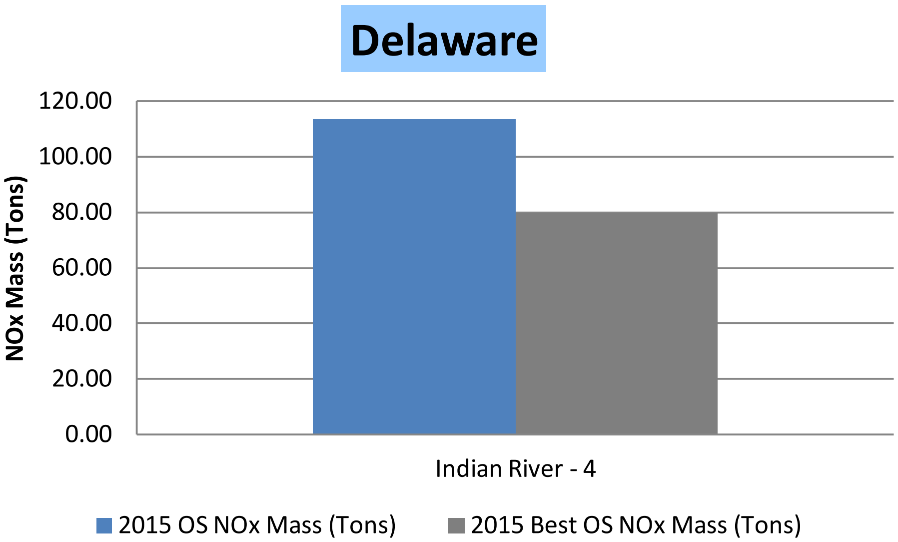
- Arkansas
- Delaware
- Georgia
- Iowa
- Illinois
- Kansas
- Louisiana
- Massachusetts
- Maryland
- Michigan
- Minnesota
- Nebraska
- New Hampshire
- New Jersey
- New York
- South Carolina
- Tennessee
- Texas
- Virginia
- Wisconsin

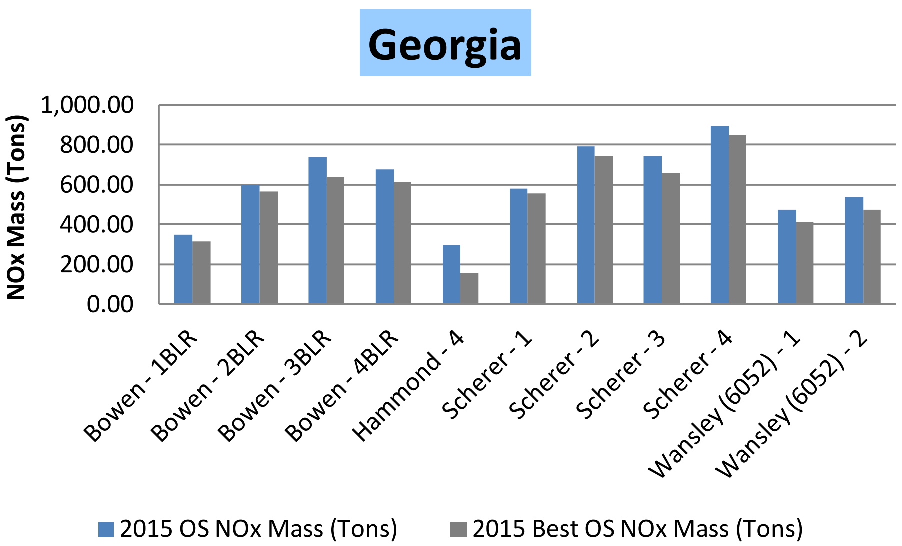


Optimization Appears to be Underway

2015 Ozone Season Total NOx Emissions – Actual and Best Rates from Past



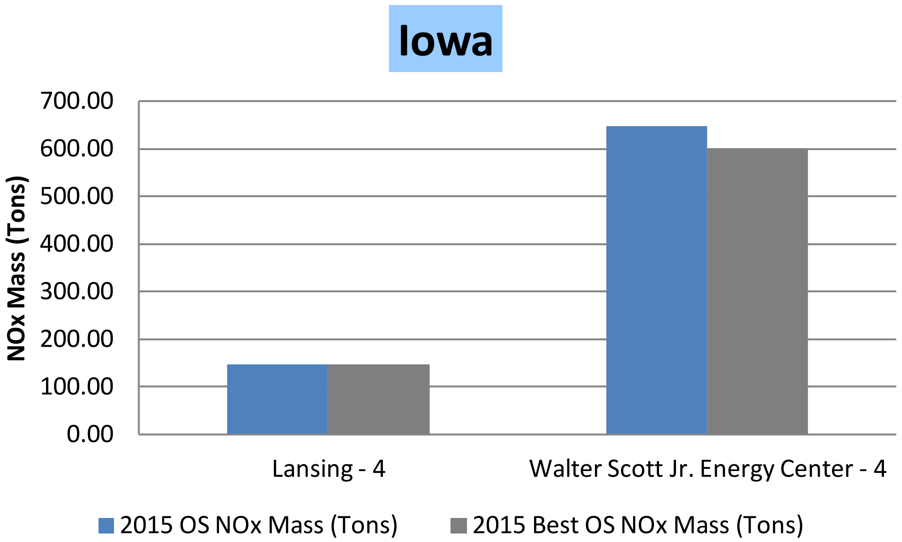


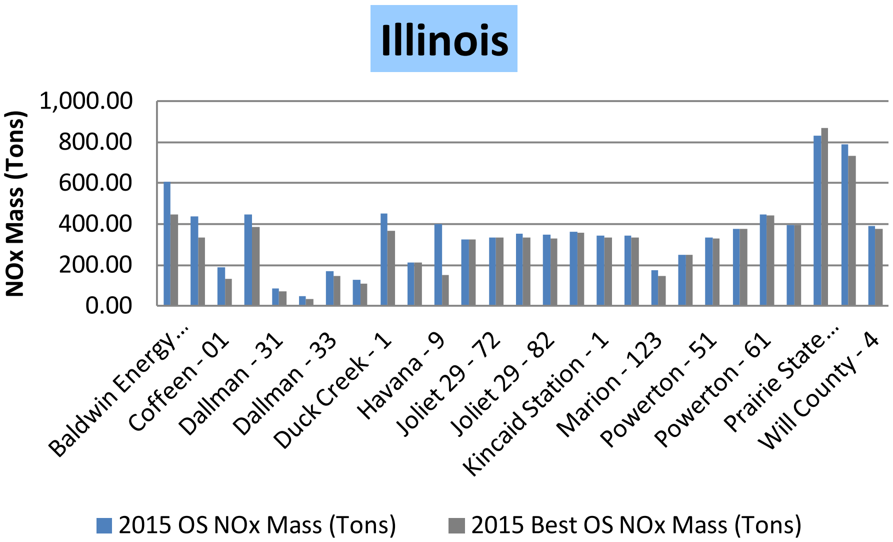


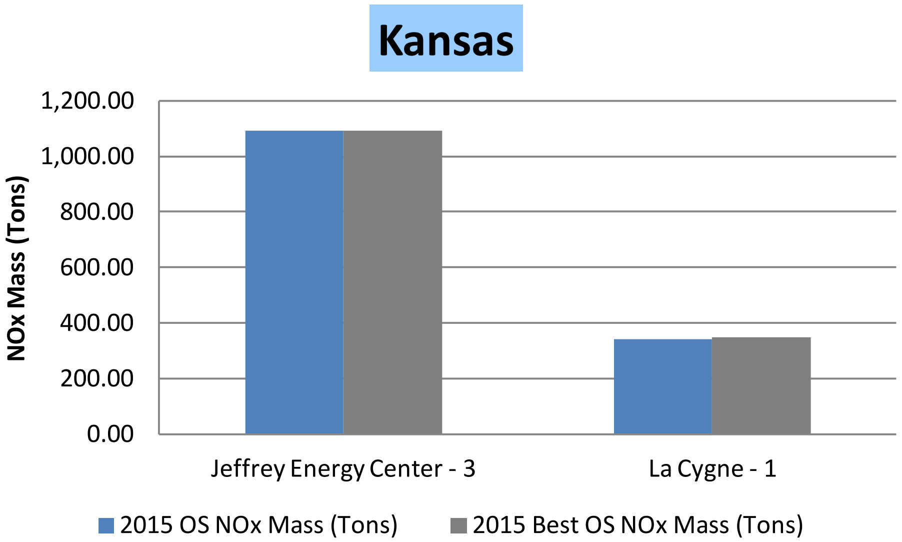
	2015 Actual OS NOx Mass (Tons)	2015 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Arkansas	938	902	36	0.04%
Delaware	114	80	34	0.04%
Georgia	6,682	5,973	708	0.86%

Optimization Appears to be Underway

2015 Ozone Season Total NOx Emissions – Actual and Best Rates from Past



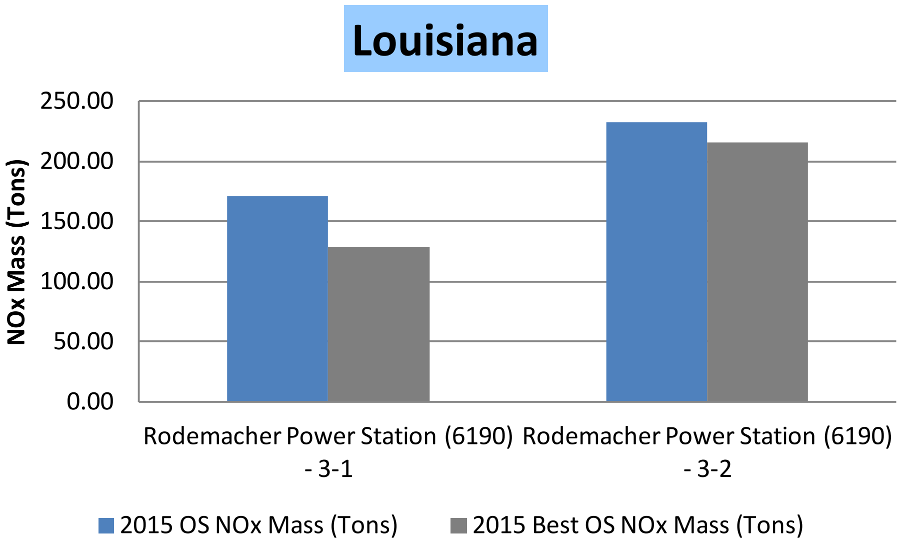


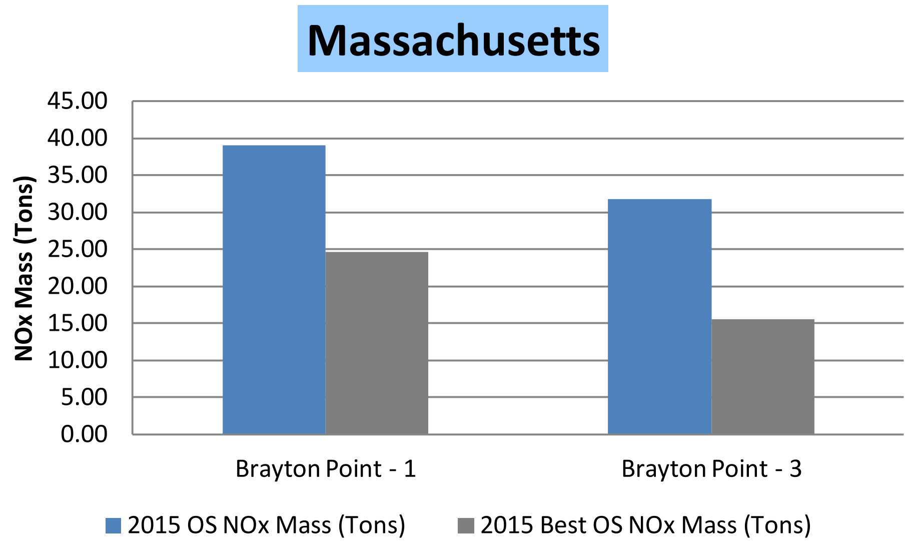


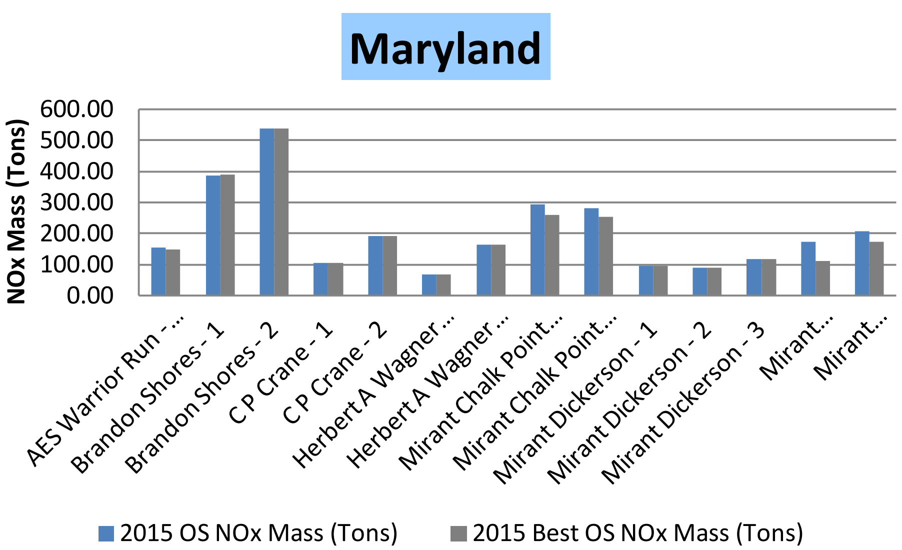
	2015 Actual OS NOx Mass (Tons)	2015 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Iowa	793	748	46	0.06%
Illinois	9,569	8,652	917	1.12%
Kansas	1,432	1,438	6	0.01%

Optimization Appears to be Underway

2015 Ozone Season Total NOx Emissions – Actual and Best Rates from Past







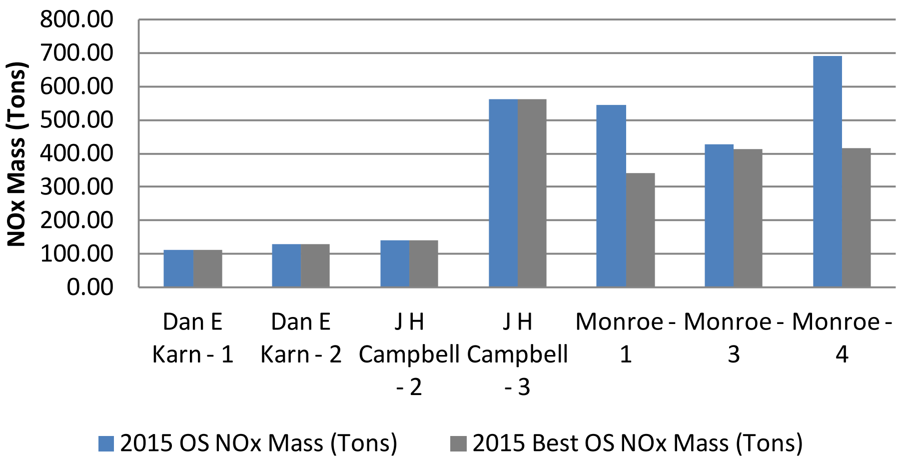
	2015 Actual OS NOx Mass (Tons)	2015 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Louisiana	403	345	59	0.07%
Massachusetts	71	40	31	0.04%
Maryland	2,859	2,702	156	0.19%

Appendix A - 25

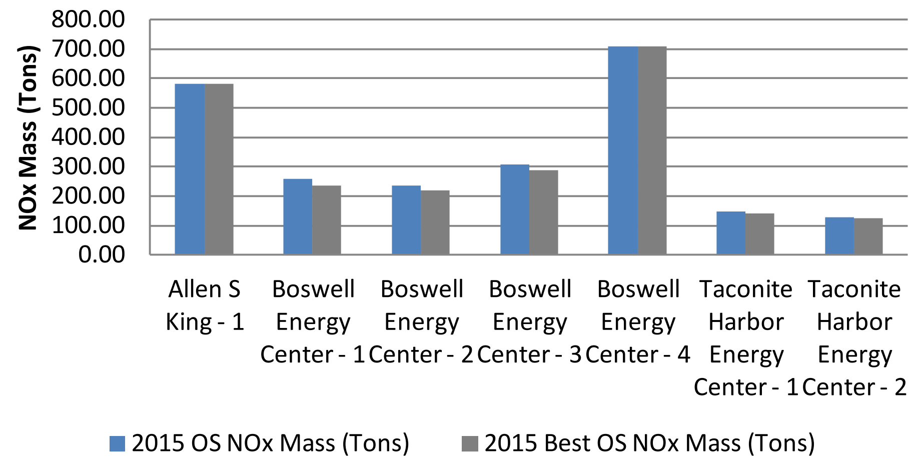
Optimization Appears to be Underway

2015 Ozone Season Total NOx Emissions – Actual and Best Rates from Past

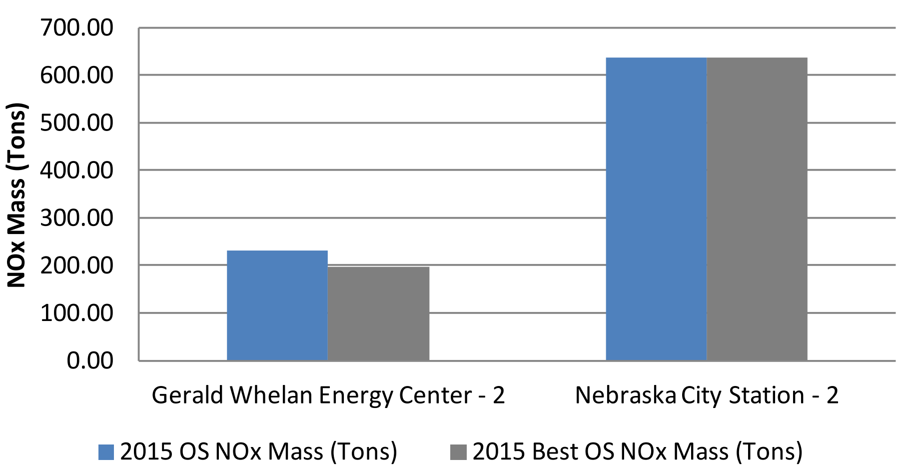
Michigan



Minnesota



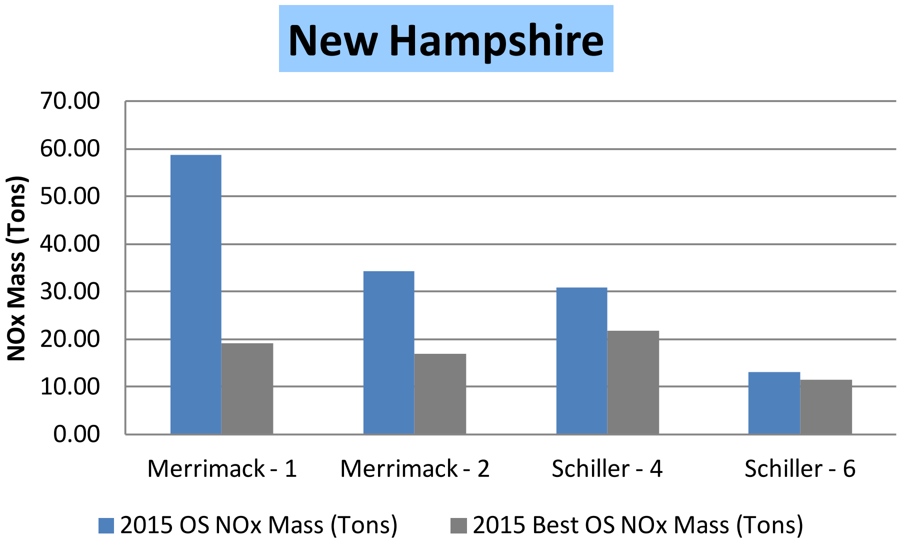
Nebraska

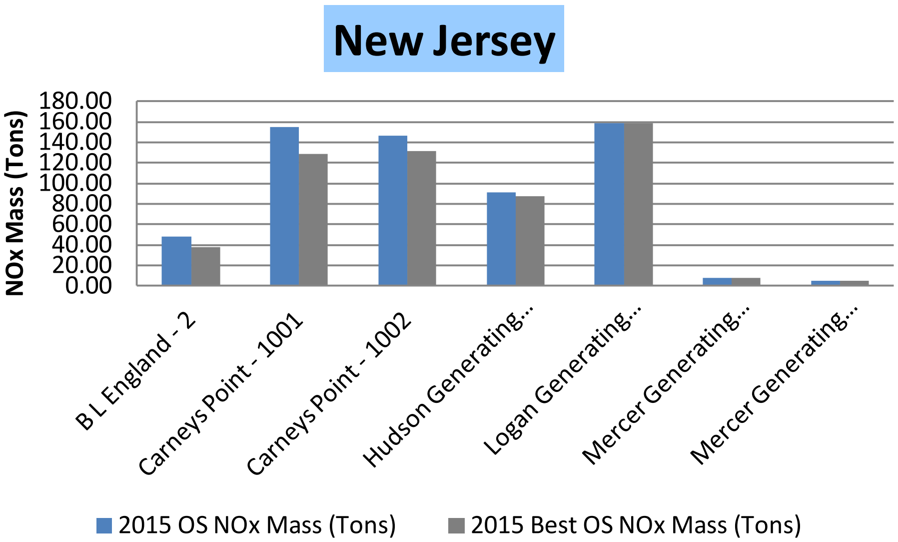


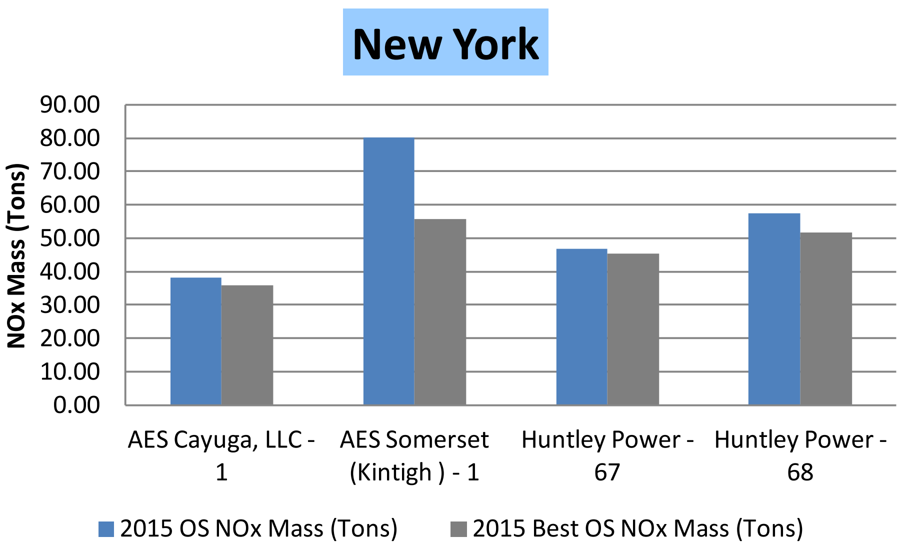
	2015 Actual OS NOx Mass (Tons)	2015 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Michigan	2,608	2,115	494	0.60%
Minnesota	2,366	2,296	69	0.08%
Nebraska	870	835	35	0.04%

Optimization Appears to be Underway

2015 Ozone Season Total NOx Emissions – Actual and Best Rates from Past





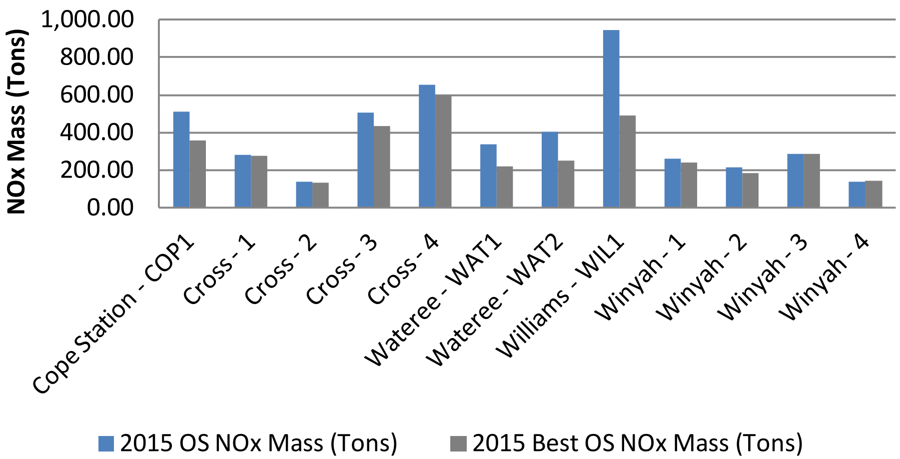


	2015 Actual OS NOx Mass (Tons)	2015 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
New Hampshire	137	70	67	0.08%
New Jersey	611	556	55	0.07%
New York	223	189	34	0.04%

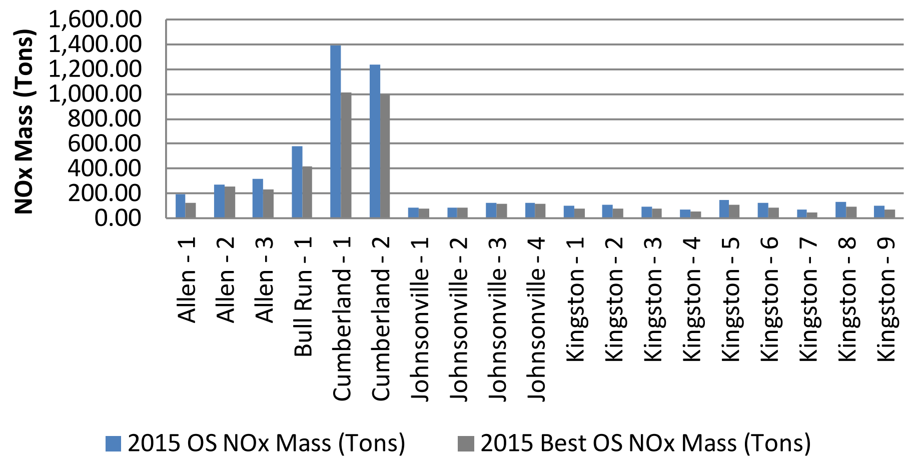
Optimization Appears to be Underway

2015 Ozone Season Total NOx Emissions – Actual and Best Rates from Past

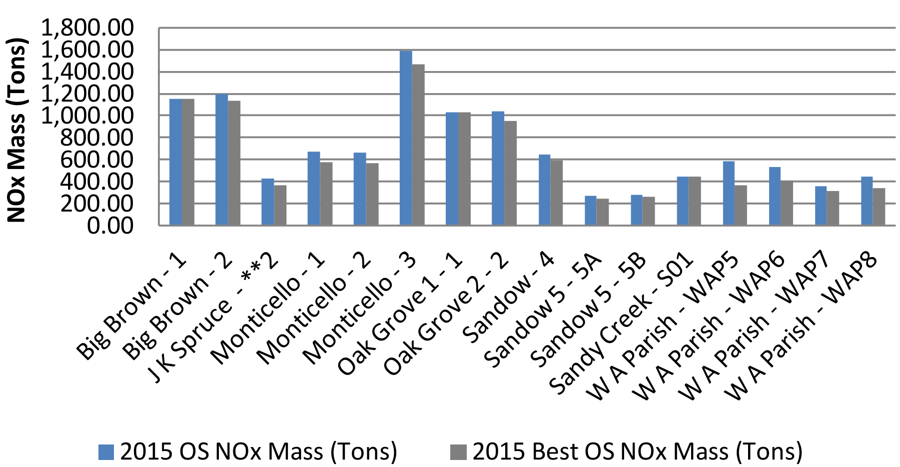
South Carolina



Tennessee



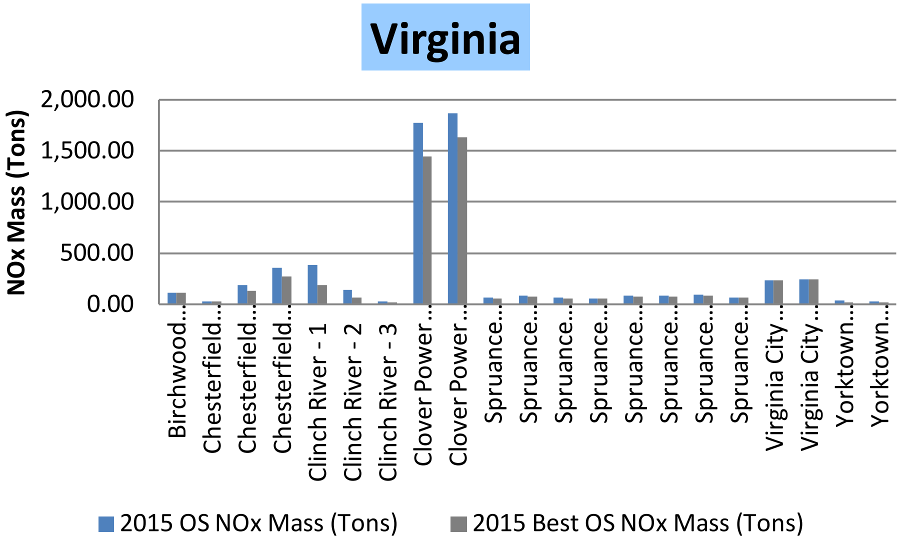
Texas

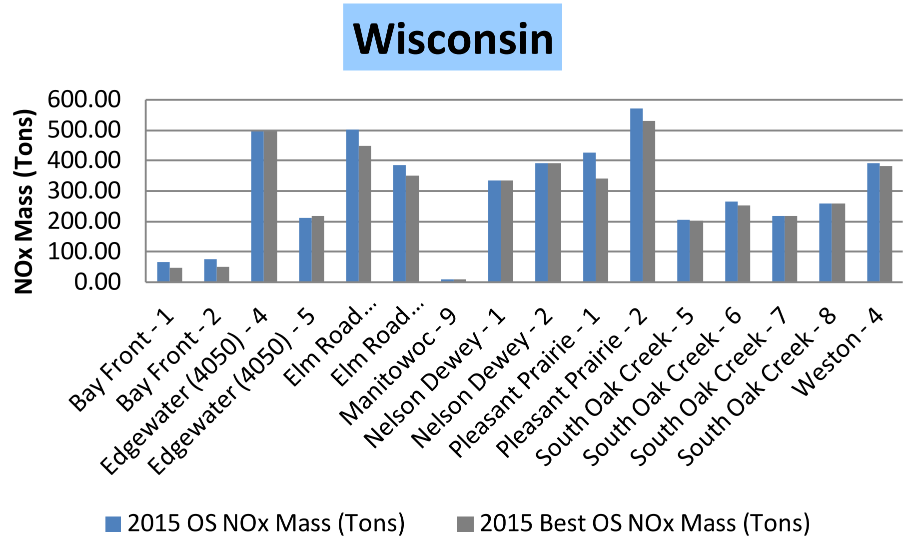


	2015 Actual OS NOx Mass (Tons)	2015 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
South Carolina	4,678	3,613	1,065	1.30%
Tennessee	5,361	4,144	1,216	1.49%
Texas	11,372	10,231	1,096	1.34%

Optimization Appears to be Underway

2015 Ozone Season Total NOx Emissions – Actual and Best Rates from Past





	2015 Actual OS NOx Mass (Tons)	2015 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Virginia	6,034	4,962	1,072	1.31%
Wisconsin	4,811	4,525	287	0.35%

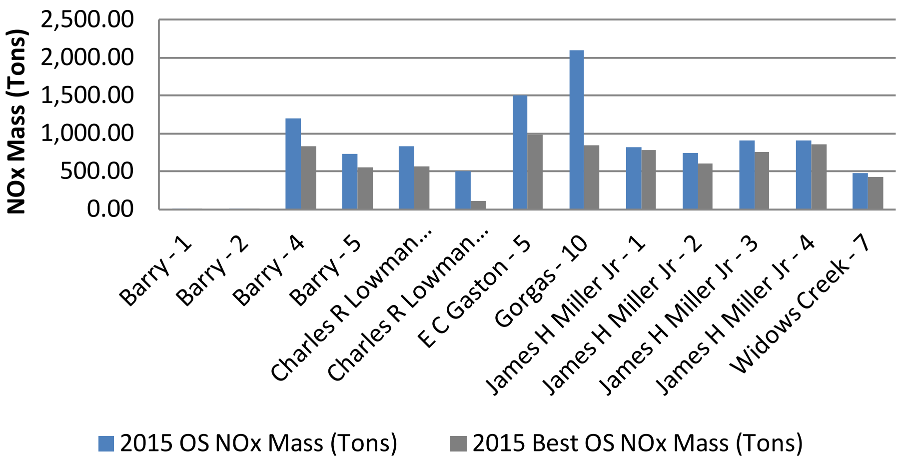
Review of Optimization Needed

- States with a meaningful portion of their units with rates exceeding best historical rates and higher than expected 2015 rates
  - Alabama
  - Florida
  - Indiana
  - Kentucky
  - Missouri
  - North Carolina
  - Ohio
  - Pennsylvania
  - West Virginia

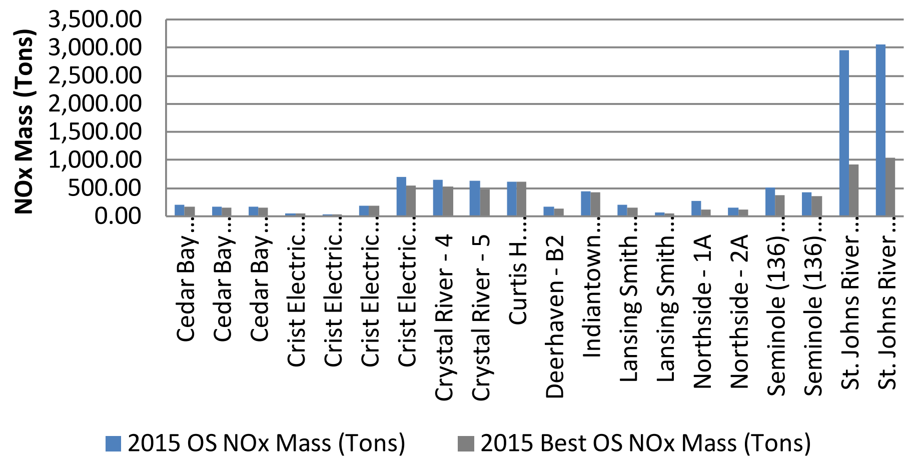
Review of Optimization Needed

2015 Ozone Season Total NOx Emissions – Actual and Best Rates from Past

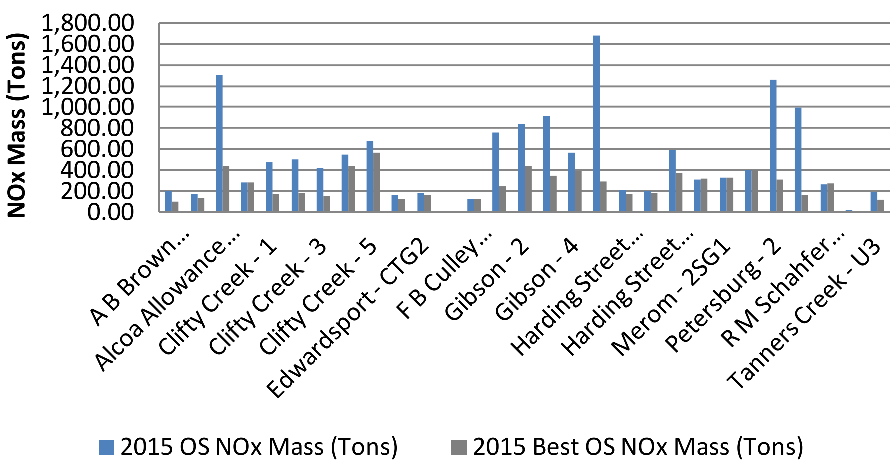
Alabama



Florida



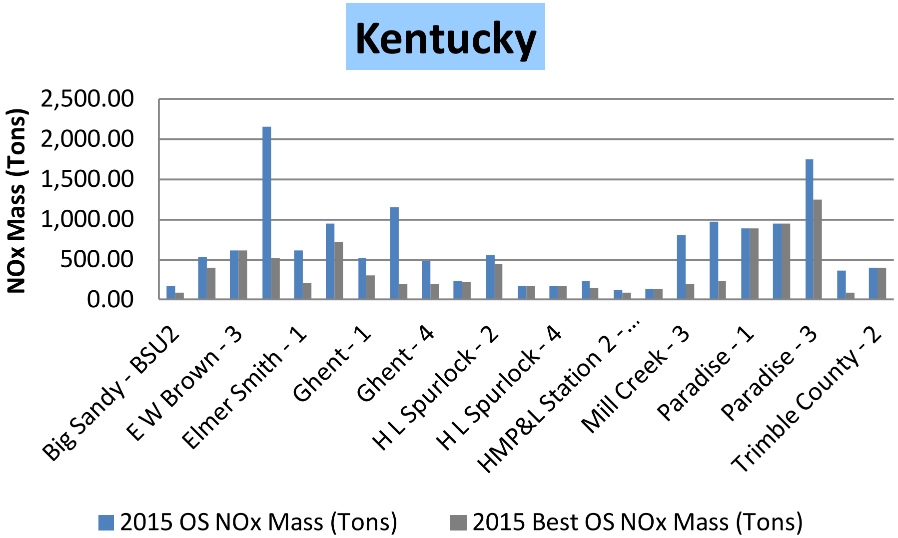
Indiana

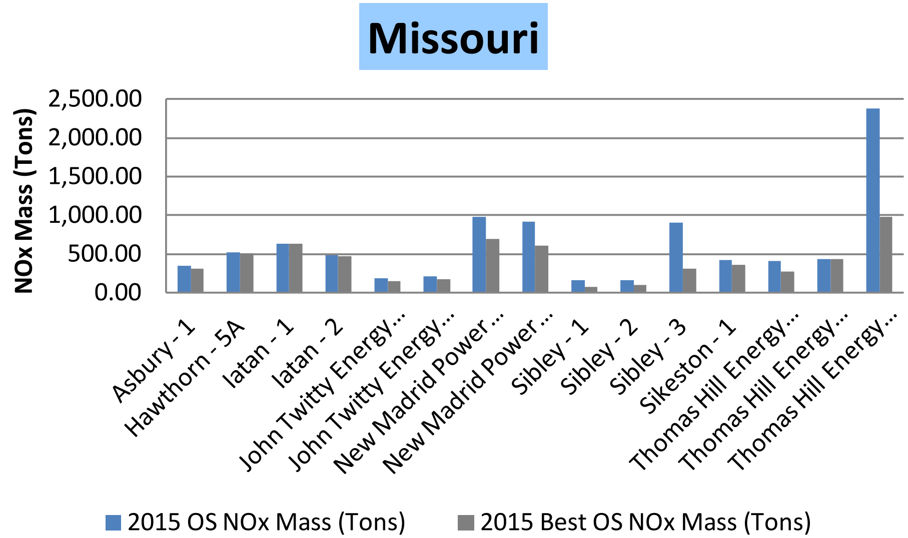


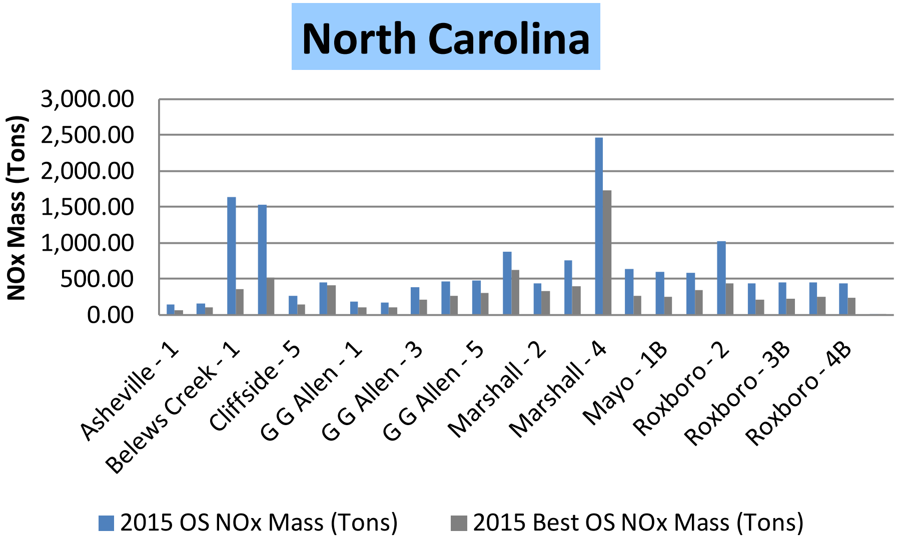
	2015 Actual OS NOx Mass (Tons)	2015 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Alabama	10,713	7,308	3,405	4.16%
Florida	11,666	6,659	5,007	6.11%
Indiana	14,591	7,246	7,344	8.97%

Review of Optimization Needed

2015 Ozone Season Total NOx Emissions – Actual and Best Rates from Past





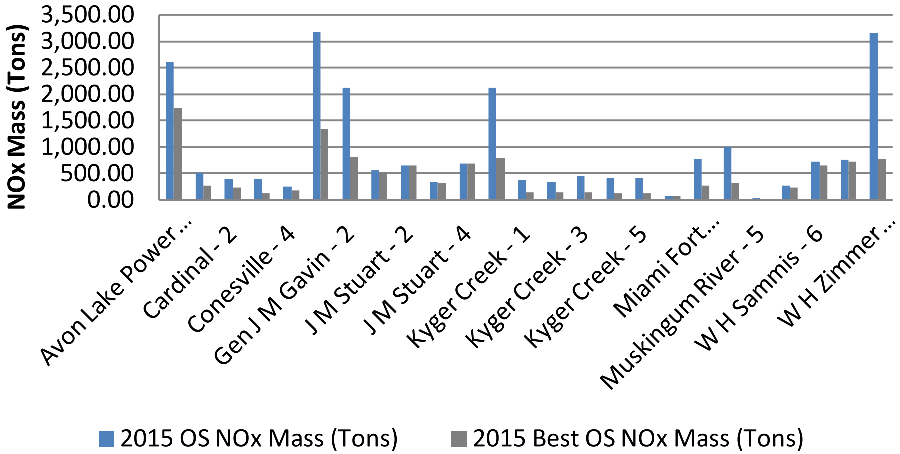


	2015 Actual OS NOx Mass (Tons)	2015 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Kentucky	14,907	8,588	6,319	7.72%
Missouri	9,138	6,082	3,056	3.73%
N. Carolina	15,025	7,973	7,052	8.61%

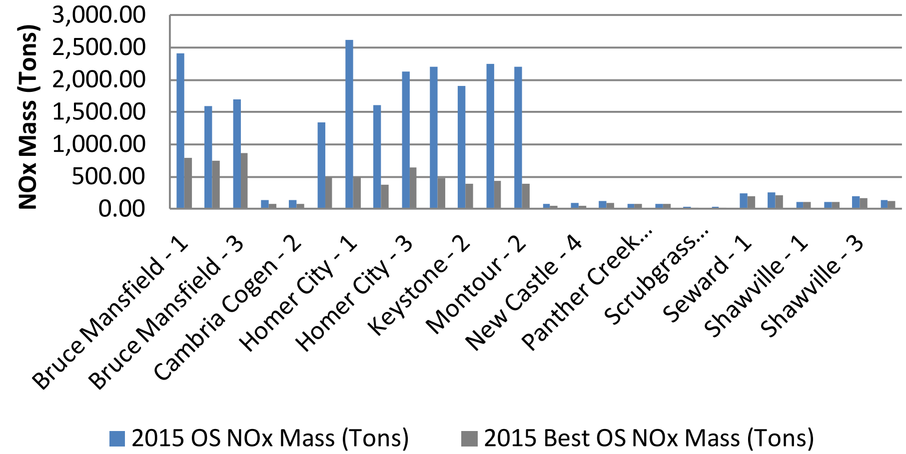
Review of Optimization Needed

2015 Ozone Season Total NOx Emissions – Actual and Best Rates from Past

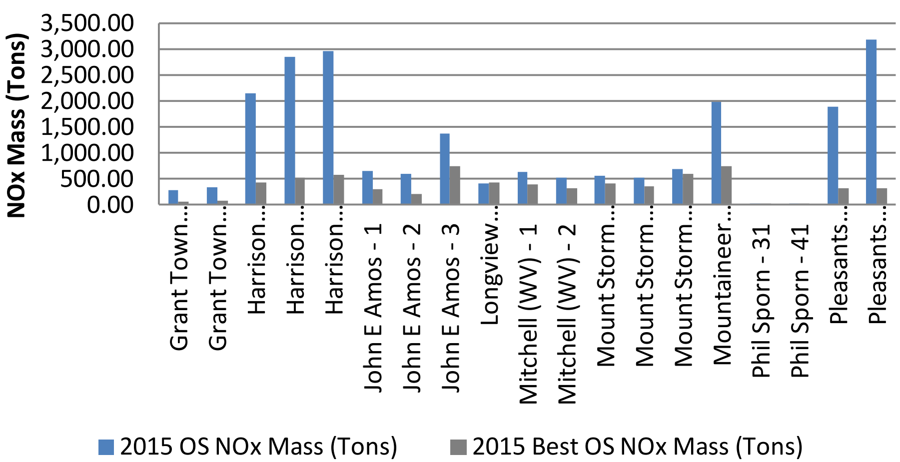
Ohio



Pennsylvania



West Virginia



	2015 Actual OS NOx Mass (Tons)	2015 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Ohio	22,668	11,532	11,136	13.60%
Pennsylvania	23,841	7,562	16,279	19.88%
West Virginia	21,662	6,827	14,835	18.11%

Some Observations

- There are more states with units that appear to be optimizing controls than states with units that are not
  - Many of the states identified in the 176A Petition appear to have many units not optimizing controls
  - With reasonable efforts to optimize controls approximately 400 tons of daily NOx reductions could be achieved on high ozone days
- Many states have a majority of their units close to meeting best historical rates.
  - AR, DE, GA, IA, IL, KA, LO, MA, MD, MI, MN, NE, NH, NJ, NY, SC, TN, TX, VA and WI all have a majority of reported units close to best historical rates
- Many states have a significant number of units emitting at rates that are noticeably higher than best historical rates
  - AL, FL, IN, KY, MO, NC, OH, PA and WV all have units exceeding best historical rates
- Ozone has been low in some areas despite optimization concerns … Reduced emissions, kind weather and chemistry appear to have all played a role

Wrap-Up/Next Steps

- Additional continuing analysis appears to be called for
  - Charge the Air Directors to increase efforts to better understand why optimization is not occurring in some states and is clearly taking place in others?
- Highlights the need for "common" federally enforceable requirements to optimize controls as a playing field that is not level creates competitive advantages for some … which can affect a voluntary effort
- Good Neighbor SIPs are now required/past due for many states
- Many of the units that routinely optimize controls have language similar to the language below (discussed by SCOOT Workgroups) as part of federally enforceable regulations, permit conditions or consent decrees

… for each day during the ozone season, the owner or operator of an affected EGU shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturers specifications, good engineering practices and good air pollution control practices for minimizing emissions (as defined in 40 CFR Section 60.11(d)) …

Part V – 2016 Ozone Season Analysis of Optimization of SCR/SNCR Controls at Coal-Fired EGUs

The following presentation provides a summary of the results of the 2016 ozone season analysis for all 29 states in the eastern modeling domain, using the methodologies discussed in Part II of this appendix. This analysis was performed using May and June data only, as full 2016 ozone season data was unavailable at the time of the analysis. Also included in this presentation is additional analysis performed by MDE to address comments from states and power plant owners in response to the 2015 ozone season analysis. MDE received feedback that many coal-fired EGUs with SCR/SNCR controls cannot reach their historical best NOx emission rates due to either operating at low capacity or tuning the SCR for mercury reductions to comply with MATS. MDE has performed extensive analysis to address the low capacity issue and has found that though low capacity may have some impact on emission rates, the units identified for this study still can achieve over 80% of the initial calculated NOx reductions even at lower capacity. Initial analysis of mercury data indicates that not all units are capable of utilizing the SCR for mercury oxidation, and those that do should still be able to comply with MATS while achieving reasonable NOx rates.

Maryland Department of the Environment

The 2016 Voluntary Control Effort

An effort to optimize the use of existing control technologies

An Assessment of Optimization of Controls At Coal-Fired Units in the Eastern Modeling Domain
August 3, 2016

New to the 2016 Study

- Calculated lost benefit from optimization curves
- Assessment of optimization of SCR for MATS

What We Did

- Analyzed the emissions data submitted by sources for 2016 Second Quarter (May and June only) Ozone Season in the Eastern Modeling Domain
  - AL, AR, DE, FL, GA, IA, IL, IN, KS, KY, LA, MA, MD, MI, MN, MO, NC, NE, NH, NJ, NY, OH, PA, SC, TN, TX, VA, WI & WV
    - CT, MS, & OK are not included because there are no coal-fired EGUs with SCR or SNCR.
    - VT is not included because there are no coal-fired EGUs.
- Looked at 2016 ozone season average emission rates at 361 individual units. As of 8/3/2016 351 units have reported 2016 ozone season data to CAMD.
  - 2015: 385 units. Change is due to unit retirements, fuel-switching and new units with previously un reported controls.
- Compared those rates to the lowest demonstrated ozone season average emission rate from the past (2005-2015)
- Placed individual units into three bins based upon the above rate comparisons
  - **BIN 1** - Review not needed - Equal or better performance compared to past - optimization underway (53 units)
  - **BIN 2** - Review needed but lower priority - Slightly poorer performance compared to past (194 units)
  - **BIN 3** - High priority for review - Noticeably poorer performance compared to past (81 units)
  - 23 units did not operate, retired or switched fuels
  - 10 units did not report 2nd quarter data
    - FL – 4
    - MA – 1
    - MI – 1
    - MN – 3
    - TX - 1
- Calculated potential lost NOx reductions

BIN Number 1

… units with 2016 rates better than … or close to … best historical rates

State	Facility	Unit	2016 OS Rate (lb/mmBtu)	Best OS Rate (lb/mmBtu)	Deviation	State	Facility	Unit	2016 OS Rate (lb/mmBtu)	Best OS Rate (lb/mmBtu)	Deviation
AL	E C Gaston	5	0.07	0.08	-14%	MO	Sibley	2	0.25	0.42	-40%
AL	J H Miller	3	0.06	0.06	-12%	NC	Marshall	2	0.17	0.20	-15%
IA	G Neal S	4	0.18	0.19	-6%	NH	Merrimack	2	0.05	0.16	-70%
IA	Lansing	4	0.05	0.05	-12%	NY	Cayuga	1	0.08	0.18	-56%
IA	Walter Scott	4	0.05	0.5	-6%	OH	Avon Lake	12	0.23	0.28	-18%
IL	Prairie	1	0.06	0.07	-15%	OH	J M Stuart	2	0.10	0.11	-7%
IN	R Schahfer	14	0.09	0.10	-6%	PA	Conemaugh	1	0.20	0.23	-12%
KS	Jeffrey	1	0.04	0.05	-24%	PA	Conemaugh	2	0.18	0.20	-10%
KS	La Cygne	1	0.08	0.08	-5%	TN	Johnsonville	1	0.14	0.17	-14%
KY	E W Brown	3	0.15	0.17	-11%	TN	Johnsonville	2	0.14	0.17	-16%
KY	H L Spurlock	4	0.06	0.06	-8%	TN	Johnsonville	3	0.14	0.16	-16%
LA	Big Cajun 2	2B3	0.11	0.12	-5%	TN	Johnsonville	4	0.13	0.16	-17%
LA	Rodemacher	3-2	0.04	0.04	-5%	TX	Big Brown	2	0.12	0.13	-6%
MD	AES Warrior	001	0.05	0.05	-5%	TX	Monticello	3	0.13	0.15	-11%
MD	Chalk Point	1	0.08	0.10	-21%	TX	Twin Oaks	U1	0.09	0.10	-6%
MD	Dickerson	1	0.21	0.22	-6%	TX	Twin Oaks	U2	0.09	0.10	-10%
MD	Dickerson	3	0.21	0.22	-6%	VA	VA City	1	0.06	0.06	-9%
MI	Monroe	3	0.05	0.06	-13%	VA	VA City	2	0.06	0.06	-8%
MN	Taconite	1	0.11	0.12	-5%	WI	South Oak	7	0.05	0.06	-16%
MO	J Twitty	1	0.06	0.08	-28%	WI	Weston	4	0.05	0.05	-5%

Top 40 out of 53

BIN Number 2

… Units with 2016 rates that are worse than (but not more than double) best historical rates and an emission rate greater than 0.1 lb/mmBtu for SCR and 0.2 lb/mmBtu for SNCR

State	Facility	Unit	2016 OS Rate (lb/mmBtu)	Best OS Rate (lb/mmBtu)	Deviation	State	Facility	Unit	2016 OS Rate (lb/mmBtu)	Best OS Rate (lb/mmBtu)	Deviation
AL	Barry	4	0.43	0.23	90%	NC	Roxboro	1	0.16	0.08	86%
AL	C Lowman	2	0.27	0.16	63%	NC	Roxboro	4A	0.14	0.08	72%
FL	Indiantown	1	0.24	0.15	63%	NC	Roxboro	4B	0.13	0.08	68%
IL	Dallman	31	0.12	0.09	23%	NJ	B L England	2	0.37	0.31	18%
IL	Dallman	32	0.11	0.08	25%	NY	Somerset	1	0.23	0.14	67%
IN	Clifty Creek	4	0.42	0.24	78%	OH	Gavin	1	0.12	0.07	75%
IN	Clifty Creek	5	0.38	0.24	59%	OH	Gavin	2	0.11	0.06	94%
IN	F B Culley	3	0.11	0.09	25%	OH	J M Stuart	3	0.11	0.10	15%
IN	Gibson	5	0.11	0.06	86%	OH	W Sammis	6	0.12	0.10	22%
KY	Elmer Smith	2	0.30	0.22	36%	PA	B Mansfield	1	0.15	0.08	88%
KY	Paradise	1	0.15	0.09	58%	SC	Cope	COP1	0.12	0.08	46%
KY	Paradise	2	0.12	0.09	33%	SC	Wateree	WAT1	0.11	0.06	82%
MD	Chalk	2	0.23	0.19	19%	SC	Williams	WIL1	0.11	0.06	84%
MN	Allen King	1	0.10	0.09	19%	TN	Bull Run	1	0.10	0.06	68%
MO	Asbury	1	0.17	0.09	89%	VA	Clover	1	0.28	0.23	19%
NC	G G Allen	1	0.21	0.16	25%	VA	S Genco	BLR01A	0.33	0.26	28%
NC	G G Allen	2	0.20	0.17	22%	VA	S Genco	BLR02A	0.34	0.25	35%
NC	G G Allen	3	0.31	0.17	80%	VA	S Genco	BLR02B	0.30	0.25	16%
NC	G G Allen	4	0.34	0.18	92%	WV	Harrison	1	0.10	0.06	59%
NC	Marshall	1	0.23	0.20	19%	WV	John Amos	3	0.12	0.06	91%

There are a total of 194 units in this Bin – 55 have rates above 0.1 or 0.2 lb/mmBtu; 34 with SCR, 21 with SNCR. These are the top 40 out of those 55 units.

BIN Number 3

- BIN Number 3 includes 81 units that warrant the most significant review.
- It has been subdivided into three categories - All units in BIN 3 have rates that are more than double best historical rates:
  - 9 units have 2016 rates less than 0.1 lb/mmBtu
  - 34 units have 2016 rates between 0.1 and 0.2 lb/mmBtu
  - 38 units have 2016 rates greater than 0.2 lb/mmBtu

*Units with 2016 rates that are **more than double** best historical rates and 2016 NOx rates **less than 0.1 lb/mmBtu***

State	Facility	Unit	2016 OS Rate (lb/mmBtu)	Best OS Rate (lb/mmBtu)	Deviation	State	Facility	Unit	2016 OS Rate (lb/mmBtu)	Best OS Rate (lb/mmBtu)	Deviation
FL	Northside	1A	0.05	0.03	109%						
IL	Havana	9	0.08	0.03	164%						
MI	Monroe	1	0.08	0.04	113%						
NC	Asheville	1	0.09	0.05	104%						
OH	Cardinal	2	0.09	0.04	111%						
OH	Cardinal	3	0.10	0.02	326%						
VA	Chesterfield	5	0.07	0.03	127%						
WV	J E Amos	1	0.08	0.03	138%						
WV	J E Amos	2	0.09	0.03	201%						

* All with SCR

BIN Number 3

*Units with 2016 rates that are **more than double** best historical rates and 2016 NOx rates **between 0.1 and 0.2 lb/mmBtu***

State	Facility	Unit	2016 OS Rate (lb/mmBtu)	Best OS Rate (lb/mmBtu)	Deviation	State	Facility	Unit	2016 OS Rate (lb/mmBtu)	Best OS Rate (lb/mmBtu)	Deviation
AL	Gorgas	10	0.17	0.07	154%	NC	Mayo	1B	0.18	0.06	186%
FL	Deerhaven	B2	0.14	0.06	141%	NC	Roxboro	2	0.12	0.06	106%
GA	Hammond	4	0.12	0.06	125%	NC	Roxboro	3A	0.19	0.07	156%
IN	A B Brown	1	0.16	0.08	110%	NC	Roxboro	3B	0.19	0.08	149%
IN	Gibson	1	0.18	0.03	424%	OH	Cardinal	1	0.11	0.03	215%
IN	Gibson	2	0.16	0.07	131%	OH	Miami	8	0.14	0.05	156%
IN	Gibson	3	0.18	0.07	166%	PA	B Mansfield	2	0.17	0.08	108%
IN	Gibson	4	0.18	0.06	187%	PA	B Mansfield	3	0.19	0.07	150%
IN	Petersburg	2	0.17	0.05	242%	PA	Scrubgrass	1	0.14	0.06	142%
KY	East Bend	2	0.13	0.05	152%	SC	Wateree	WAT2	0.11	0.05	105%
KY	Ghent	3	0.19	0.03	592%	WV	Harrison	3	0.16	0.07	147%
KY	Ghent	4	0.12	0.03	331%	WV	Mountaineer	1	0.11	0.04	186%
KY	HMP&L	H1	0.14	0.06	123%	WV	Pleasants	2	0.20	0.04	411%
KY	Mill Creek	3	0.10	0.05	128%						
KY	Trimble Cty	1	0.11	0.03	272%						
KY	Trimble Cty	2	0.10	0.04	146%						
MI	J H Campbell	3	0.13	0.04	219%						
NC	Belews Creek	1	0.15	0.03	424%						
NC	Belews Creek	2	0.13	0.04	238%						
NC	Cliffside	5	0.14	0.06	143%						
NC	Mayo	1A	0.18	0.06	188%						

* All but 1 with SCR

BIN Number 3

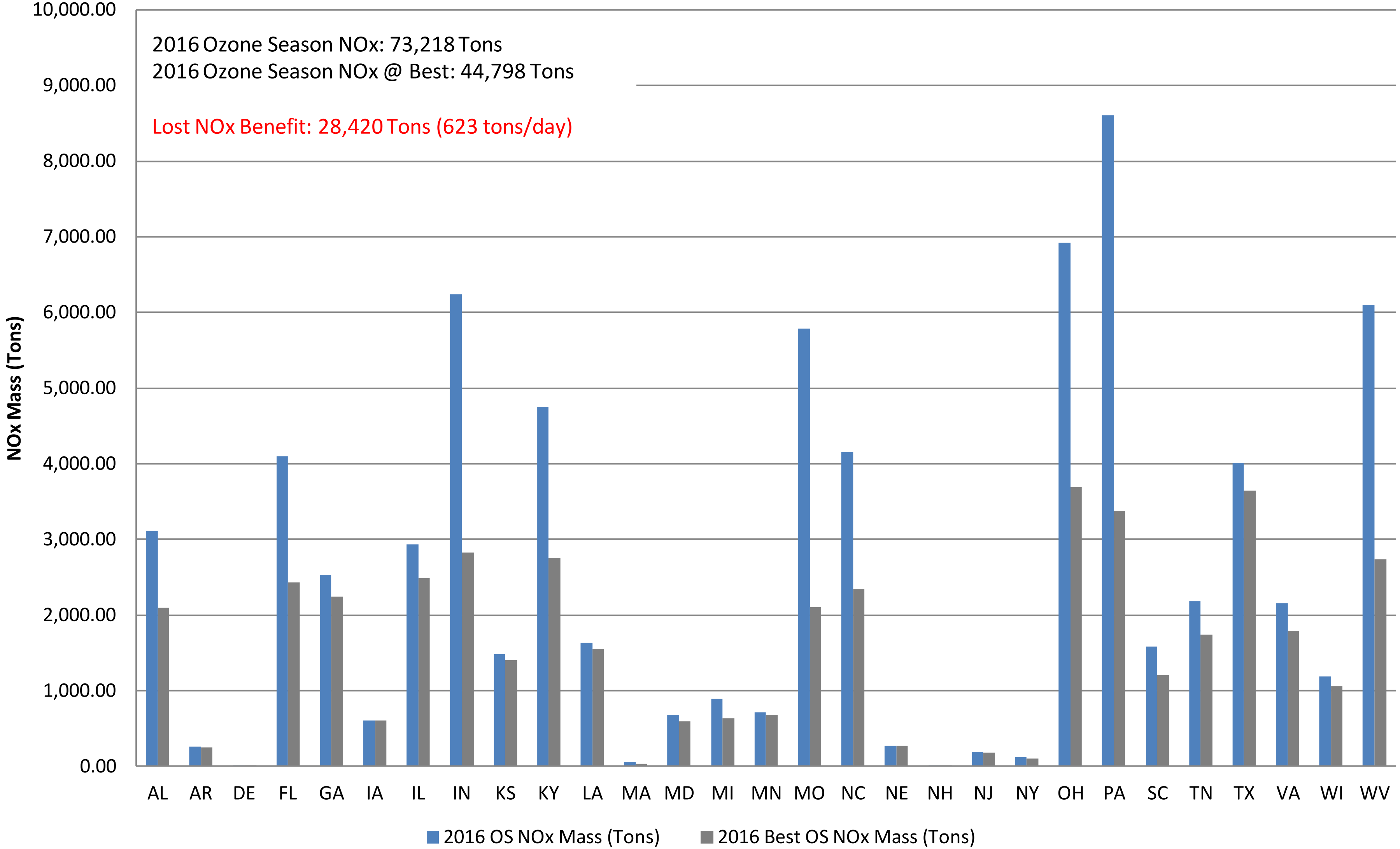
*… units with 2016 rates that are **more than double** best historical rates and 2016 NOx rates **above 0.2 lb/mmBtu***

State	Facility	Unit	2016 OS Rate (lb/mmBtu)	Best OS Rate (lb/mmBtu)	Deviation	State	Facility	Uni t	2016 OS Rate (lb/mmBtu)	Best OS Rate (lb/mmBtu)	Deviation
AL	C Lowman	3	0.27	0.06	356%	OH	Kyger Creek	4	0.21	0.08	164%
FL	St. Johns Rvr	1	0.43	0.13	239%	OH	Kyger Creek	5	0.23	0.08	188%
FL	St. Johns Rvr	2	0.34	0.13	165%	OH	W H Zimmer	1	0.21	0.06	276%
IN	Alcoa	4	0.30	0.09	220%	PA	Cambria Cog	1	0.23	0.09	141%
IN	Clifty Creek	1	0.36	0.07	391%	PA	Cambria Cog	2	0.22	0.09	128%
IN	Clifty Creek	2	0.37	0.08	391%	PA	Cheswick	1	0.35	0.09	287%
IN	Clifty Creek	3	0.35	0.07	376%	PA	Homer City	1	0.27	0.07	302%
IN	Petersburg	3	0.20	0.05	332%	PA	Homer City	2	0.33	0.08	305%
KY	Elmer Smith	1	0.25	0.12	107%	PA	Homer City	3	0.23	0.09	159%
KY	Paradise	3	0.25	0.10	148%	PA	Keystone	1	0.22	0.04	411%
MO	New Madrid	2	0.65	0.09	594%	PA	Keystone	2	0.22	0.04	403%
MO	Sibley	1	0.73	0.34	115%	PA	Montour	1	0.36	0.06	512%
MO	Sibley	3	0.40	0.08	410%	PA	Montour	2	0.37	0.06	538%
MO	Thomas Hill	MB1	0.43	0.10	349%	VA	Birchwood	001	0.21	0.09	138%
MO	Thomas Hill	MB2	0.49	0.12	322%	WV	Grant Town	1A	0.31	0.07	337%
MO	Thomas Hill	MB3	0.22	0.10	134%	WV	Grant Town	1B	0.31	0.07	335%
OH	Killen	2	0.24	0.09	169%	WV	Harrison	2	0.23	0.07	255%
OH	Kyger Creek	1	0.20	0.08	160%	WV	Pleasants	1	0.21	0.04	430%
OH	Kyger Creek	2	0.23	0.08	192%						
OH	Kyger Creek	3	0.24	0.08	208%						

* All but 5 with SCR

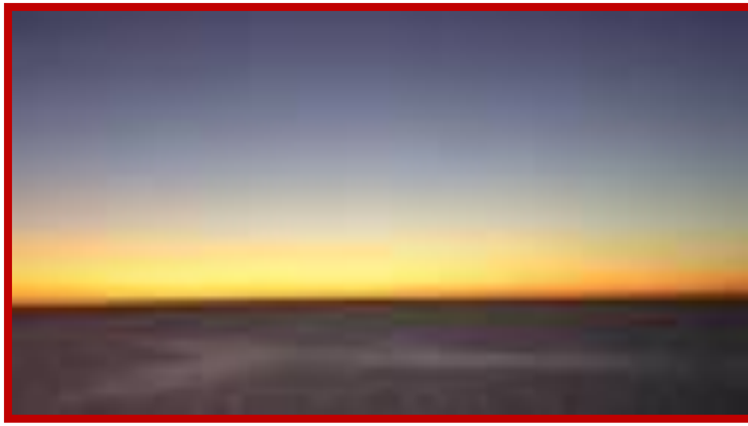
Lost NOx Reductions - By State

2016 Ozone Season Total NOx Emissions - Actual and Best Rates from Past



Optimization Appears to be Underway

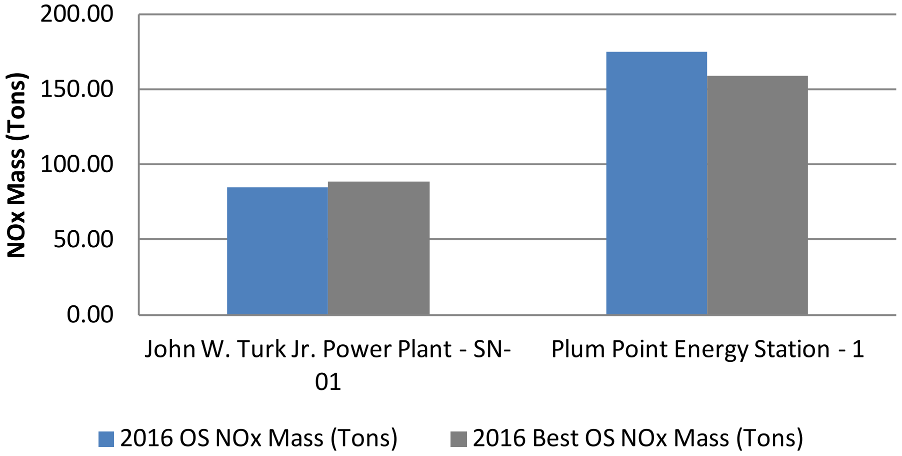
- States with the majority of their units meeting or out-performing best historical rates:
  - Arkansas
  - Delaware
  - Georgia
  - Iowa
  - Illinois
  - Kansas
  - Louisiana
  - Massachusetts
  - Maryland
  - Michigan
  - Minnesota
  - Nebraska
  - New Hampshire
  - New Jersey
  - New York
  - South Carolina
  - Tennessee
  - Texas
  - Virginia
  - Wisconsin



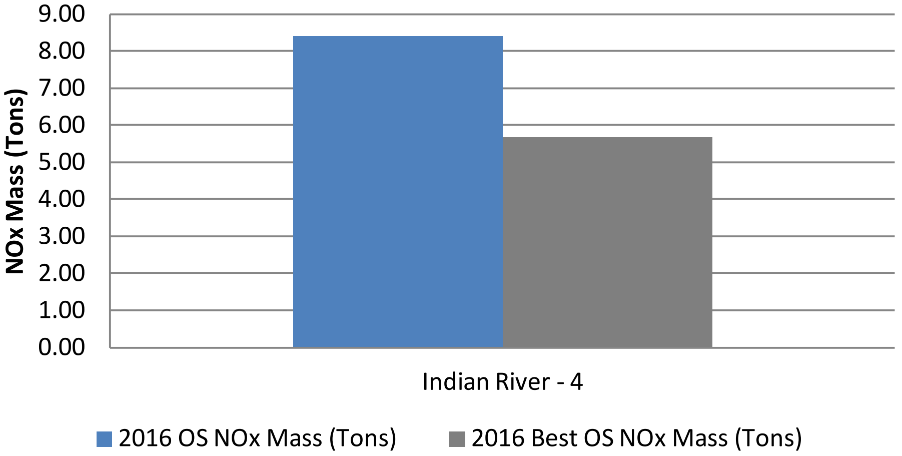
Optimization Appears to be Underway

2016 Ozone Season Total NOx Emissions – Actual and Best Rates from Past

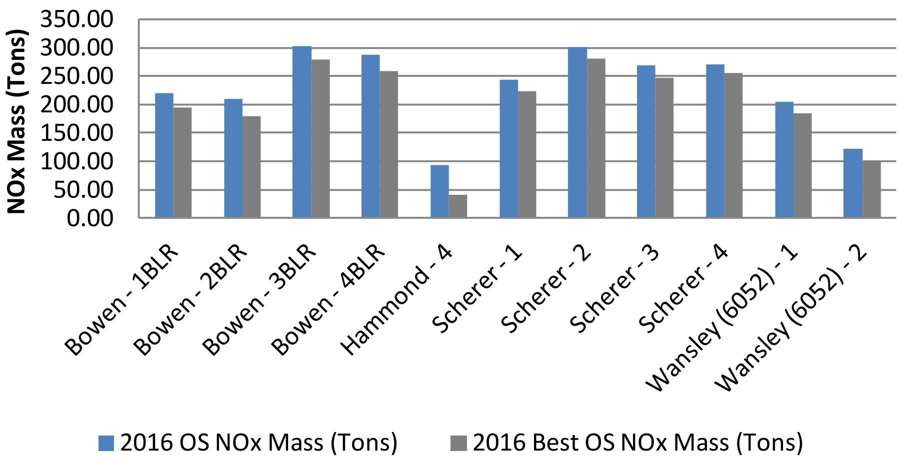
Arkansas



Delaware



Georgia

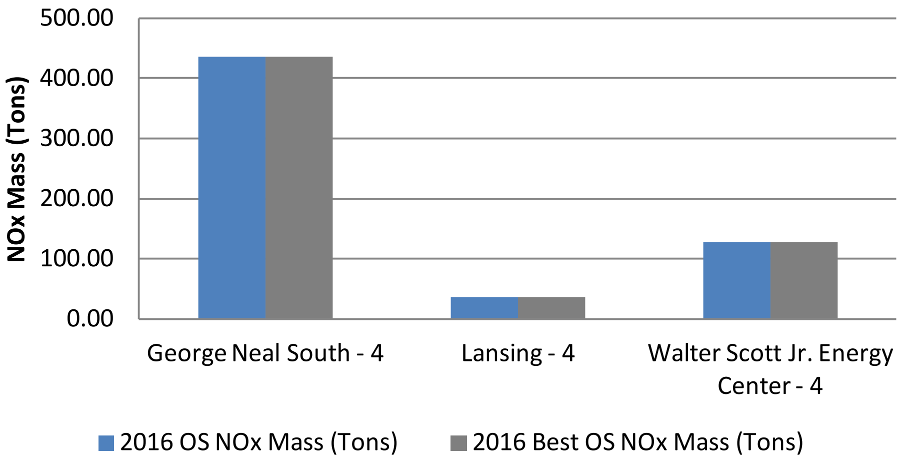


	2016 Actual OS NOx Mass (Tons)	2016 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Arkansas	260	248	12	0.04%
Delaware	8	6	3	0.01%
Georgia	2,525	2,246	279	0.98%

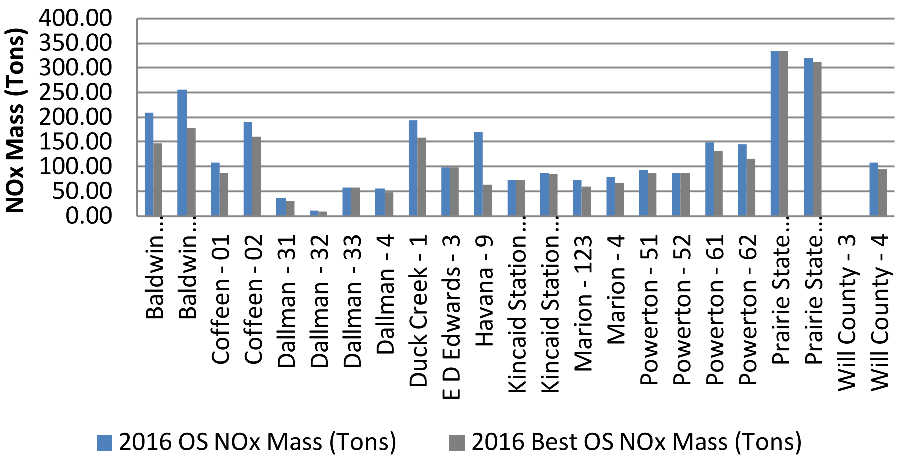
Optimization Appears to be Underway

2016 Ozone Season Total NOx Emissions – Actual and Best Rates from Past

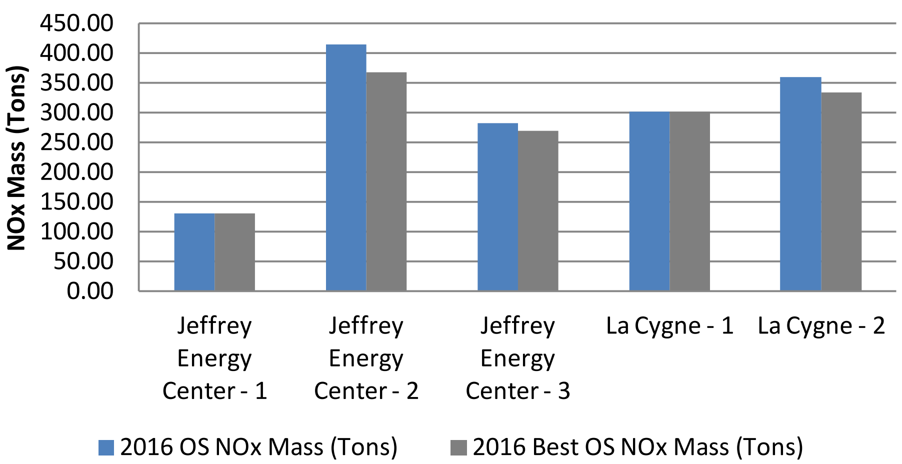
Iowa



Illinois



Kansas

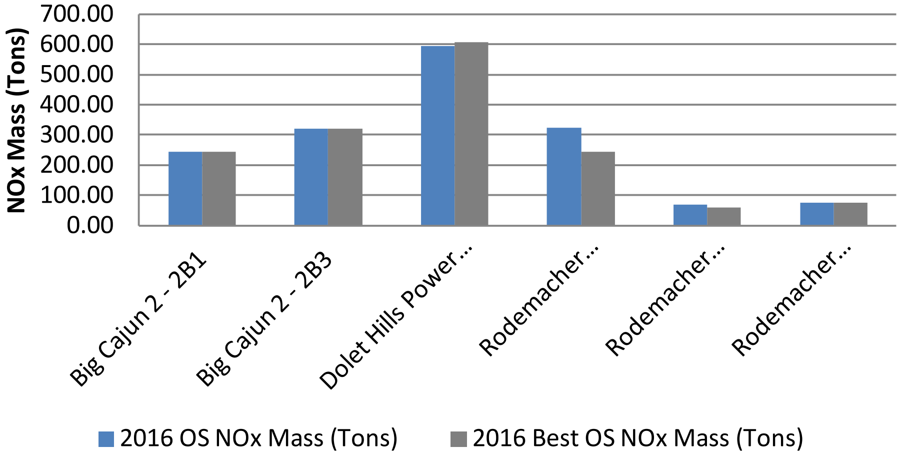


	2016 Actual OS NOx Mass (Tons)	2016 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Iowa	600	600	0	0.00%
Illinois	2,936	2,484	451	1.59%
Kansas	1,487	1,400	86	0.30%

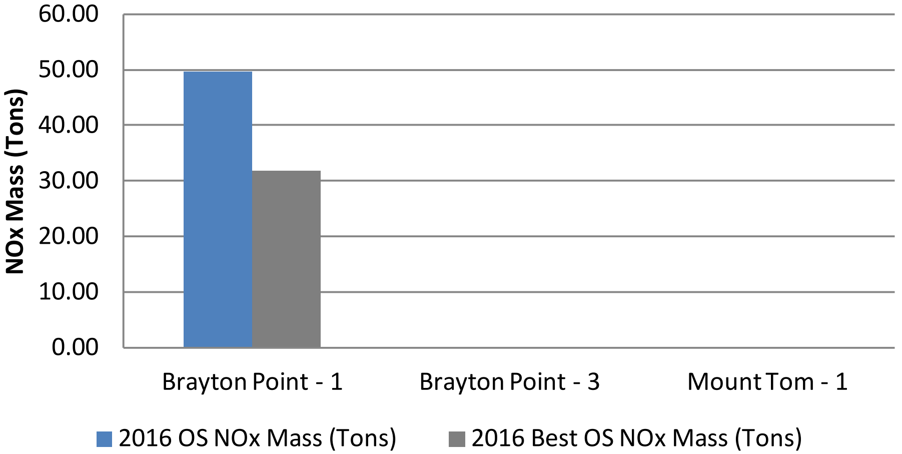
Optimization Appears to be Underway

2016 Ozone Season Total NOx Emissions – Actual and Best Rates from Past

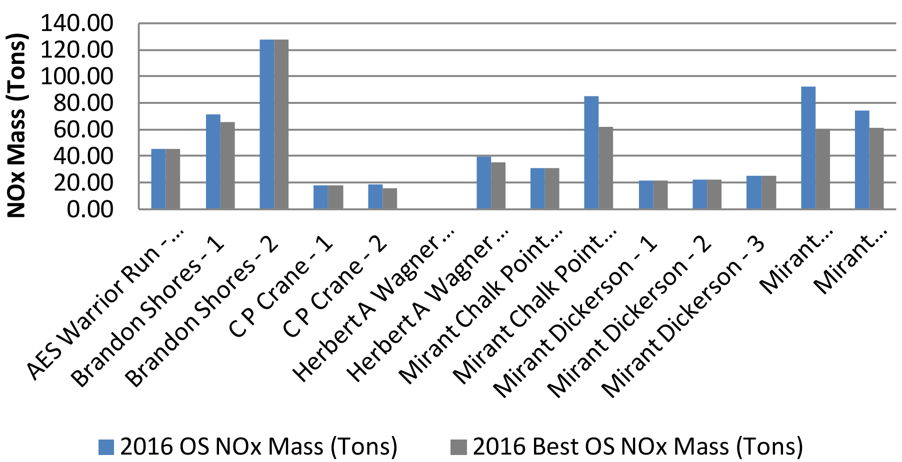
Louisiana



Massachusetts



Maryland

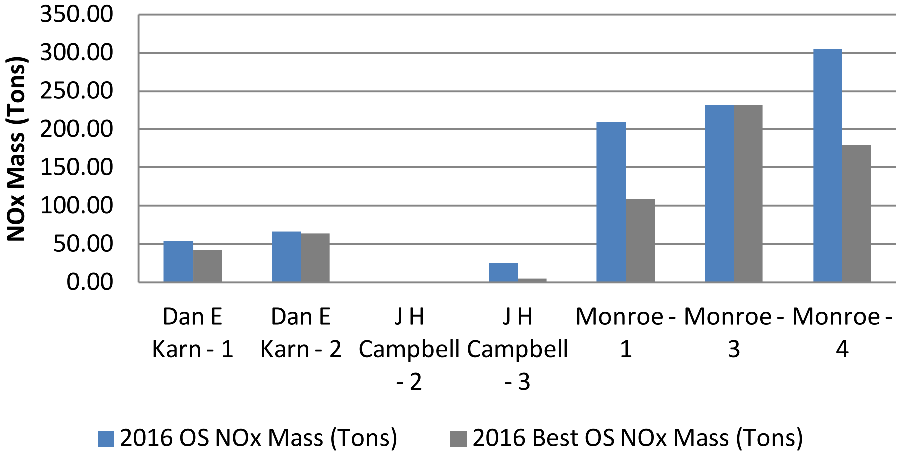


	2016 Actual OS NOx Mass (Tons)	2016 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Louisiana	1,630	1,554	76	0.27%
Massachusetts	50	32	18	0.06%
Maryland	672	591	81	0.29%

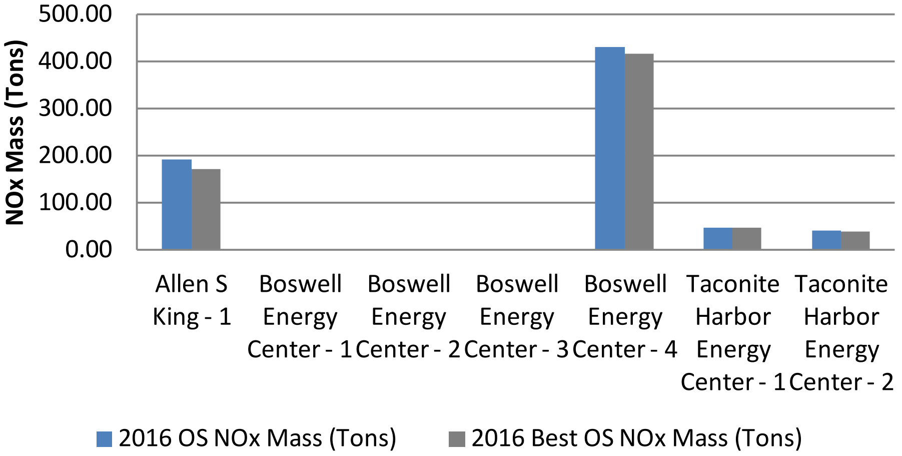
Optimization Appears to be Underway

2016 Ozone Season Total NOx Emissions – Actual and Best Rates from Past

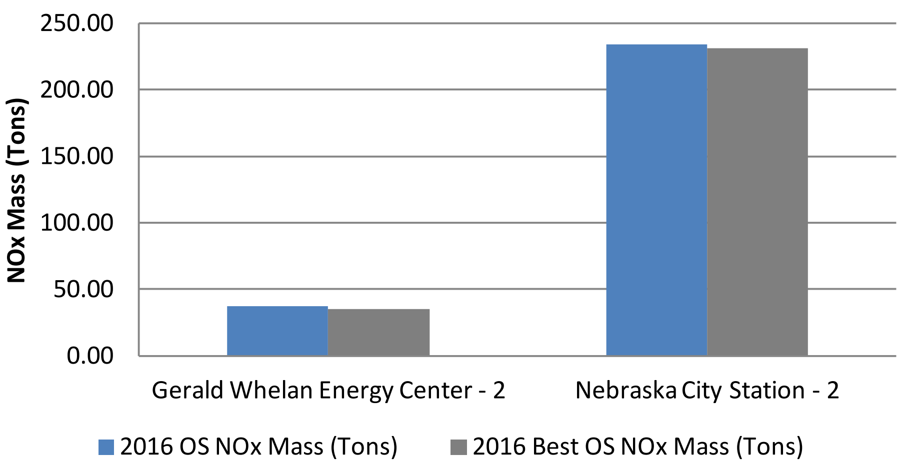
Michigan



Minnesota



Nebraska

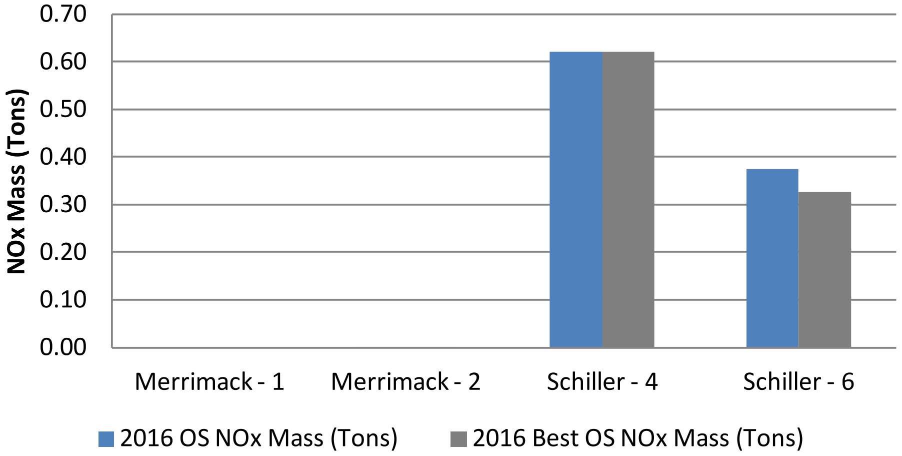


	2016 Actual OS NOx Mass (Tons)	2016 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Michigan	890	630	260	0.91%
Minnesota	710	673	37	0.13%
Nebraska	272	266	5	0.02%

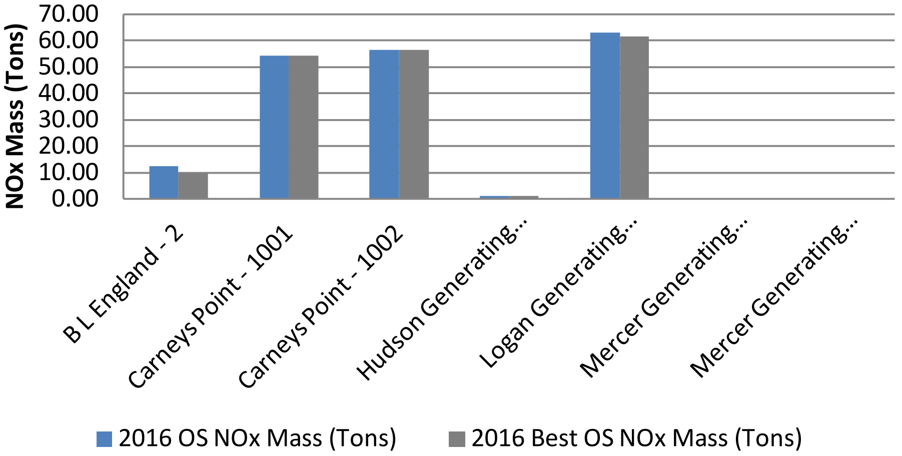
Optimization Appears to be Underway

2016 Ozone Season Total NOx Emissions – Actual and Best Rates from Past

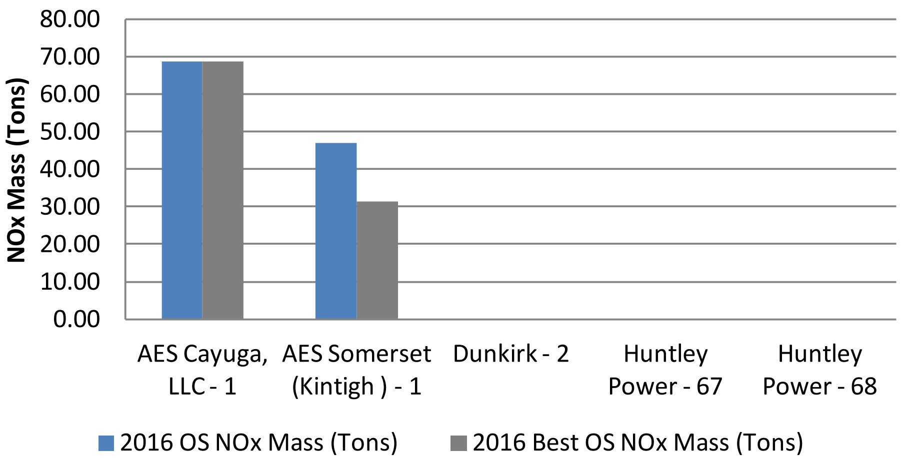
New Hampshire



New Jersey



New York

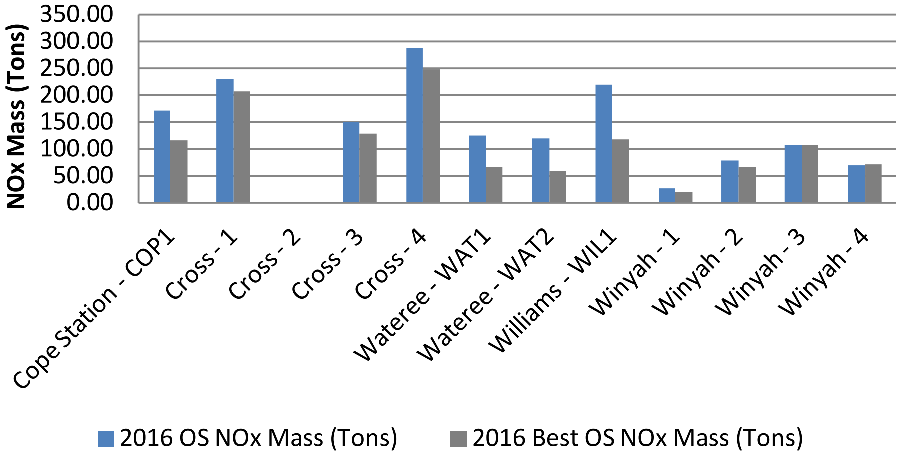


	2016 Actual OS NOx Mass (Tons)	2016 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
N Hampshire	1	1	0	0.00%
New Jersey	187	183	4	0.01%
New York	116	100	16	0.05%

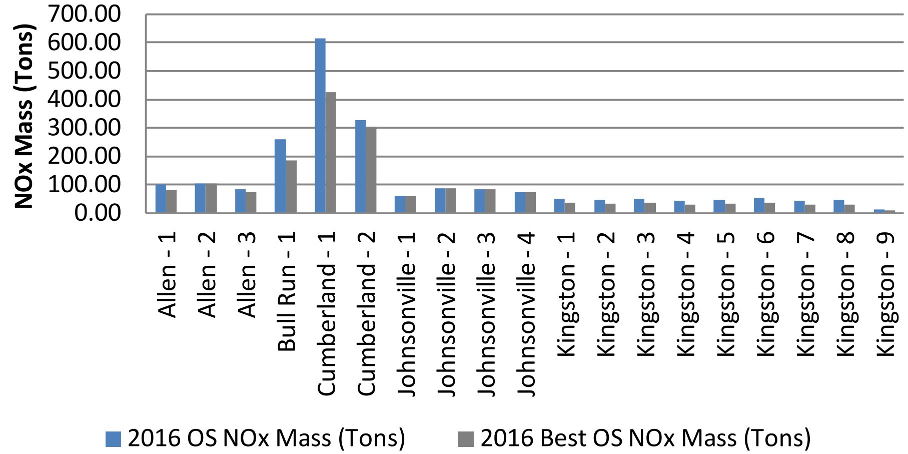
Optimization Appears to be Underway

2016 Ozone Season Total NOx Emissions – Actual and Best Rates from Past

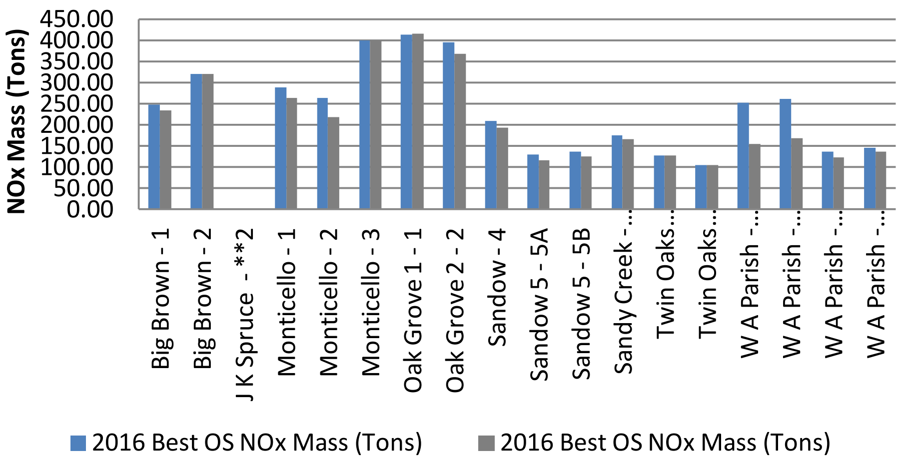
South Carolina



Tennessee



Texas

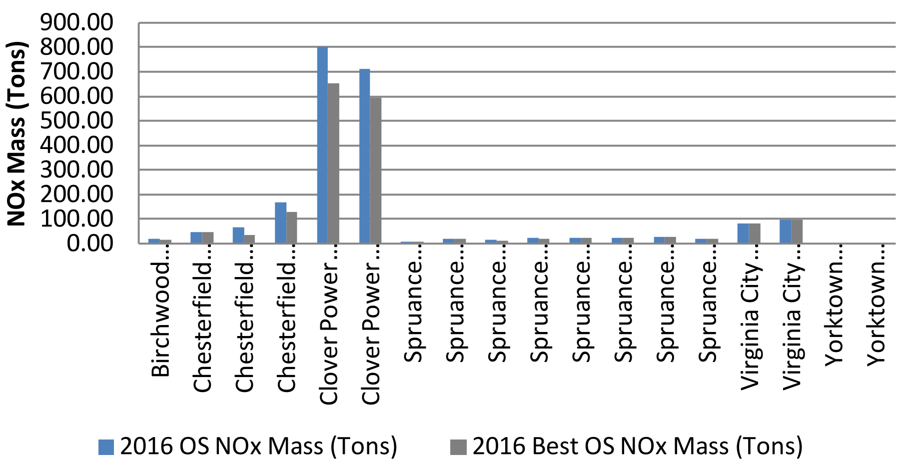


	2016 Actual OS NOx Mass (Tons)	2016 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
S Carolina	1,582	1,207	375	1.32%
Tennessee	2,185	1,740	445	1.56%
Texas	4,011	3,639	372	1.31%

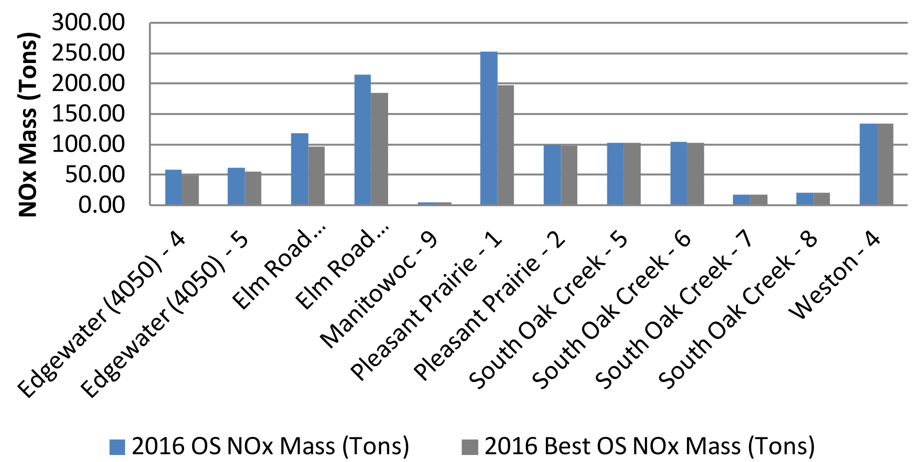
Optimization Appears to be Underway

2016 Ozone Season Total NOx Emissions – Actual and Best Rates from Past

Virginia



Wisconsin



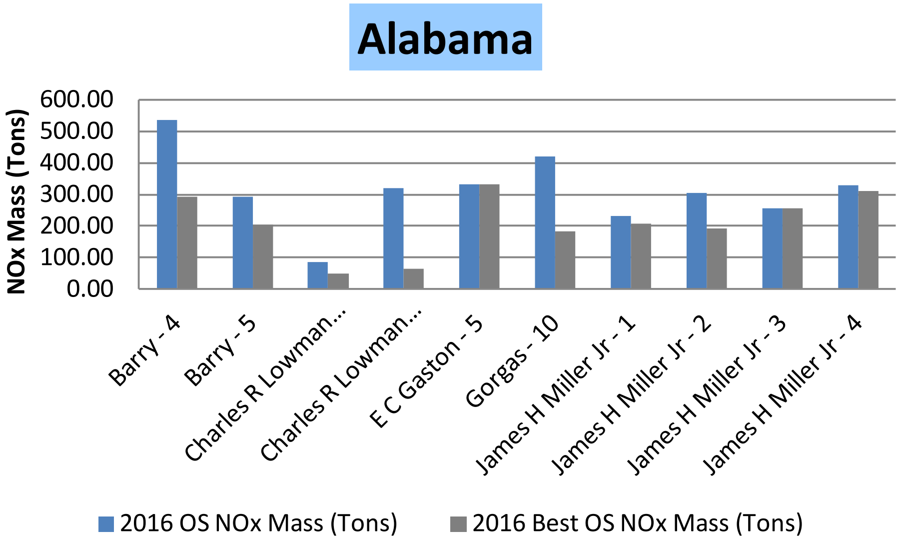
	2016 Actual OS NOx Mass (Tons)	2016 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Virginia	2,155	1,792	364	1.28%
Wisconsin	1,187	1,059	127	0.45%

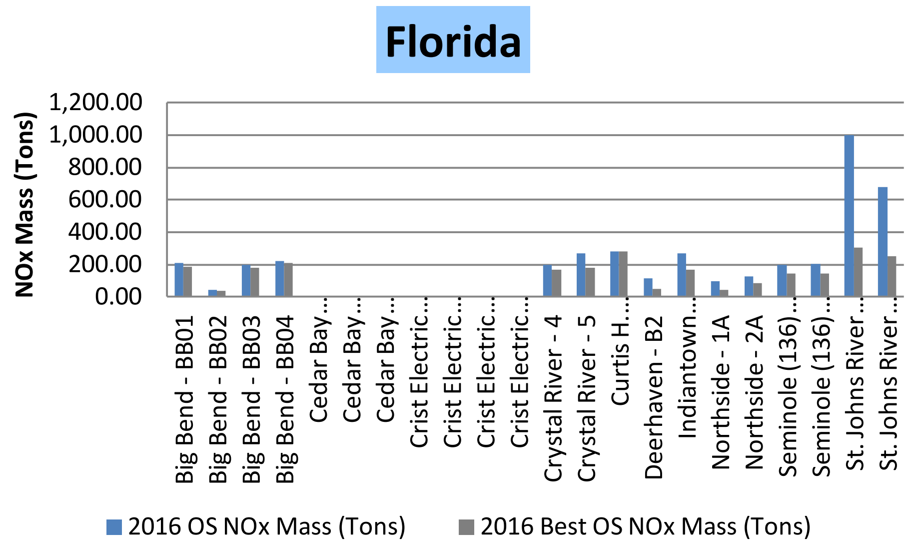
Review of Optimization Needed

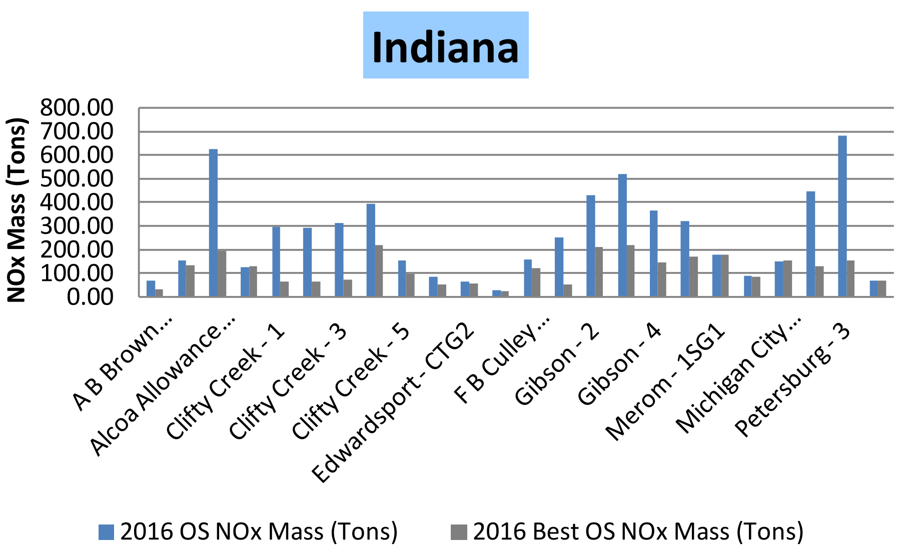
- States with a meaningful portion of the units with rates exceeding best historical rates and higher than expected 2016 rates
  - Alabama
  - Florida
  - Indiana
  - Kentucky
  - Missouri
  - North Carolina
  - Ohio
  - Pennsylvania
  - West Virginia

Review of Optimization Needed

2016 Ozone Season Total NOx Emissions – Actual and Best Rates from Past





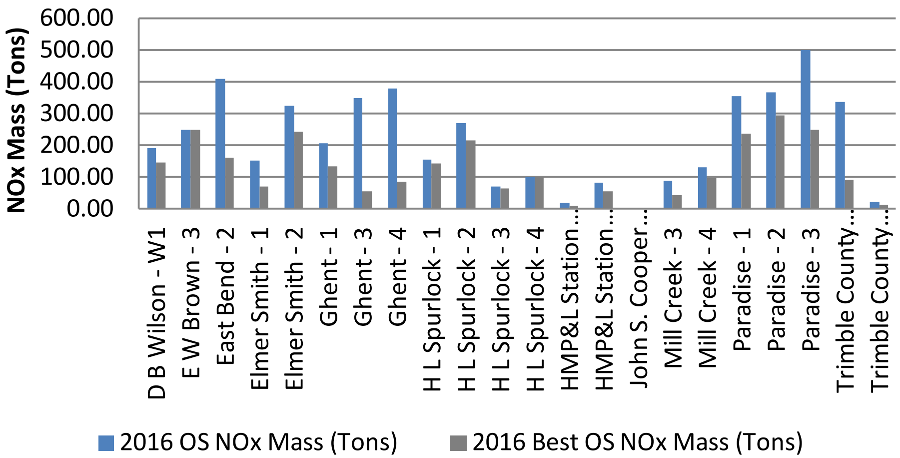


	2016 Actual OS NOx Mass (Tons)	2016 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Alabama	3,106	2,096	1,010	3.55%
Florida	4,097	2,430	1,667	5.87%
Indiana	6,241	2,823	3,418	12.03%

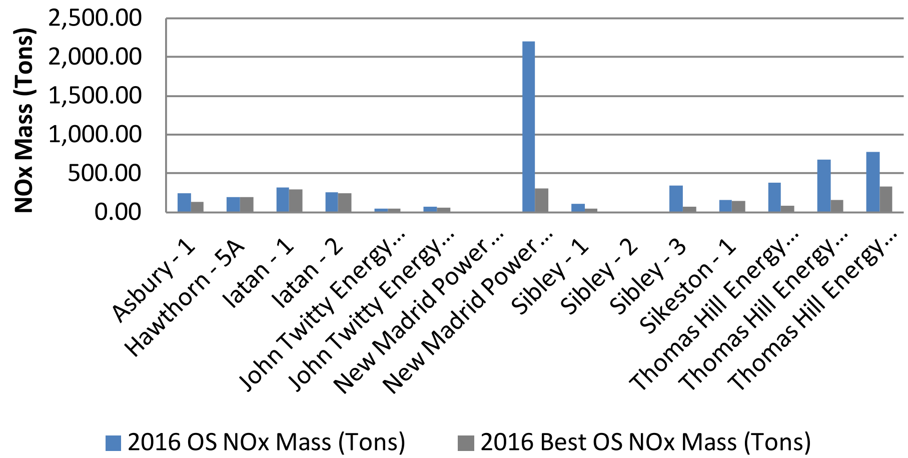
Review of Optimization Needed

2016 Ozone Season Total NOx Emissions – Actual and Best Rates from Past

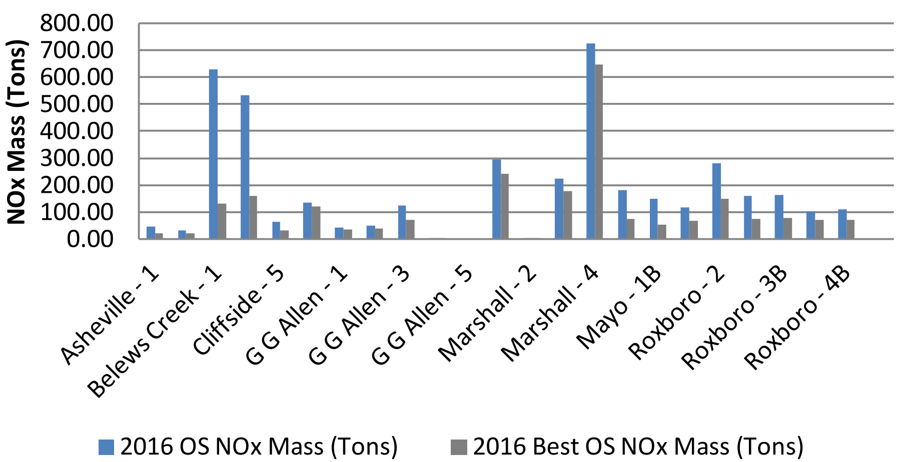
Kentucky



Missouri



North Carolina

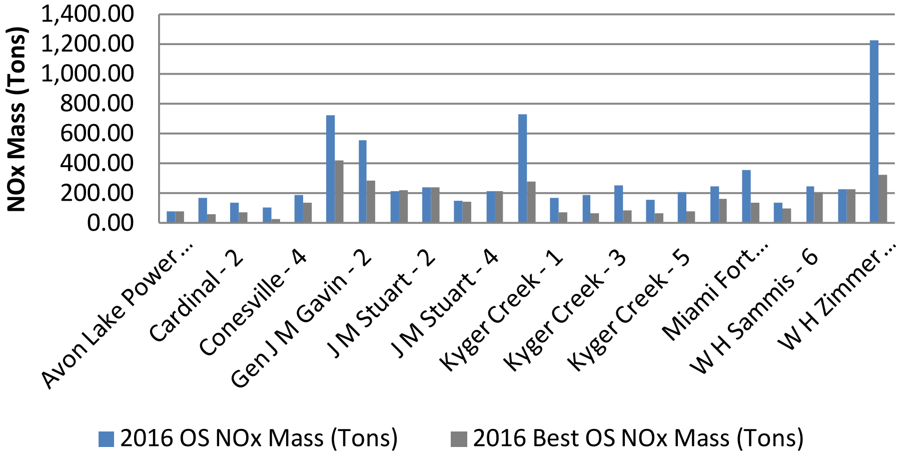


	2016 Actual OS NOx Mass (Tons)	2016 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Kentucky	4,751	2,753	1,998	7.03%
Missouri	5,784	2,103	3,681	12.95%
North Carolina	4,158	2,337	1,821	6.41%

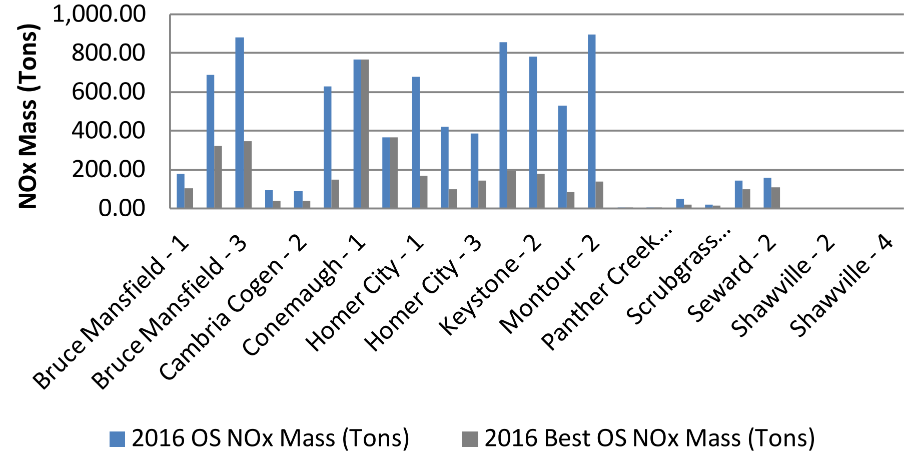
Review of Optimization Needed

2016 Ozone Season Total NOx Emissions – Actual and Best Rates from Past

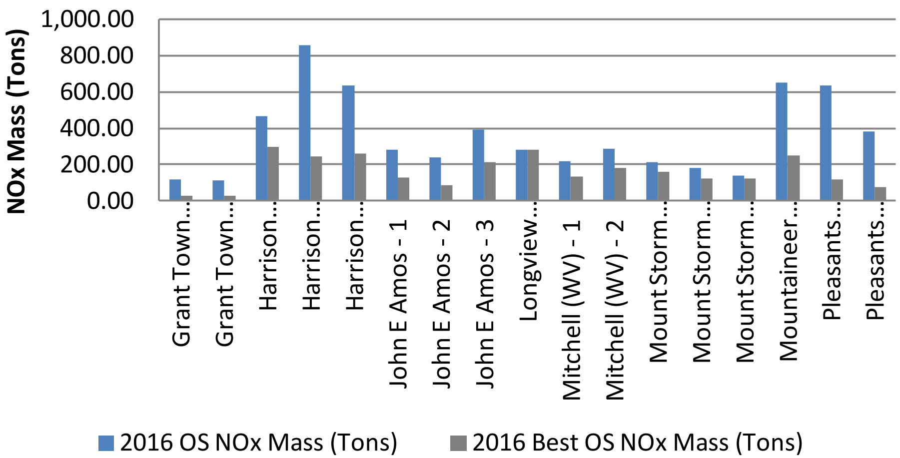
Ohio



Pennsylvania



West Virginia



	2016 Actual OS NOx Mass (Tons)	2016 @ Best Rates OS NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Ohio	6,918	3,696	3,222	11.34%
Pennsylvania	8,604	3,377	5,226	18.39%
W. Virginia	6,099	2,735	3,365	11.84%

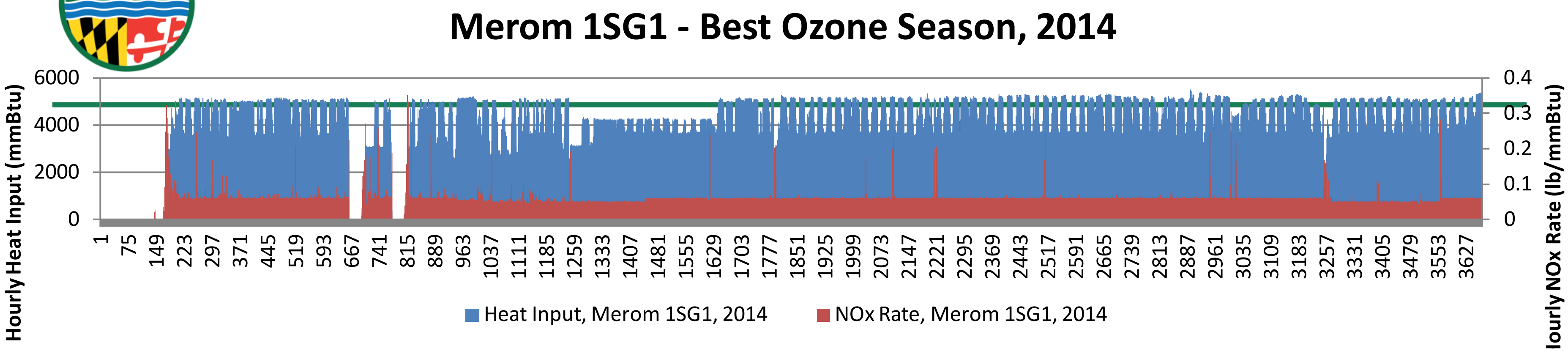
Operating Curve Analysis

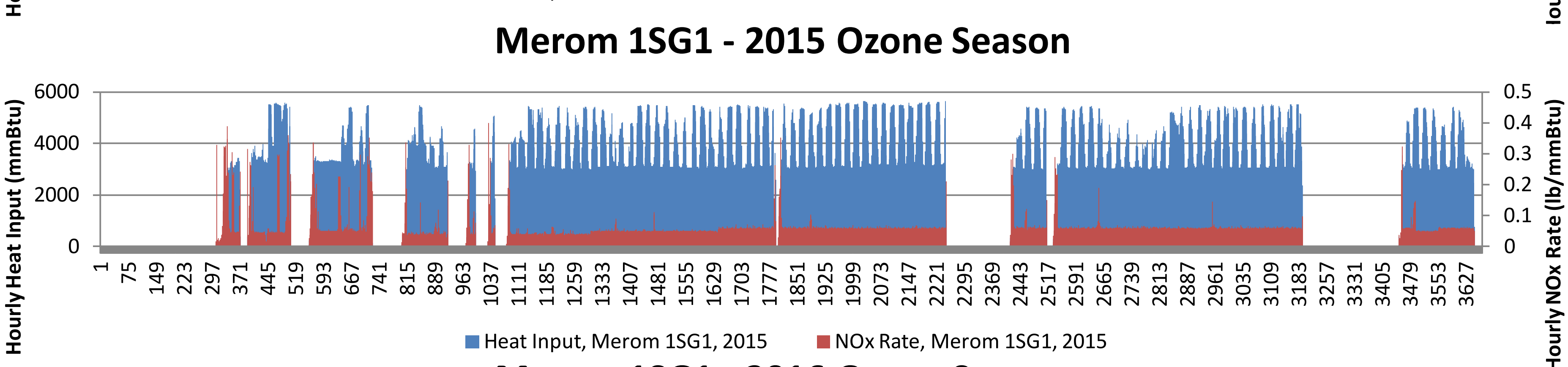
- MDE received feedback that many coal-fired EGUs with SCR/SNCR cannot hit their historical best NOX emission rates due to recent changes in operating patterns
  - Lower heat input → Lower SCR efficiency → Higher NOX rate

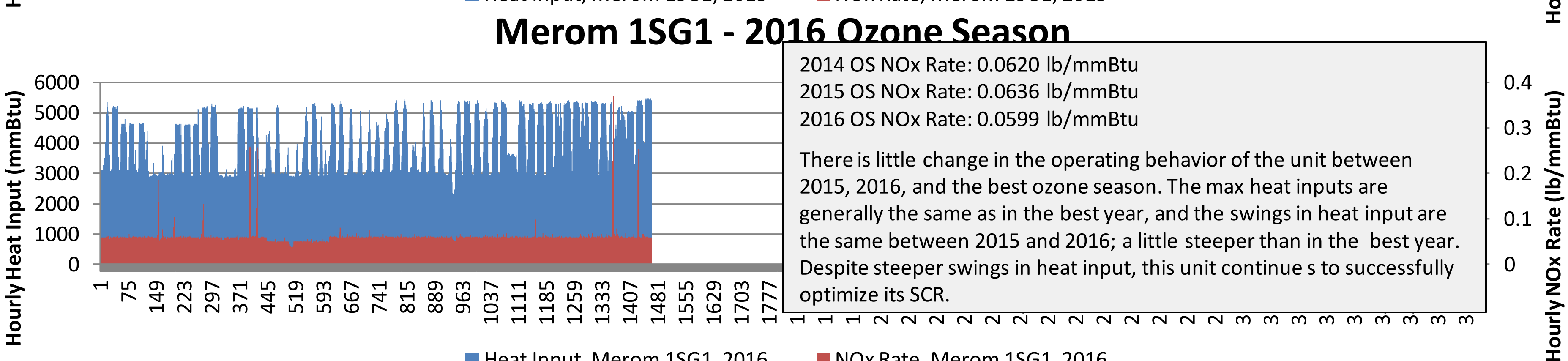
- Assuming that all other factors remain constant, we should expect a similar relationship between NOx emission rate and heat input between best ozone season and recent ozone seasons

- MDE used CAMD hourly data to analyze the relationship between heat input and NOx emission rate between best, 2015, and 2016 ozone seasons – referred to as operating curves

Operating Curve Analysis – Bin 1 Unit Example



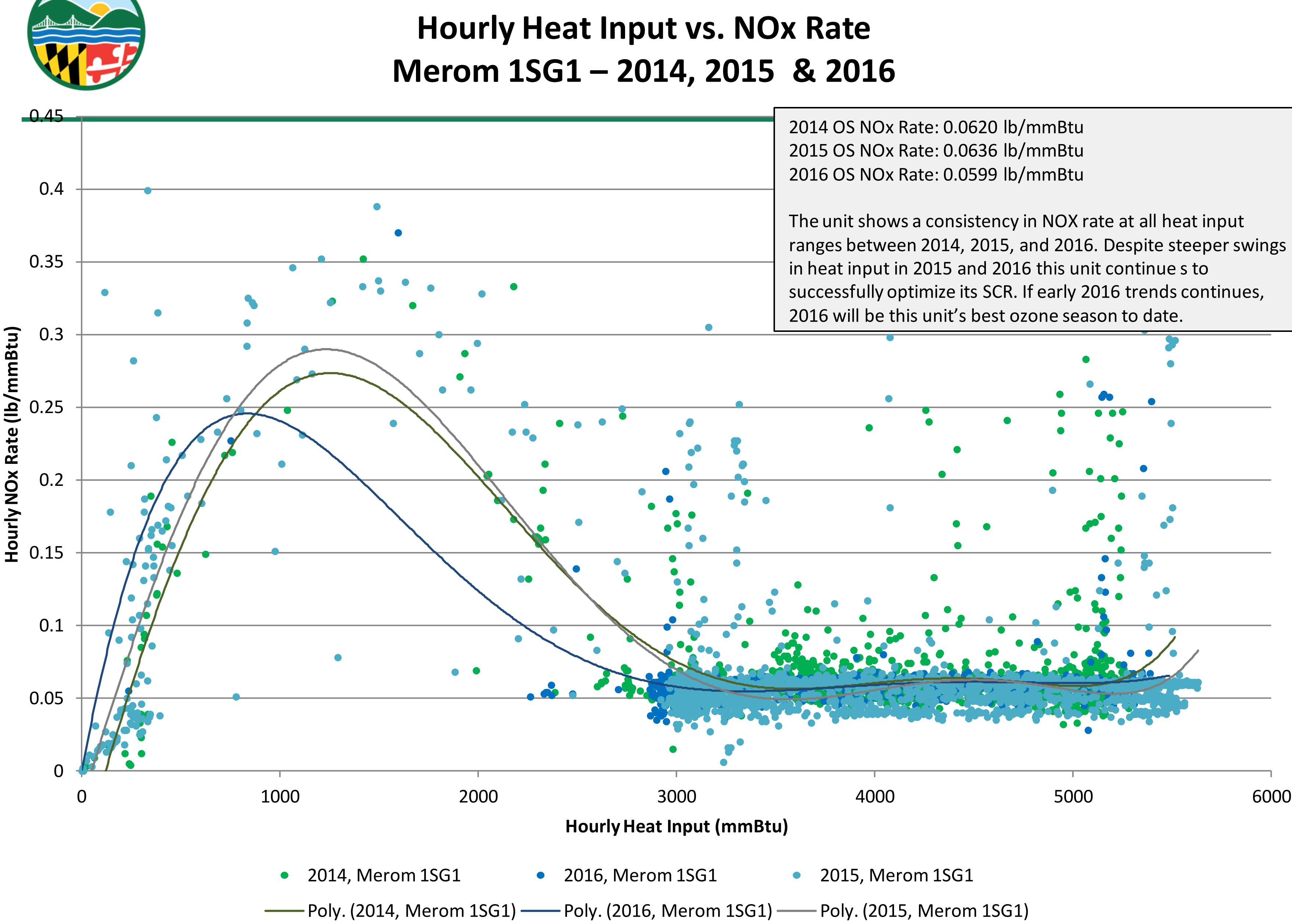




2014 OS NOx Rate: 0.0620 lb/mmBtu
2015 OS NOx Rate: 0.0636 lb/mmBtu
2016 OS NOx Rate: 0.0599 lb/mmBtu

There is little change in the operating behavior of the unit between 2015, 2016, and the best ozone season. The max heat inputs are generally the same as in the best year, and the swings in heat input are the same between 2015 and 2016; a little steeper than in the best year. Despite steeper swings in heat input, this unit continue s to successfully optimize its SCR.

Operating Curve Analysis – Bin 1 Unit Example

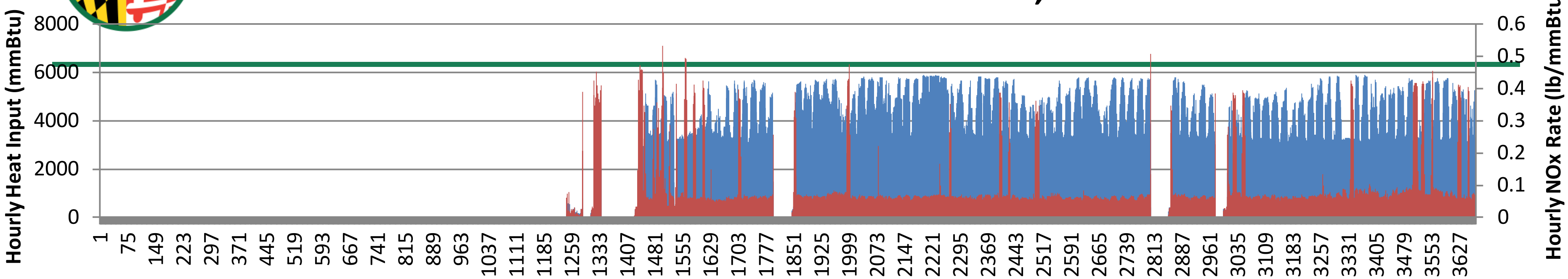


2014 OS NOx Rate: 0.0620 lb/mmBtu
2015 OS NOx Rate: 0.0636 lb/mmBtu
2016 OS NOx Rate: 0.0599 lb/mmBtu

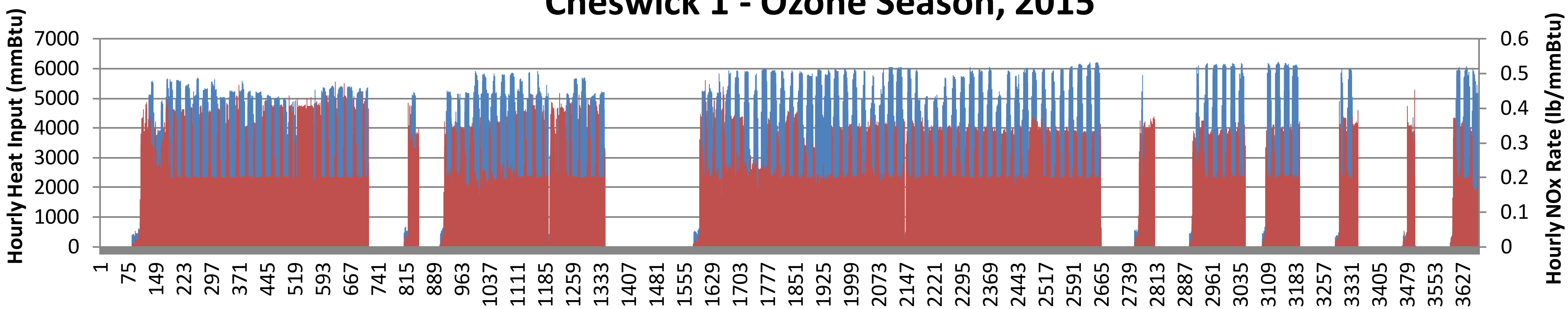
The unit shows a consistency in NOX rate at all heat input ranges between 2014, 2015, and 2016. Despite steeper swings in heat input in 2015 and 2016 this unit continue s to successfully optimize its SCR. If early 2016 trends continues, 2016 will be this unit's best ozone season to date.

Operating Curve Analysis – Bin 3 Unit Example

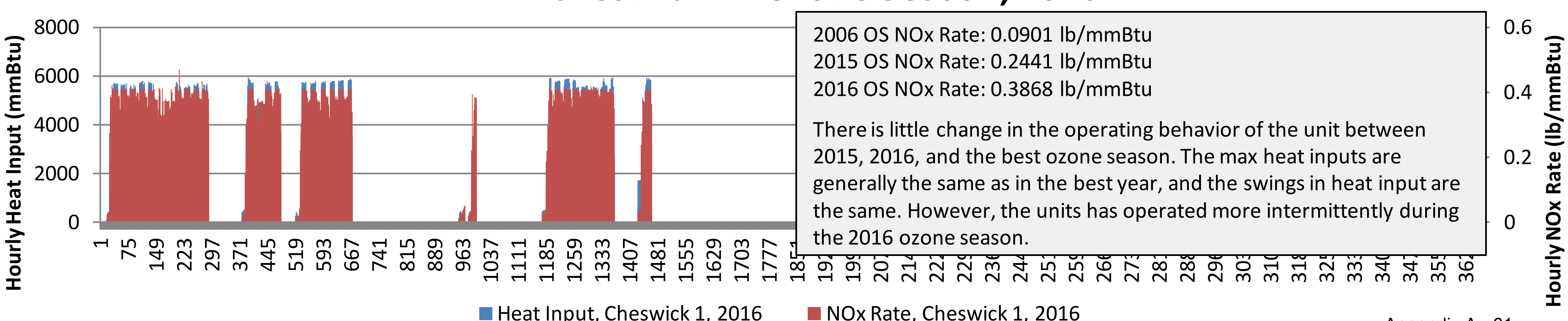
Cheswick 1 - Best Ozone Season, 2006



Cheswick 1 - Ozone Season, 2015



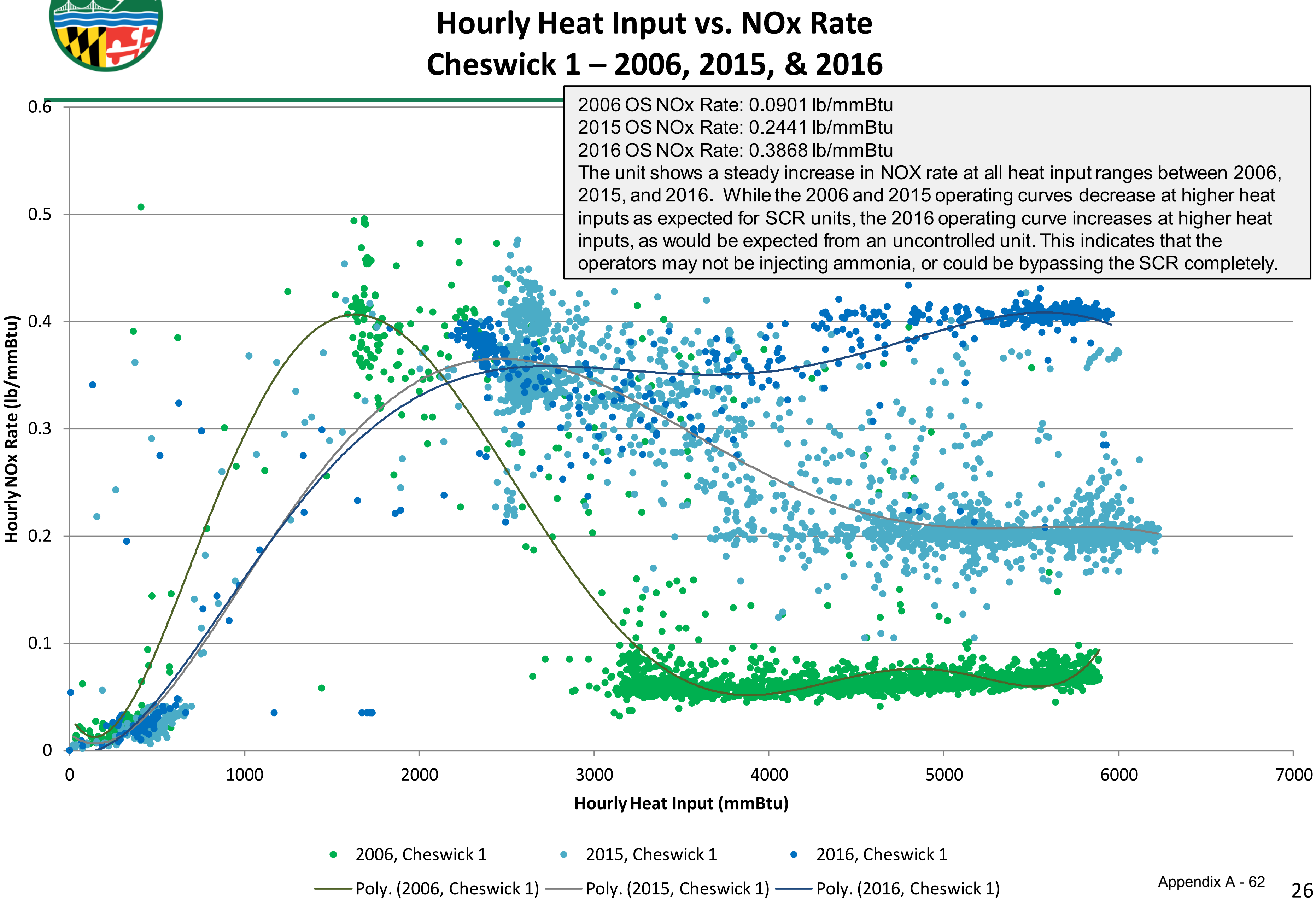
Cheswick 1 - Ozone Season, 2016



2006 OS NOx Rate: 0.0901 lb/mmBtu
2015 OS NOx Rate: 0.2441 lb/mmBtu
2016 OS NOx Rate: 0.3868 lb/mmBtu

There is little change in the operating behavior of the unit between 2015, 2016, and the best ozone season. The max heat inputs are generally the same as in the best year, and the swings in heat input are the same. However, the units has operated more intermittently during the 2016 ozone season.

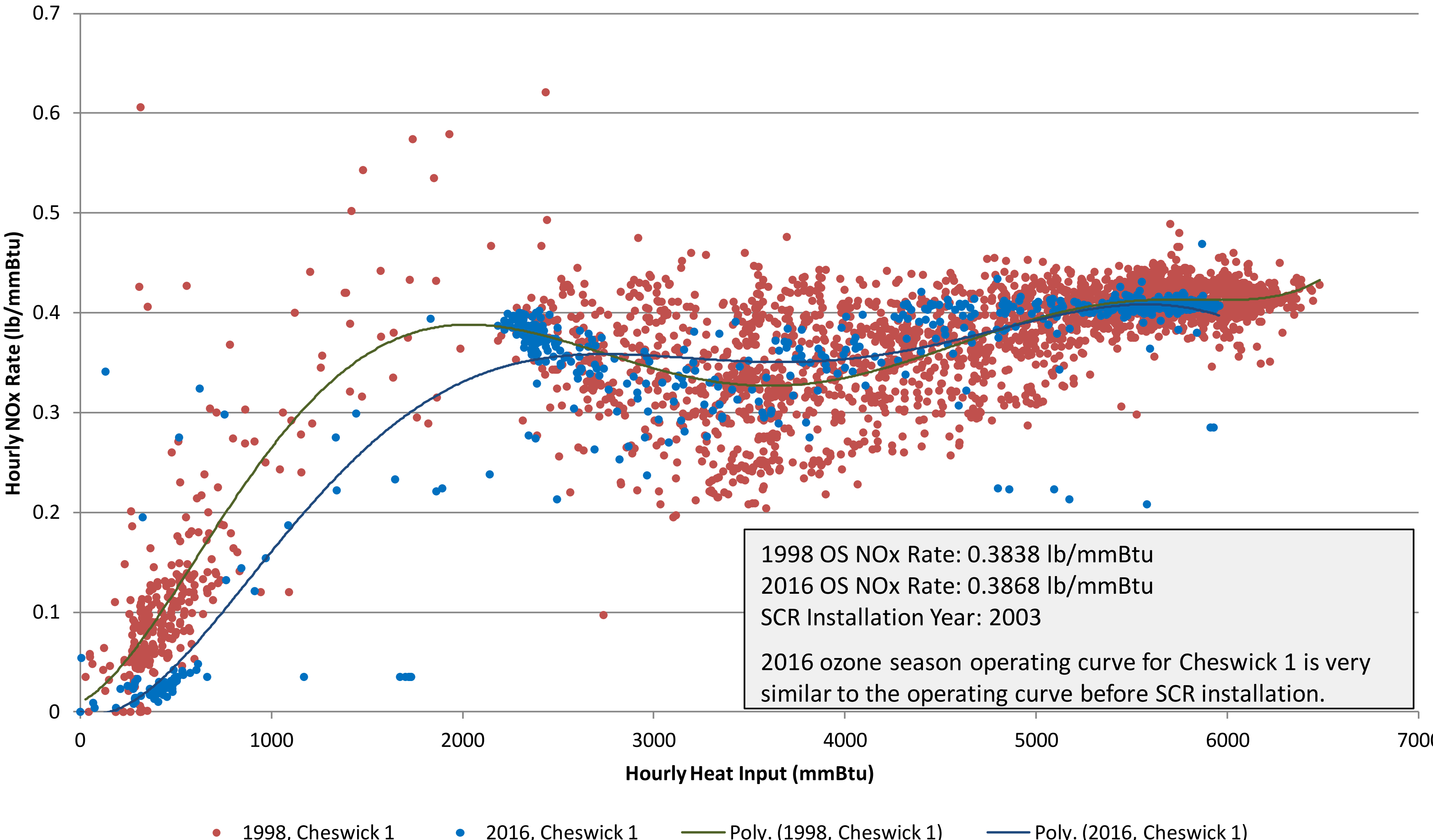
Operating Curve Analysis – Bin 3 Unit Example



Operating Curve Analysis – Bin 3 Unit Example

Hourly Heat Input vs. NOx Rate
Cheswick 1 – 1998, 2016

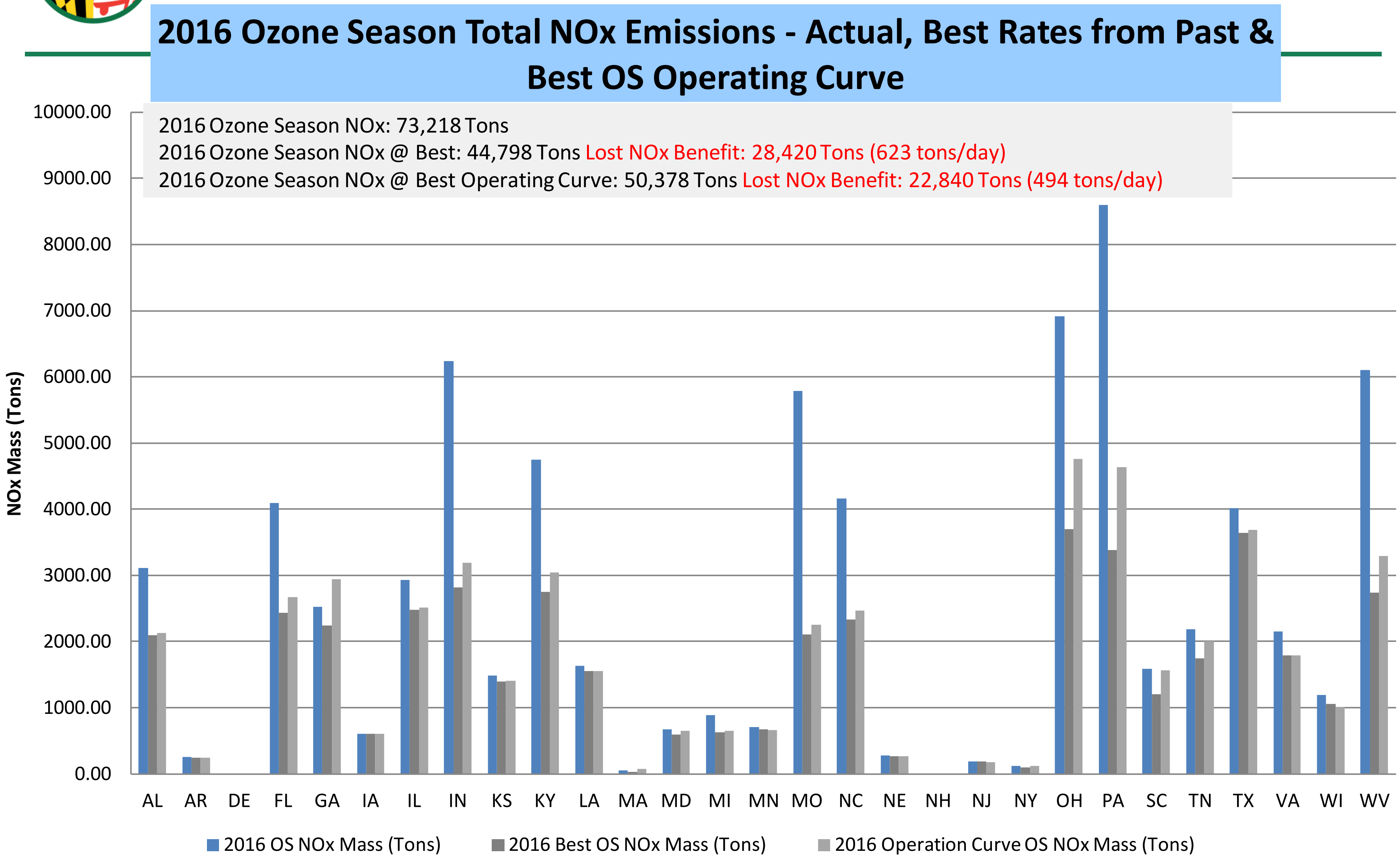
Pre-SCR Installation



NOx Savings Calculations

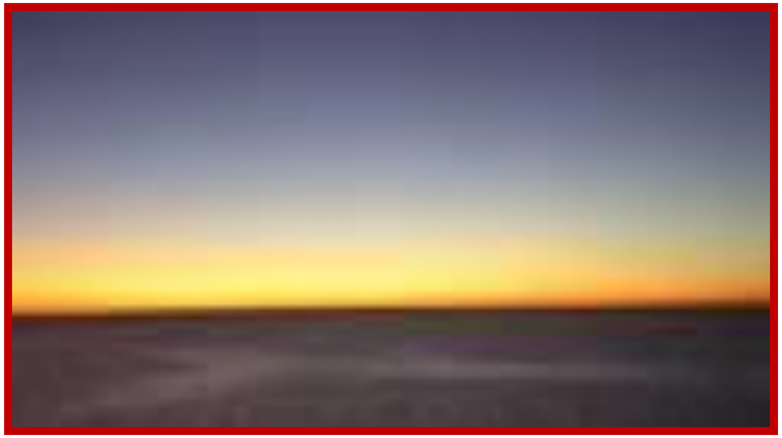
- Original methodology: Calculate 2016 NOx mass if exceeding units met best ozone season average rate.
  - Assume that unit can meet best historical ozone season rate throughout the entire ozone season
- New methodology (for SCR units only): Calculate 2016 NOx mass if exceeding units met historical best ozone season operating curve
  - Assume that NOx rate is a function of heat input, and unit can follow the same operating curve as the best historical ozone season

Lost NOx Reductions - By State



Optimization Appears to be Underway

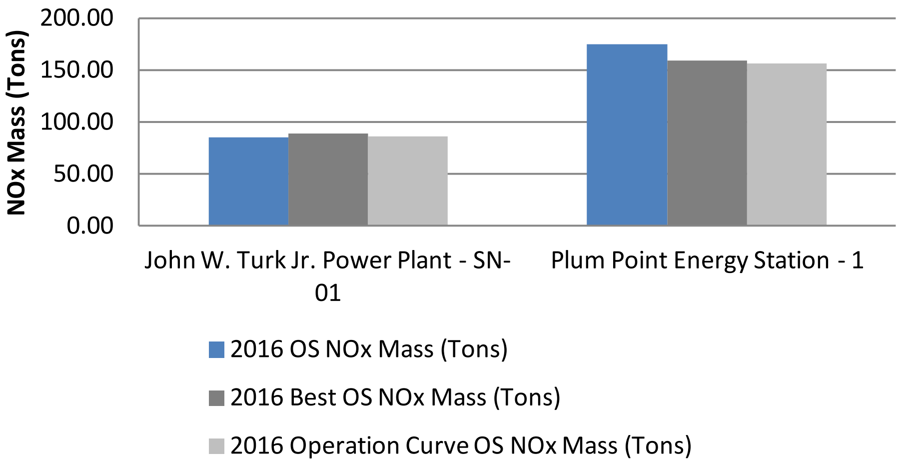
- States with the majority of their units meeting or out-performing best historical rates
  - Arkansas
  - Delaware
  - Georgia
  - Iowa
  - Illinois
  - Kansas
  - Louisiana
  - Massachusetts
  - Maryland
  - Michigan
  - Minnesota
  - Nebraska
  - New Hampshire
  - New Jersey
  - New York
  - South Carolina
  - Tennessee
  - Texas
  - Virginia
  - Wisconsin



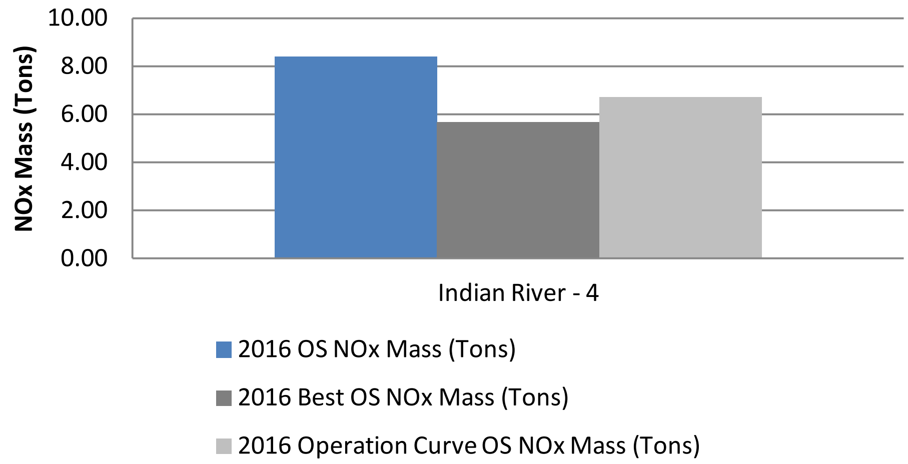
Optimization Appears to be Underway

2016 Ozone Season Total NOx Emissions – Actual, Best Rates from Past & Best Operating Curve

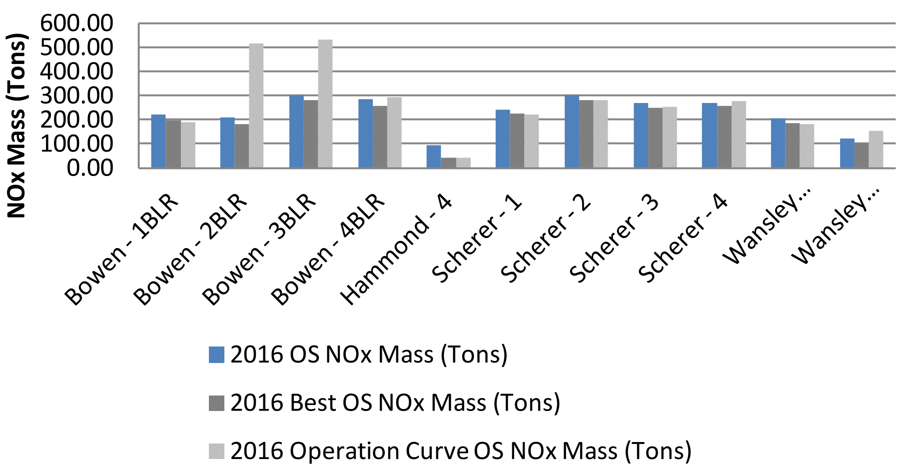
Arkansas



Delaware



Georgia

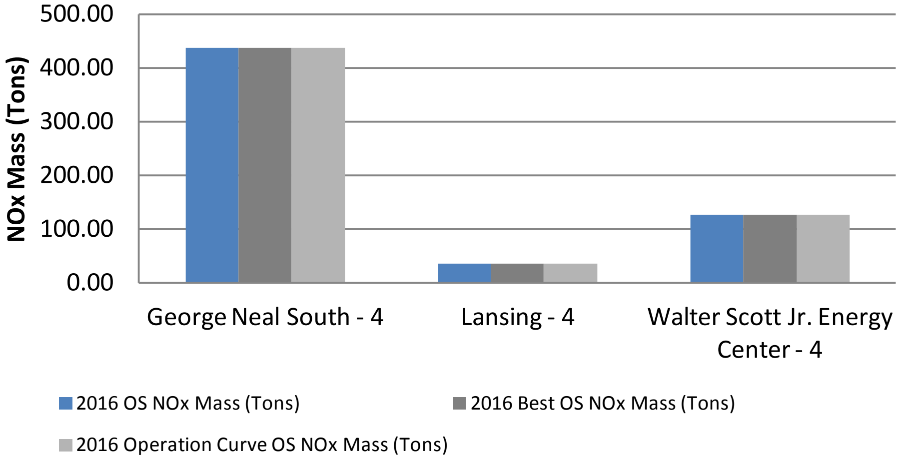


	2016 Actual OS NOx Mass (Tons)	2016 @ Best Op Curve NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Arkansas	260	243	17	0.08%
Delaware	8	7	2	0.01%
Georgia	2,524	2,940	416	1.82%

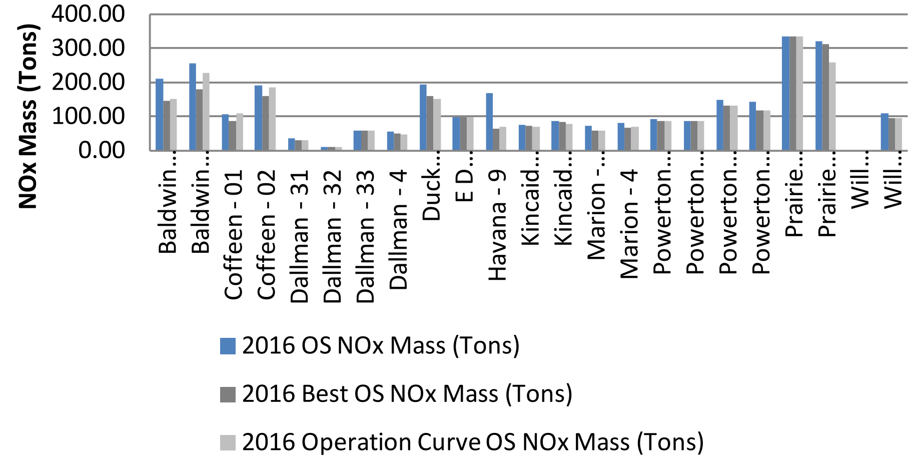
Optimization Appears to be Underway

2016 Ozone Season Total NOx Emissions – Actual, Best Rates from Past & Best Operating Curve

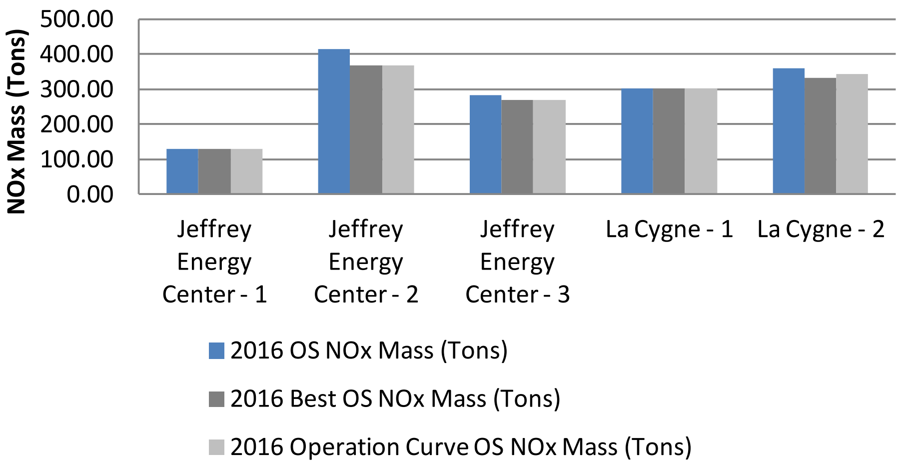
Iowa



Illinois



Kansas



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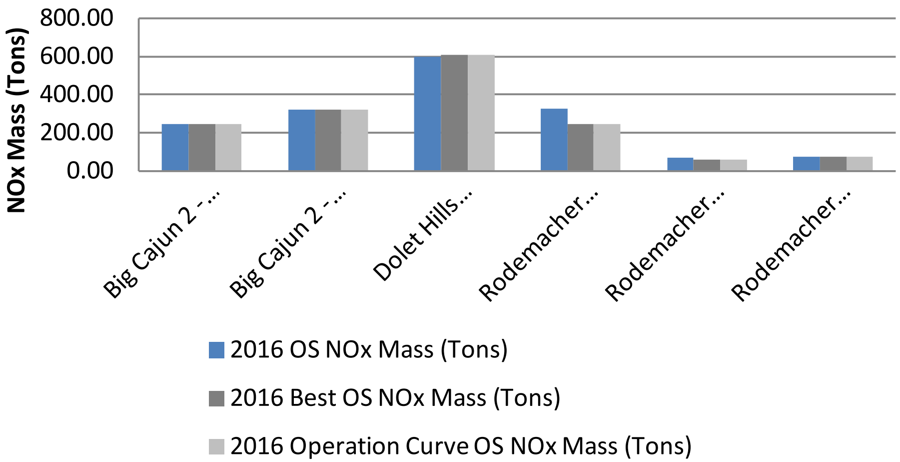
Iowa	600	600	0	0.00%
Illinois	2,936	2,518	417	1.83%
Kansas	1,487	1,411	76	0.33%

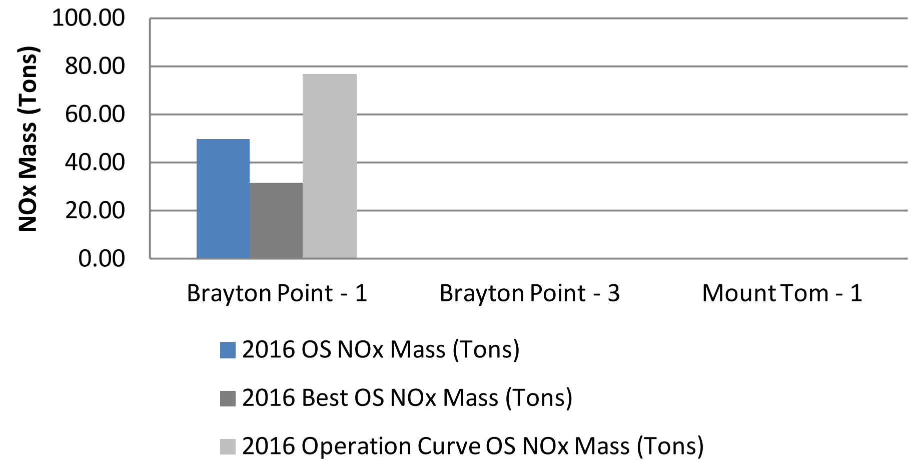
Optimization Appears to be Underway

2016 Ozone Season Total NOx Emissions – Actual, Best Rates from Past & Best Operating Curve

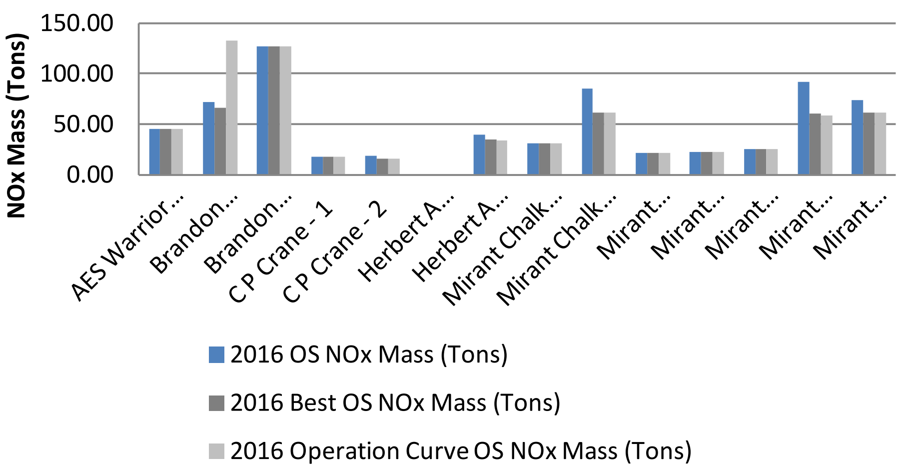
Louisiana



Massachusetts



Maryland



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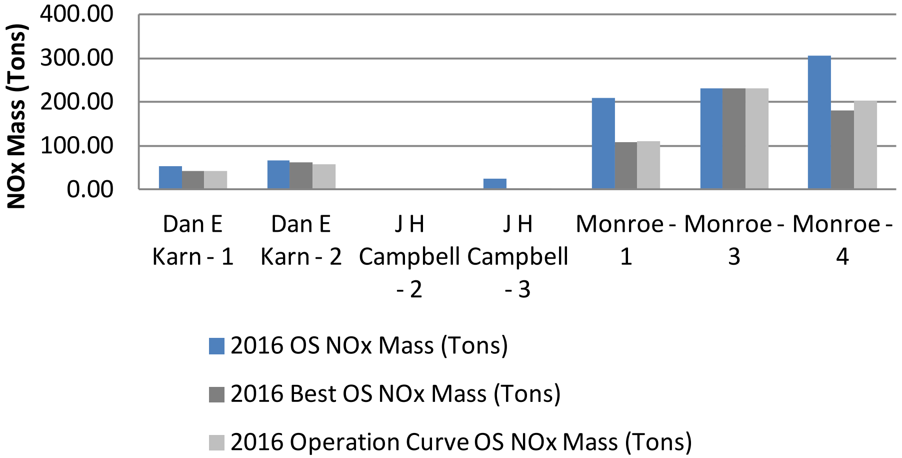
Massachusetts	50	77	27	0.12%
Maryland	672	654	18	0.08%

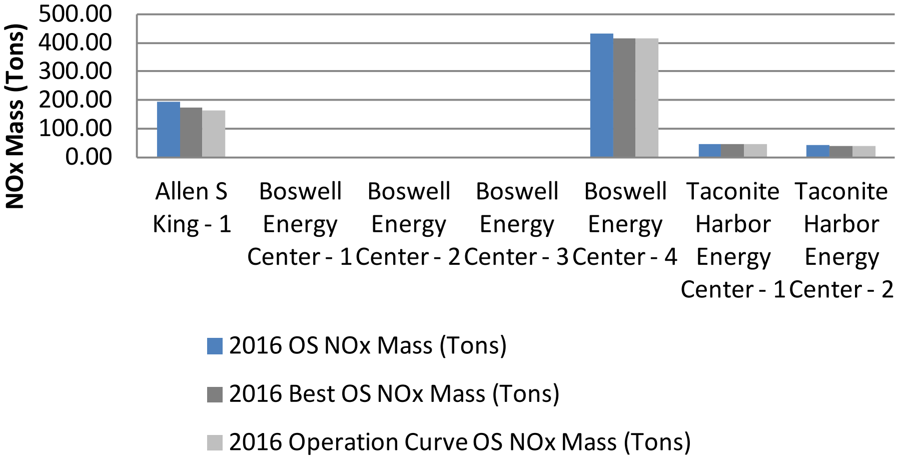
Optimization Appears to be Underway

2016 Ozone Season Total NOx Emissions – Actual, Best Rates from Past & Best Operating Curve

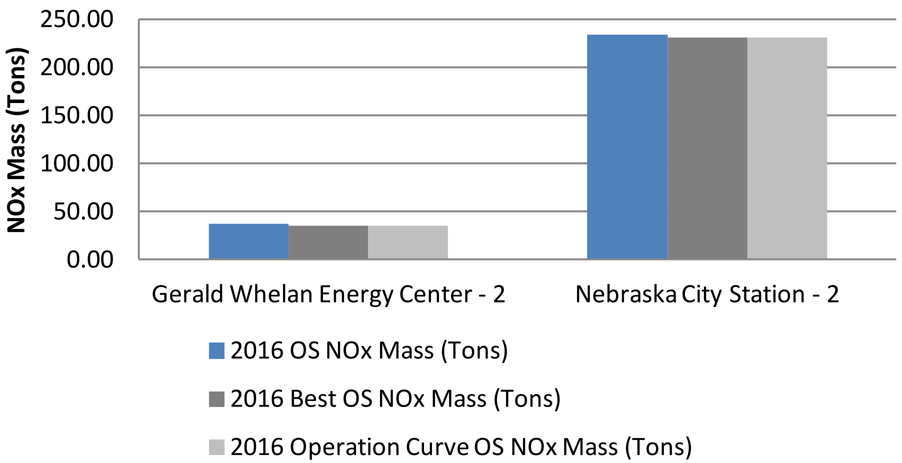
Michigan



Minnesota



Nebraska

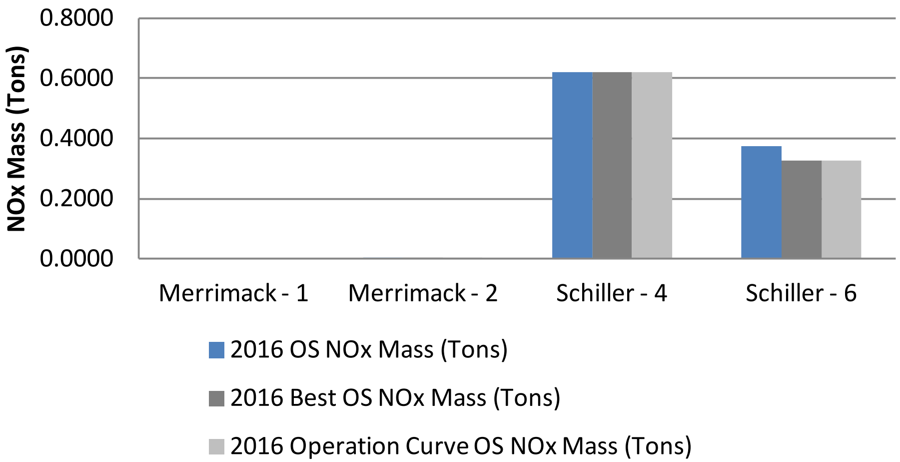


	2016 Actual OS NOx Mass (Tons)	2016 @ Best Op Curve NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Michigan	890	649	241	1.06%
Minnesota	710	666	44	0.19%
Nebraska	272	265	6	0.03%

Optimization Appears to be Underway

2016 Ozone Season Total NOx Emissions – Actual, Best Rates from Past & Best Operating Curve

New Hampshire



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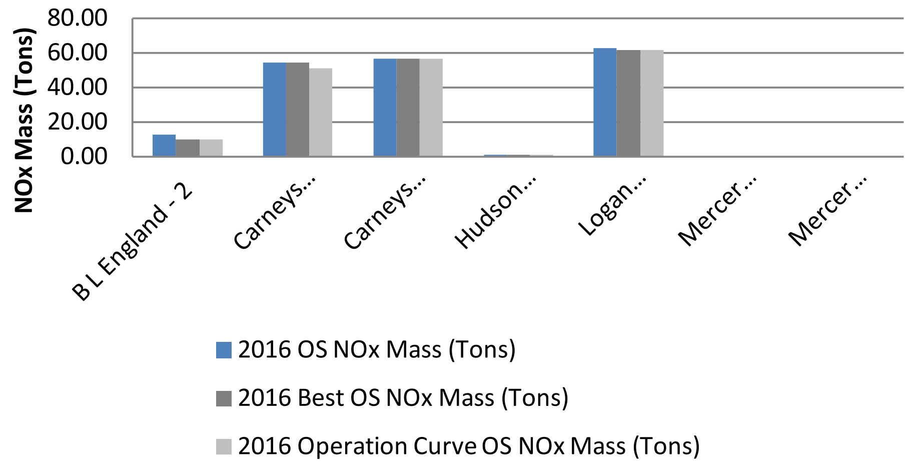
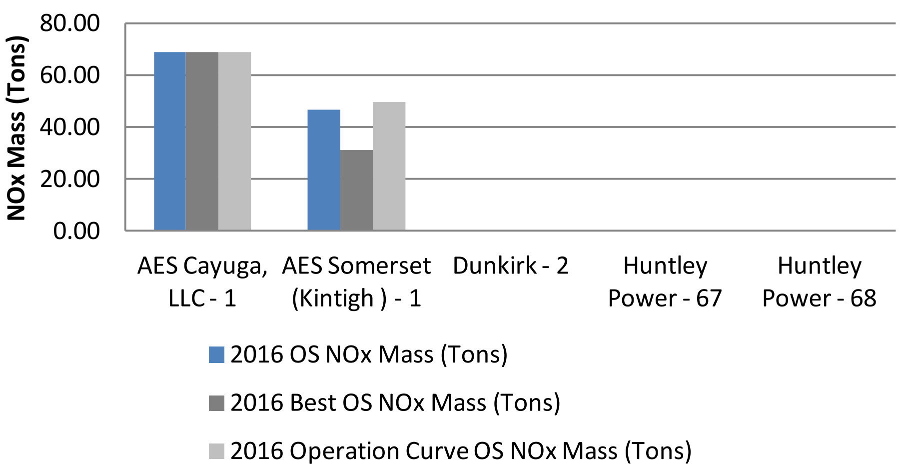


New York

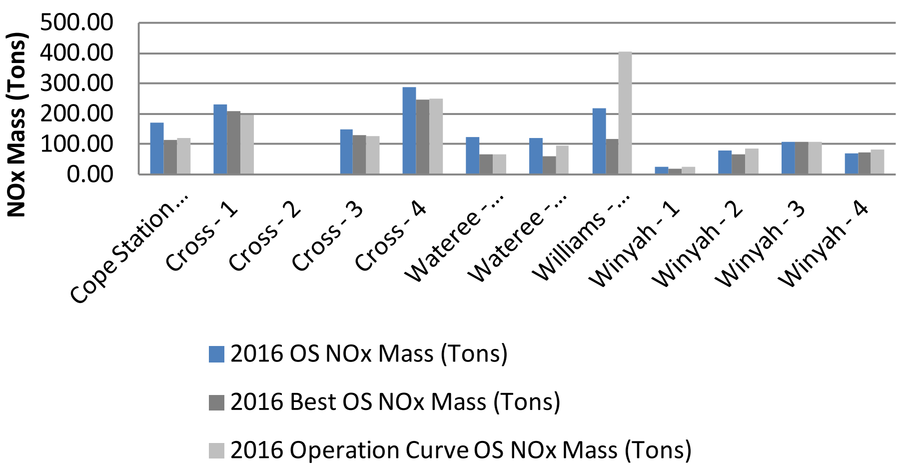


	2016 Actual OS NOx Mass (Tons)	2016 @ Best Op Curve NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
N Hampshire	1	1	0	0.00%
New Jersey	187	180	7	0.03%
New York	116	118	3	0.01%

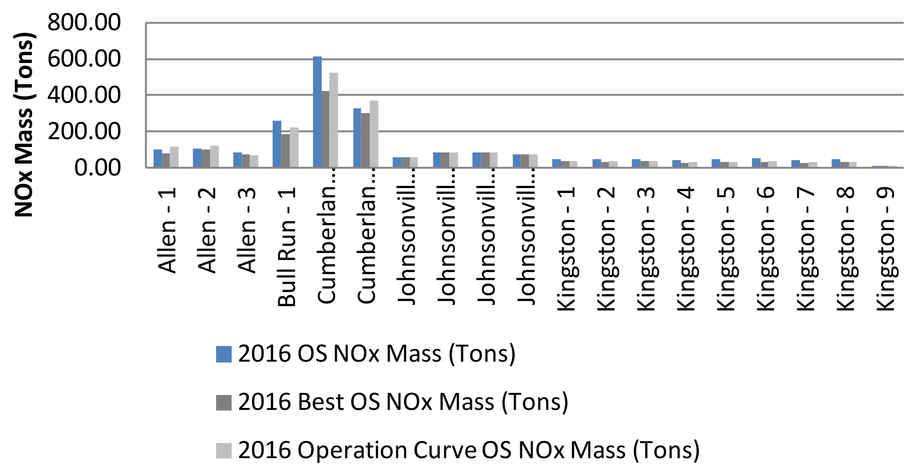
Optimization Appears to be Underway

2016 Ozone Season Total NOx Emissions – Actual, Best Rates from Past & Best Operating Curve

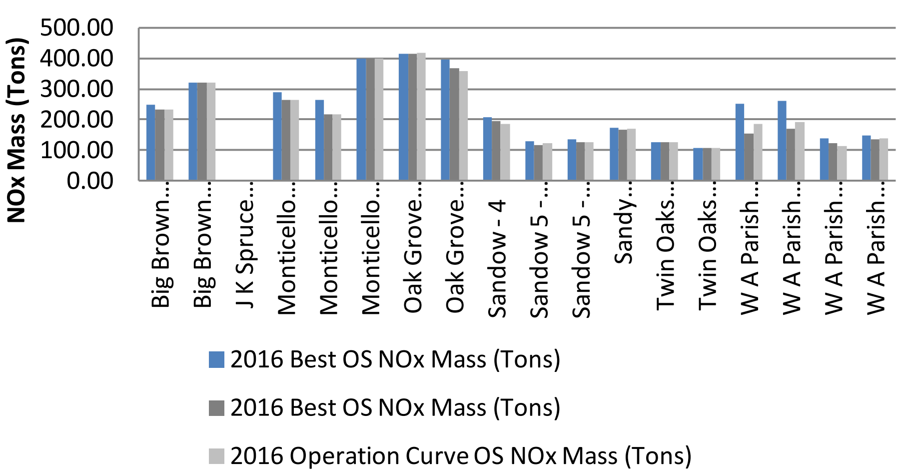
South Carolina



Tennessee



Texas

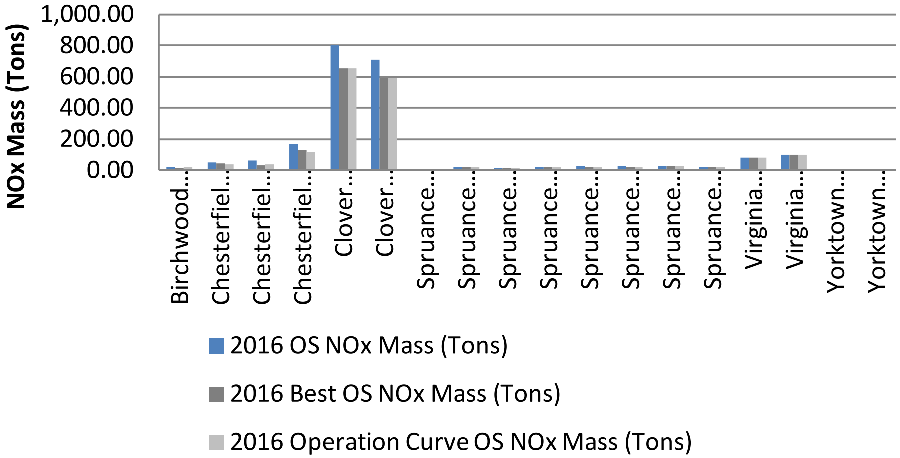


	2016 Actual OS NOx Mass (Tons)	2016 @ Best Op Curve NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
S Carolina	1,582	1,563	20	0.09%
Tennessee	2,185	2,004	181	0.79%
Texas	4,011	3,684	327	1.43%

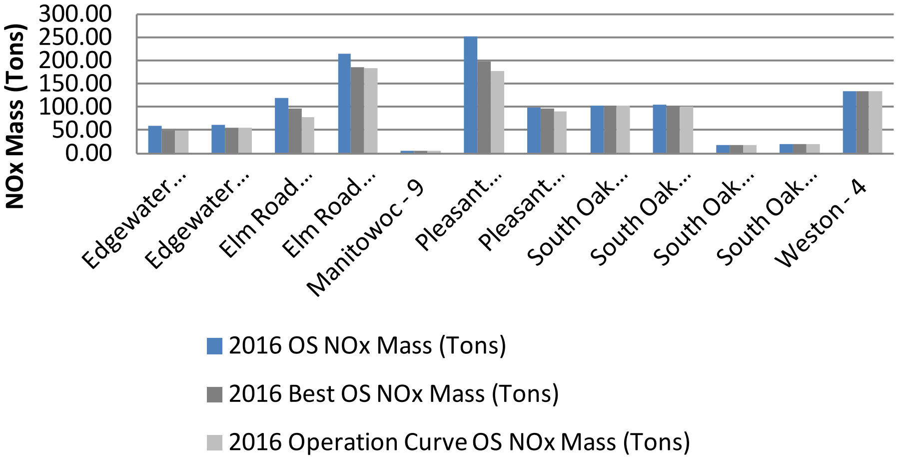
Optimization Appears to be Underway

2016 Ozone Season Total NOx Emissions – Actual, Best Rates from Past & Best Operating Curve

Virginia



Wisconsin



	2016 Actual OS NOx Mass (Tons)	2016 @ Best Op Curve NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Virginia	2,155	1,786	369	1.62%
Wisconsin	1,187	1,016	171	0.75%

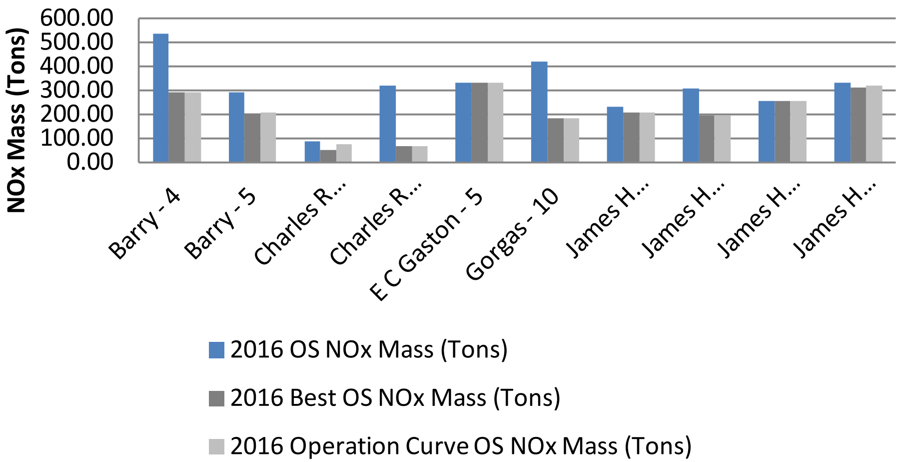
Review of Optimization Needed

- States with a meaningful portion of the units with rates exceeding best historical rates and higher than expected 2016 rates
  - Alabama
  - Florida
  - Indiana
  - Kentucky
  - Missouri
  - North Carolina
  - Ohio
  - Pennsylvania
  - West Virginia

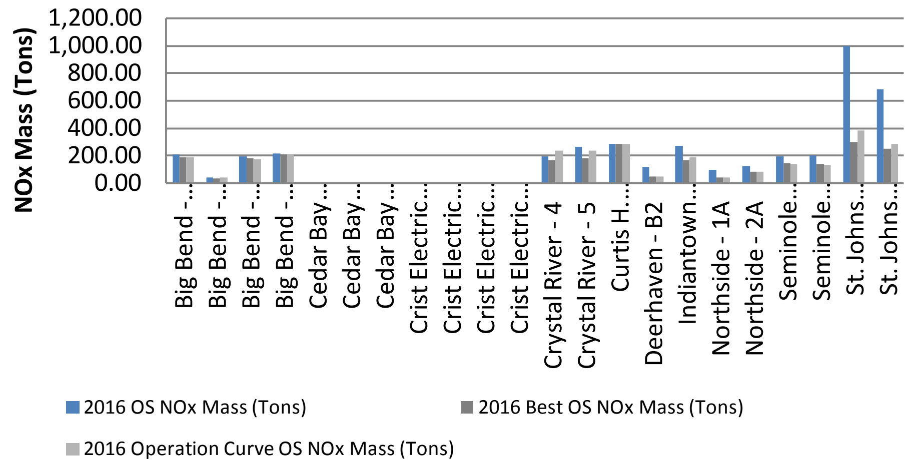
Review of Optimization Needed

2016 Ozone Season Total NOx Emissions – Actual, Best Rates from Past & Best Operating Curve

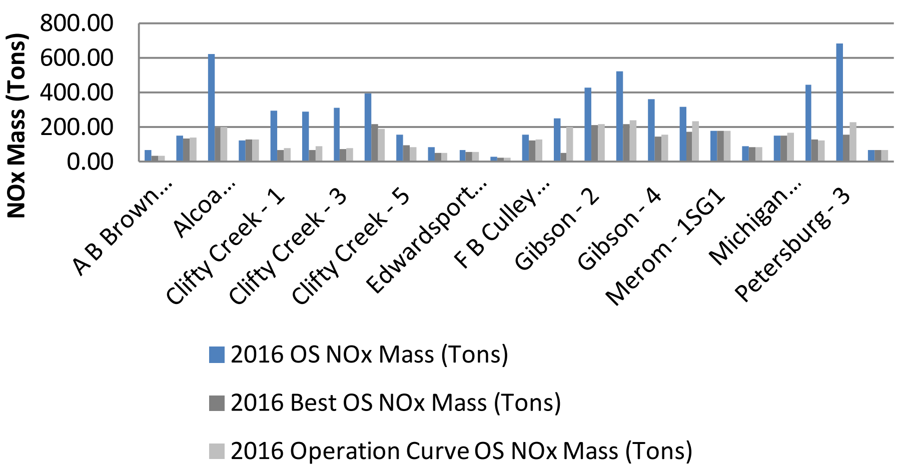
Alabama



Florida



Indiana

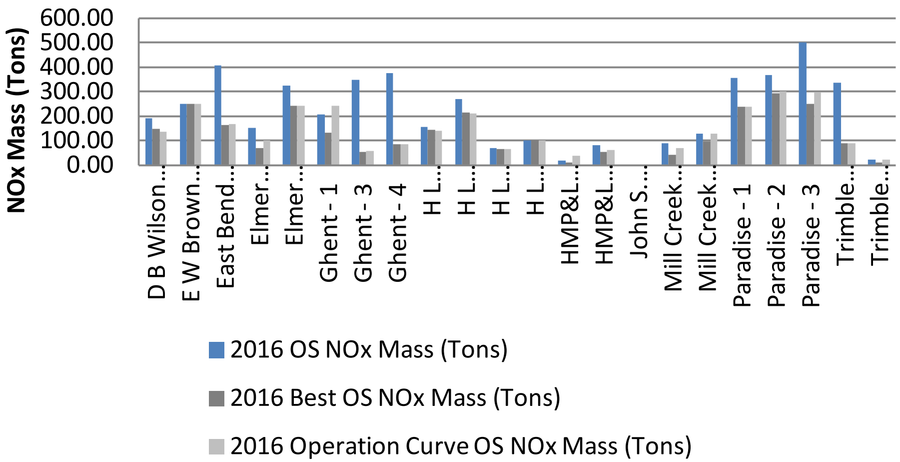


	2016 Actual OS NOx Mass (Tons)	2016 @ Best Op Curve NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Alabama	3,106	2,127	979	4.29%
Florida	4,097	2,672	1,425	6.24%
Indiana	6,241	3,195	3,046	13.34%

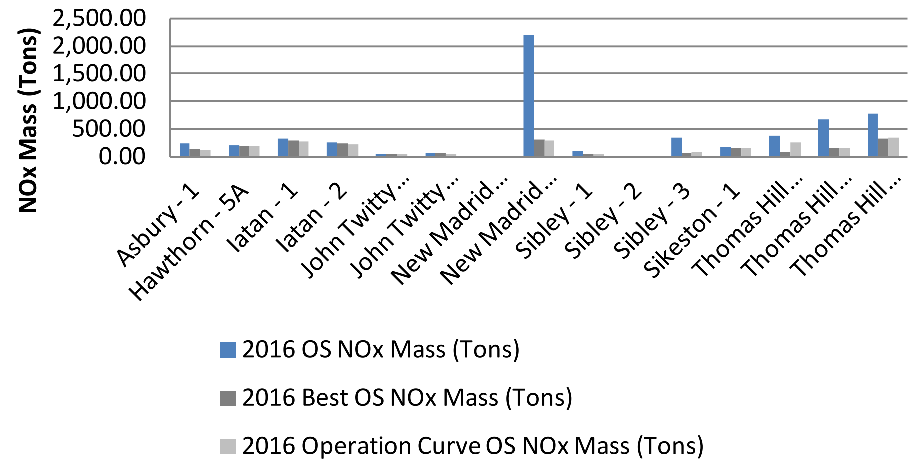
Review of Optimization Needed

2016 Ozone Season Total NOx Emissions – Actual, Best Rates from Past & Best Operating Curve

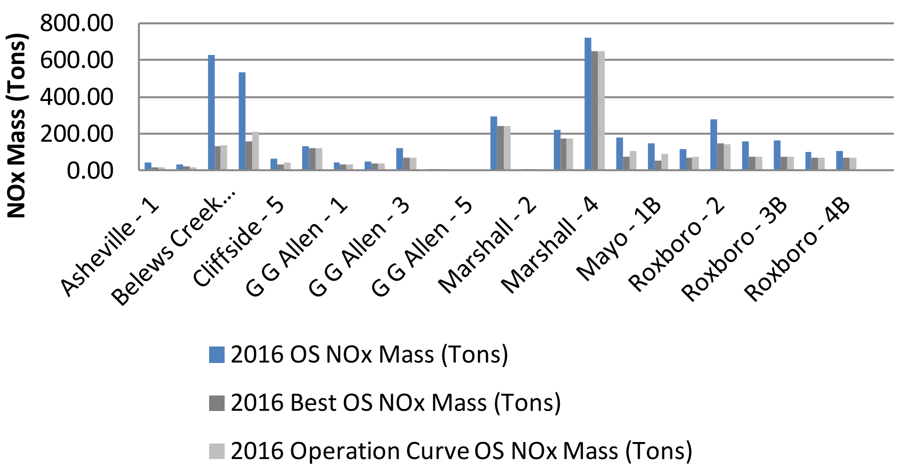
Kentucky



Missouri



North Carolina

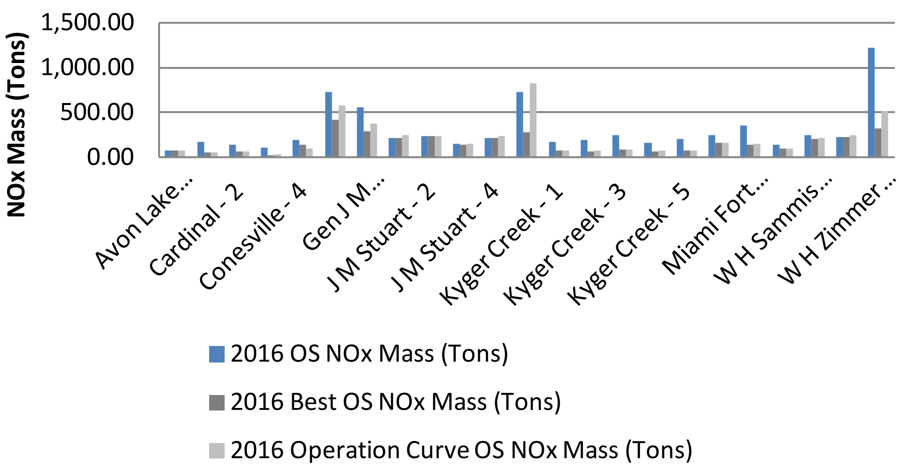


	2016 Actual OS NOx Mass (Tons)	2016 @ Best Op Curve NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Kentucky	4,751	3,047	1,704	7.46%
Missouri	5,784	2,251	3,533	15.47%
North Carolina	4,158	2,471	1,687	7.39%

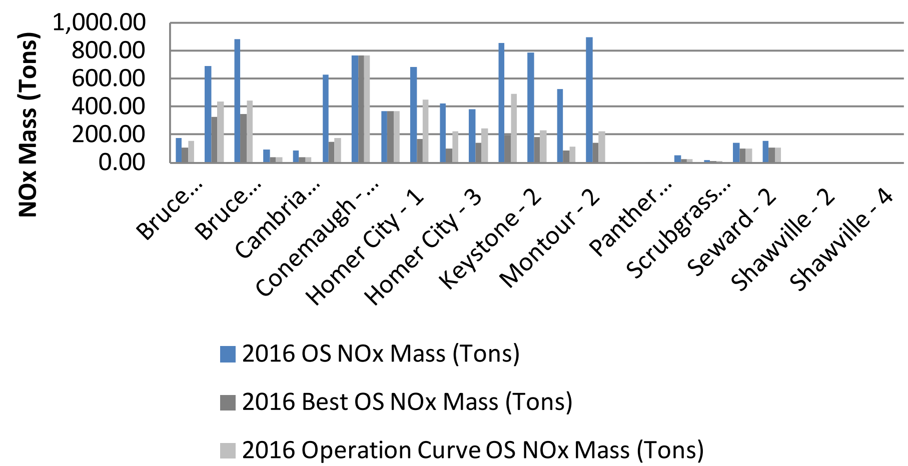
Review of Optimization Needed

2016 Ozone Season Total NOx Emissions – Actual, Best Rates from Past & Best Operating Curve

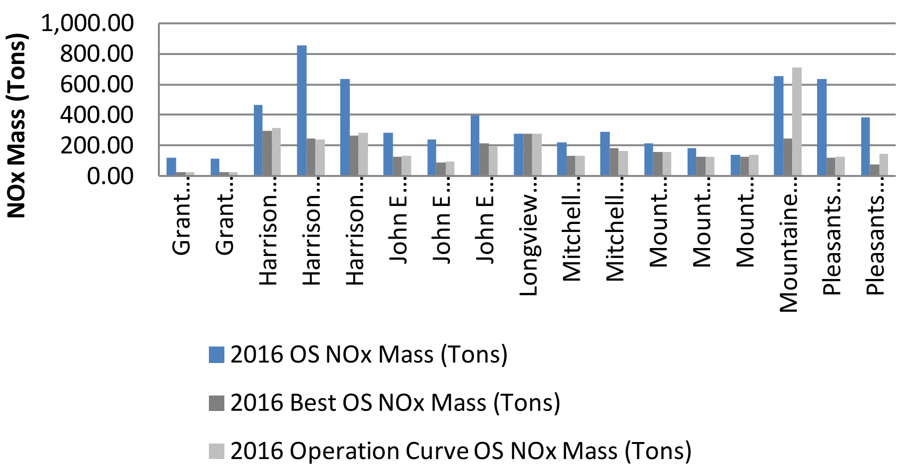
Ohio



Pennsylvania



West Virginia



	2016 Actual OS NOx Mass (Tons)	2016 @ Best Op Curve NOx Mass (Tons)	Lost Savings (Tons)	% of Total Loss
Ohio	6,918	4,758	2,160	9.46%
Pennsylvania	8,604	4,633	3,971	17.39%
W. Virginia	6,099	3,292	2,808	12.29%

Some Observations

- There are more states with units that appear to be optimizing controls than states with units that are not
  - Many of the states identified in the 176A Petition appear to have many units not optimizing controls. 116 of 177 units in 176A states appear to not be optimizing controls.
  - With reasonable efforts to optimize controls, approximately 600 tons of additional daily NOx reductions could have been achieved. Across the whole 2015 ozone season the additional daily NOx reduction was 685 tons.
- Many states have a majority of their units close to meeting best historical rates.
  - AR, DE, GA, IA, IL, KS, LA, MA, MD, MI, MN, NE, NH, NJ, NY, SC, TN, TX, VA and WI all have a majority of reported units close to best historical rates
  - These are the same states that had a majority of reported units close to best historical rates in 2015.
- Many states have a significant number of units emitting at rates that are noticeably higher than best historical rates
  - AL, FL, IN, KY, MO, NC, OH, PA and WV all have units exceeding best historical rates
  - These are the same states that had a majority of reported units exceeding best historical rates in 2015.
- Preliminary data indicates that most units did not change their bin designations between 2015 and 2016 Q2. There is some improvement and some backsliding, but overall, most units did not make a significant enough change in their 2016 ozone season emission rate (compared to it's best) to warrant changing it's bin designation.

Additional Analysis – Hg

- MDE received feedback that many coal-fired EGUs with SCR/SNCR cannot hit their historical best NOX emission rates due to SCR tuning for Hg oxidation in order to comply with MATS
  - Studies suggest that operation of SCR units below the peak design temperature and NH3 flow would likely improve mercury oxidation. These conditions are not favorable for NOX removal.
  - Very small universe of units (155) that *could* do this. Must burn bituminous, have SCR and wFGD.

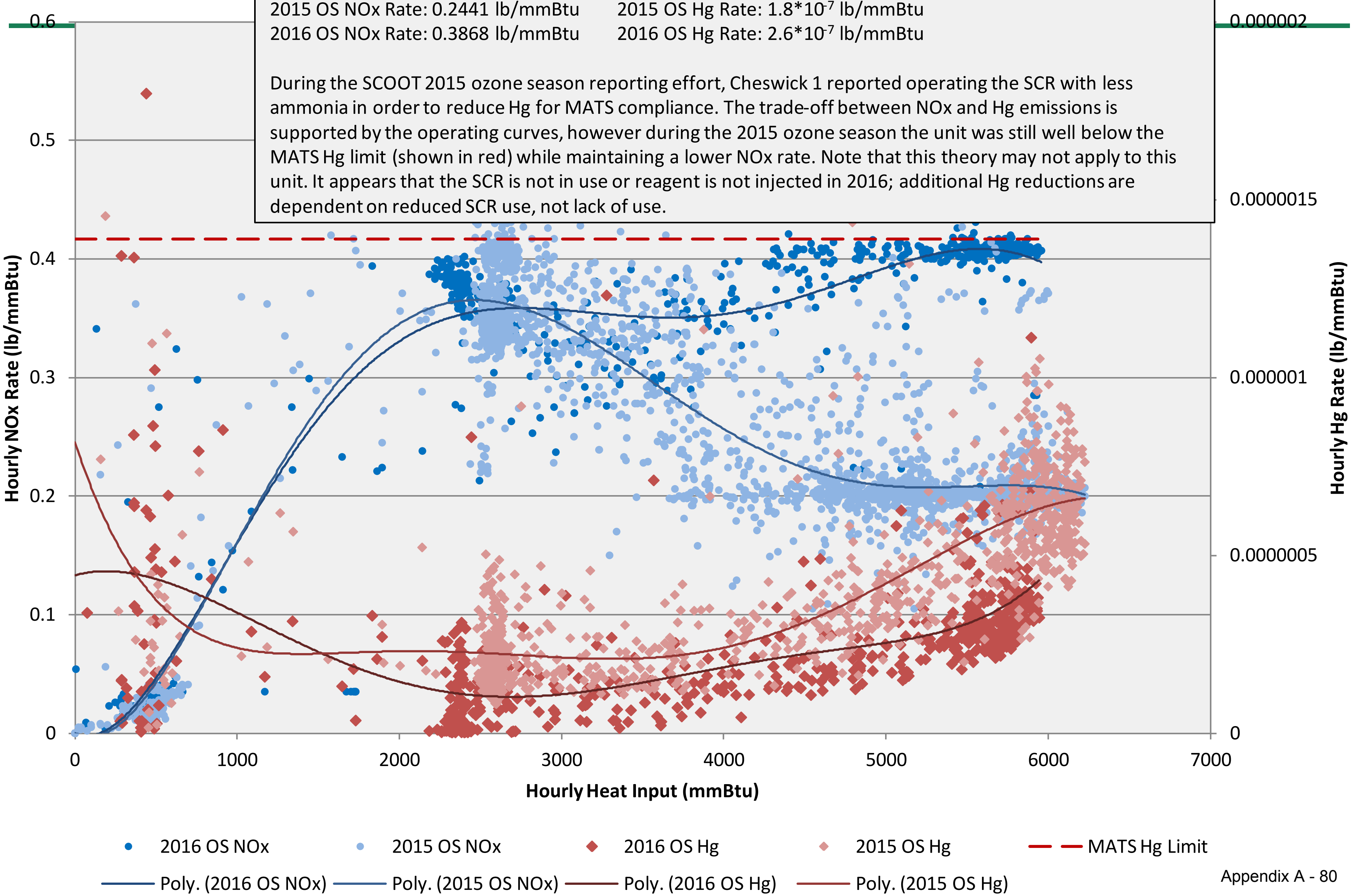
- MDE is also using hourly Hg data to analyze Hg operating curves in addition to NOx operating curves to assess the relationship between SCR NOx reduction and MATS compliance

Unit Using SCR for Hg Oxidation

Hourly NOx and Hg Emission Rates vs. Heat Input
Cheswick 1 – 2015, 2016

2015 OS NOx Rate: 0.2441 lb/mmBtu   2015 OS Hg Rate: 1.8×10^{-7} lb/mmBtu
2016 OS NOx Rate: 0.3868 lb/mmBtu   2016 OS Hg Rate: 2.6×10^{-7} lb/mmBtu

During the SCOOT 2015 ozone season reporting effort, Cheswick 1 reported operating the SCR with less ammonia in order to reduce Hg for MATS compliance. The trade-off between NOx and Hg emissions is supported by the operating curves, however during the 2015 ozone season the unit was still well below the MATS Hg limit (shown in red) while maintaining a lower NOx rate. Note that this theory may not apply to this unit. It appears that the SCR is not in use or reagent is not injected in 2016; additional Hg reductions are dependent on reduced SCR use, not lack of use.



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APPENDIX B

Maryland's 2015 NOx Regulations for Coal-Fired Electric Generating Units

Title 26 DEPARTMENT OF THE ENVIRONMENT

Subtitle 11 AIR QUALITY

Chapter 38 Control of NO_x Emissions from Coal-Fired Electric Generating Units

Authority: Environment Article, §§1-404, 2-103, and 2-301—2-303, Annotated Code of Maryland

.01 Definitions.

A. In this chapter, the following terms have the meanings indicated.

B. Terms Defined.

(1) “Affected electric generating unit” means any one of the following coal-fired electric generating units:

(a) Brandon Shores Units 1 and 2;

(b) C.P. Crane Units 1 and 2;

(c) Chalk Point Units 1 and 2;

(d) Dickerson Units 1, 2, and 3;

(e) H.A. Wagner Units 2 and 3;

(f) Morgantown Units 1 and 2; and

(g) Warrior Run.

(2) “Emergency operations” means an event called when PJM Interconnection, LLC or a successor independent system operator, acts to invoke one or more of the Warning or Action procedures in accordance with PJM Manual 13, Revision 57, as amended, to avoid potential interruption in electric service and maintain electric system reliability.

(3) “Operating day” means a 24-hour period beginning midnight of one day and ending the following midnight, or an alternative 24-hour period approved by the Department, during which time an installation is operating, consuming fuel, or causing emissions.

(4) “Ozone season” means the period beginning May 1 of any given year and ending September 30 of the same year.

(5) System.

(a) "System" means all affected electric generating units within the State of Maryland subject to this chapter that are owned, operated, or controlled by the same person and are located:

(i) In the same ozone nonattainment area as specified in 40 CFR Part 81; or

(ii) Outside any designated ozone nonattainment area as specified in 40 CFR Part 81.

(b) "System" includes at least two affected electric generating units.

(6) "System operating day" means any day in which an electric generating unit in a system operates.

(7) "30-day rolling average emission rate" means a value in lbs/MMBtu calculated by:

(a) Summing the total pounds of pollutant emitted from the unit during the current operating day and the previous 29 operating days;

(b) Summing the total heat input to the unit in MMBtu during the current operating day and the previous 29 operating days; and

(c) Dividing the total number of pounds of pollutant emitted during the 30 operating days by the total heat input during the 30 operating days.

(8) "30-day systemwide rolling average emission rate" means a value in lbs/MMBtu calculated by:

(a) Summing the total pounds of pollutant emitted from the system during the current system operating day and the previous 29 system operating days;

(b) Summing the total heat input to the system in MMBtu during the current system operating day and the previous 29 system operating days; and

(c) Dividing the total number of pounds of pollutant emitted during the 30 system operating days by the total heat input during the 30 system operating days.

(9) "24-hour block average emission rate" means a value in lbs/MMBtu calculated by:

(a) Summing the total pounds of pollutant emitted from the unit during 24 hours between midnight of one day and ending the following midnight;

(b) Summing the total heat input to the unit in MMBtu during 24 hours between midnight of one day and ending the following midnight; and

(c) Dividing the total number of pounds of pollutant emitted during 24 hours between midnight of one day and ending the following midnight by the total heat input during 24 hours between midnight of one day and ending the following midnight.

(10) "24-hour systemwide block average emission rate" means a value in lbs/MMBtu calculated by:

(a) Summing the total pounds of pollutant emitted from the system during 24 hours between midnight of one day and ending the following midnight;

(b) Summing the total heat input to the system in MMBtu during 24 hours between midnight of one day and ending the following midnight; and

(c) Dividing the total number of pounds of pollutant emitted during 24 system hours between midnight of one day and ending the following midnight by the total heat input during 24 system hours between midnight of one day and ending the following midnight.

.02 Applicability.

The provisions of this chapter apply to an affected electric generating unit as that term is defined in Regulation .01B of this chapter.

.03 2015 NO_x Emission Control Requirements.

A. Daily NO_x Reduction Requirements During the Ozone Season.

(1) Not later than 45 days after the effective date of this regulation, the owner or operator of an affected electric generating unit (the unit) shall submit a plan to the Department and EPA for approval that demonstrates how each affected electric generating unit will operate installed pollution control technology and combustion controls to meet the requirements of §A(2) of this regulation. The plan shall summarize the data that will be collected to demonstrate compliance with §A(2) of this regulation. The plan shall cover all modes of operation, including but not limited to normal operations, start-up, shut-down, and low load operations.

(2) Beginning on May 1, 2015, for each operating day during the ozone season, the owner or operator of an affected electric generating unit shall minimize NO_x emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturers' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 CFR §60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

B. Ozone Season NO_x Reduction Requirements.

(1) Except as provided in §B(3) of this regulation, the owner or operator of an affected electric generating unit shall not exceed a NO_x 30-day systemwide rolling average emission rate of 0.15 lbs/MMBtu during the ozone season.

(2) The owner or operator of an affected electric generating unit subject to the provisions of this regulation shall continue to meet the ozone season NO_x reduction requirements in COMAR 26.11.27.

(3) Ownership of Single Electric Generating Facility.

(a) An affected electric generating unit is not subject to §B(1) of this regulation if the unit is located at an electric generating facility that is the only facility in Maryland directly or indirectly owned, operated, or controlled by the owner, operator, or controller of the facility.

(b) For the purposes of this subsection, the owner includes parent companies, affiliates, and subsidiaries of the owner.

C. Annual NO_x Reduction Requirements. The owner or operator of an affected electric generating unit subject to the provisions of this regulation shall continue to meet the annual NO_x reduction requirements in COMAR 26.11.27.

D. NO_x Emission Requirements for Affected Electric Generating Units Equipped with Fluidized Bed Combustors.

(1) The owner or operator of an affected electric generating unit equipped with a fluidized bed combustor is not subject to the requirements of §§A, B(1) and (2), and C of this regulation.

(2) The owner or operator of an affected electric generating unit equipped with a fluidized bed combustor shall not exceed a NO_x 24-hour block average emission rate of 0.10 lbs/MMBtu.

.04 Additional NO_x Emission Control Requirements.

A. This regulation applies to C.P. Crane units 1 and 2, Chalk Point unit 2, Dickerson units 1, 2, and 3, and H.A. Wagner unit 2.

B. General Requirements. The owner or operator of the affected electric generating units subject to this regulation shall choose from the following:

(1) Not later than June 1, 2020:

(a) Install and operate a selective catalytic reduction (SCR) control system; and

(b) Meet a NO_x emission rate of 0.09 lbs/MMBtu, as determined on a 30-day rolling average during the ozone season;

(2) Not later than June 1, 2020, permanently retire the unit;

(3) Not later than June 1, 2020, permanently switch fuel from coal to natural gas for the unit;

(4) Not later than June 1, 2020, meet either a NO_x emission rate of 0.13 lbs/MMBtu as determined on a 24-hour systemwide block average or a systemwide NO_x tonnage cap of 21 tons per day during the ozone season.

C. When option §B(4)of this regulation is selected:

(1) Not later than May 1, 2016, the owner or operator of an affected electric generating unit shall not exceed a NO_x 30-day systemwide rolling average emission rate of 0.13 lbs/MMBtu during the ozone season.

(2) Not later than May 1, 2018, the owner or operator of an affected electric generating unit shall not exceed a NO_x 30-day systemwide rolling average emission rate of 0.11 lbs/MMBtu during the ozone season.

(3) Not later than May 1, 2020, the owner or operator of an affected electric generating unit shall not exceed a NO_x 30-day systemwide rolling average emission rate of 0.09 lbs/MMBtu during the ozone season.

D. In order to calculate the 24-hour systemwide block average emission rate and systemwide NO_x tonnage cap under §B(4) of this regulation and the systemwide rolling average emission rates under §C of this regulation:

(1) The owner or operator shall use all affected electric generating units within their system as those terms are defined in Regulation .01B of this chapter; and

(2) The unit or units NO_x emissions from all operations during the entire operating day shall be used where the unit or units burn coal at any time during that operating day.

E. Beginning June 1, 2020, if the unit or units included in a system, as that system existed on May 1, 2015, is no longer directly or indirectly owned, operated, or controlled by the owner, operator, or controller of the system:

(1) The remaining units within the system shall meet either:

(a) The requirements of §B(1)—(3) of this regulation; or

(b) A NO_x emission rate of 0.13 lbs/MMBtu as determined on a 24-hour systemwide block average and the requirements of §C(3) of this regulation.

(2) The unit or units no longer included in the system shall meet the requirements of §B(1)—(3) of this regulation.

F. For the purposes of this regulation, the owner includes parent companies, affiliates, and subsidiaries of the owner.

.05 Compliance Demonstration Requirements.

A. Procedures for Demonstrating Compliance with Regulation .03A of this Chapter.

(1) An affected electric generating unit shall demonstrate, to the Department's satisfaction, compliance with Regulation .03A(2) of this chapter, using the information collected and maintained in accordance with Regulation .03A(1) of this chapter and any additional documentation available to and maintained by the affected electric generating unit.

(2) An affected electric generating unit shall not be required to submit a unit-specific report consistent with §A(3) of this regulation when the unit emits at levels that are at or below the following rates:

Affected Unit	24-Hour Block Average NO_x Emissions in lbs/MMBtu
Brandon Shores	
Unit 1	0.08
Unit 2 <650 MWg ≥650 MWg	0.07 0.15
C.P. Crane	
Unit 1	0.30
Unit 2	0.28
Chalk Point	
Unit 1 only	0.07
Unit 2 only	0.33
Units 1 and 2 combined	0.20
Dickerson	
Unit 1 only	0.24
Unit 2 only	0.24
Unit 3 only	0.24
Two or more units combined	0.24
H.A. Wagner	

Unit 2	0.34
Unit 3	0.07
Morgantown	
Unit 1	0.07
Unit 2	0.07

(3) The owner or operator of an affected electric generating unit subject to Regulation .03A(2) of this chapter shall submit a unit-specific report for each day the unit exceeds its NO_x emission rate under §A(2) of this regulation, which shall include the following information for the entire operating day:

(a) Hours of operation for the unit;

(b) Hourly averages of operating temperature of installed pollution control technology;

(c) Hourly averages of heat input (MMBtu/hr);

(d) Hourly averages of output (MWh);

(e) Hourly averages of ammonia or urea flow rates;

(f) Hourly averages of NO_x emissions data (lbs/MMBtu and tons);

(g) Malfunction data;

(h) The technical and operational reason the rate was exceeded, such as:

(i) Operator error;

(ii) Technical events beyond the control of the owner or operator (e.g. acts of God, malfunctions); or

(iii) Dispatch requirements that mandate unplanned operation (e.g. start-ups and shut-downs, idling, and operation at low voltage or low load);

(i) A written narrative describing any actions taken to reduce emission rates; and

(j) Other information that the Department determines is necessary to evaluate the data or to ensure that compliance is achieved.

(4) An exceedance of the emissions rate under §A(2) of this regulation as a result of factors including but not limited to start-up, shut-down, days when the unit was directed by the electric grid operator to operate at low load or to operate pursuant to any emergency generation operations required by the electric grid operator, including necessary testing for such emergency operations, or which otherwise occurred during operations which are deemed consistent with the unit's technological limitations, manufacturers' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions, shall not be considered a violation of Regulation .03A(2) of this chapter provided that the provisions of the approved plan as required in Regulation .03A(1) of this chapter are met.

B. Procedures for Demonstrating Compliance with NO_x Emission Rates under this Chapter.

(1) Compliance with the NO_x emission rate limitations in Regulations .03B(1) and D(2); .04B(1)(b) and B(4), C(1)—(3), and E(1)(b); and .05A(2) of this chapter shall be demonstrated with a continuous emission monitoring system that is installed, operated, and certified in accordance with 40 CFR Part 75.

(2) For Regulations .03B(1) and .04C(1)—(3) of this chapter, in order to calculate the 30-day systemwide rolling average emission rates, if 29 system operating days are not available from the current ozone season, system operating days from the previous ozone season shall be used.

(3) For Regulation .04B(1)(b) of this chapter, in order to calculate the 30-day rolling average emission rates, if 29 operating days are not available from the current ozone season, operating days from the previous ozone season shall be used.

.06 Reporting Requirements.

A. Reporting Schedule.

(1) Beginning 30 days after the first month of the ozone season following the effective date of this chapter, each affected electric generating unit subject to the requirements of this chapter shall submit a monthly report to the Department detailing the status of compliance with this chapter during the ozone season.

(2) Each subsequent monthly report shall be submitted to the Department not later than 30 days following the end of the calendar month during the ozone season.

B. Monthly Reports During Ozone Season. Monthly reports during the ozone season shall include:

(1) Daily pass or fail of the NO_x emission rates under Regulation .05A(2) of this chapter;

(2) The reporting information as required under Regulation .05A(3) of this chapter;

(3) The 30-day systemwide rolling average emission rate for each affected electric generating unit to demonstrate compliance with Regulation .03B(1), .04C(1)—(3) of this chapter, as applicable;

(4) For an affected electric generating unit which has selected the compliance option of Regulation .04B(1) of this chapter, beginning June 1, 2020, the 30-day rolling average emission rate calculated in lbs/MMBtu;

(5) For an affected electric generating unit which has selected the compliance option of Regulation .04B(4) of this chapter, beginning June 1, 2016, the 30-day rolling average emission rate and 30-day systemwide rolling average emission rate calculated in lbs/MMBtu;

(6) For an affected electric generating unit which has selected the compliance option of Regulation .04B(4) of this chapter, beginning June 1, 2020, data, information, and calculations which demonstrate the systemwide NO_x emission rate as determined on a 24-hour block average or the actual systemwide daily NO_x emissions in tons for each day during the month; and

(7) For an affected electric generating unit which has selected the compliance option of Regulation .04E(1)(b) of this chapter, beginning June 1, 2020, data, information, and calculations which demonstrate the systemwide NO_x emission rate as determined on a 24-hour block average for each day during the month.

.07 Electric System Reliability During Ozone Seasons.

A. In the event of emergency operations, a maximum of 12 hours of operations per system per ozone season may be removed from the calculation of the NO_x limitations in Regulation .04B(4) of this chapter from the unit or units responding to the emergency operations provided that:

(1) Within one business day following the emergency operation, the owner or operator of the affected electric generating unit or units notifies the Manager of the Air Quality Compliance Program of the emergency operations taken by PJM Interconnection; and

(2) Within five business days following the emergency operation, the owner or operator of the affected electric generating unit or units provides the Department with the following information:

(a) PJM documentation of the emergency event called and the unit or units requested to operate;

(b) Unit or units dispatched for the emergency operation;

(c) Number of hours that the unit or units responded to the emergency operation and the consecutive hours that will be used towards the calculation of the NO_x limitations in Regulation .04B(4) of this chapter; and

(d) Other information regarding efforts the owner or operator took to minimize NO_x emissions in accordance with Regulation .03A(1) of this chapter on the day that the emergency operation was called.

B. Any partial hour in which a unit operated in response to emergency operations under §A of this regulation shall constitute a full hour of operations.

Effective date:

Regulations .01—.05 adopted as an emergency provision effective May 1, 2015 (42:11 Md. R. 722); adopted permanently effective August 31, 2015 (42:17 Md. R. 1111)

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Chapter revised effective December 10, 2015 (42:24 Md. R. 1506)

APPENDIX C

Ozone Transport Research and Analysis Efforts in Maryland

Ground-Level Ozone

A Path Forward for the Eastern United States

30 Years of Research and Progress: What's worked … What We've Learned … Where to Go Next

by George (Tad) Aburn, Jr., Russell R. Dickerson, Jennifer C. Hains, Duane King, Ross Salawitch, Timothy Canty, Xinrong Ren, Anne M. Thompson, and Michael Woodman

The Maryland Department of Environment partners with the University of Maryland at College Park, NASA, and other researchers to study how meteorology, photochemistry, and geography conspire to make the ozone problem so challenging.

Maryland has struggled with ozone nonattainment for over 30 years. We've seen success, we've seen some setbacks, and we've learned a lot. There are many current issues linked to ground-level ozone being discussed across the nation. The top six policy-relevant conclusions from our 30-year struggle are:

1. We understand the fundamental, policy-relevant science of ozone production in the East, and believe that continuing significant progress can be achieved.
2. An updated ozone standard is appropriate and achievable.
3. An enhanced partnership with the U.S. Environmental Protection Agency (EPA) will be essential for making continued progress with ozone because the regional contribution to ozone in almost all areas is now dominant and

is predicted to become more so as the standards tighten.

4. Stronger partnerships between state and local governments and stakeholders will also be critical.
5. The private sector and environmental advocates can make a major contribution to insuring environmental and economic progress by being strategic about litigation.
6. International transport is becoming an important issue, but not one that should be used to delay continuing progress.

Background

For more than 30 years, Maryland has struggled with meeting the federal ozone standard. During that period, the Maryland Department of Environment (MDE) has partnered with the University of Maryland at College Park, NASA, and other researchers to study how meteorology, photochemistry, and geography conspire to make the ozone problem in the Mid-Atlantic so challenging. Processes on both the local and regional scale influence ozone formation and transport.[1-10] This research has played a significant role in the progress we have made in reducing exposure to ozone (and other pollutants) and provides a clear path forward for continuing to reduce ozone levels in the eastern half of the United States. Ozone issues west of the Mississippi appear to have some similarities to those in the East, but there are also some significant differences in meteorology and geography that create different challenges. This article focuses on ozone in the East, an area of lush forests where field experiments and numerical models have shown that nitrogen oxide (NO_x) emissions combined with biogenic hydrocarbons are sufficient to generate ozone events.[11-14]

After struggling with making progress with ozone in the 1970s, 1980s, and 1990s, ozone levels in Maryland, like the rest of the East, dropped dramatically over the past 10 years (see Figure 1 on page 20). Why?

From Maryland's perspective two major shifts in eastern ozone policy drove this change:

1. An increased focus on NO_x reductions; and
2. An increased focus on significant regional reductions of NO_x across the East from mobile sources, electric generating units (EGUs), and other large emission sectors.

The classic 1990 report from the National Academy of Sciences foreshadowed the importance of these issues: the data show they were right.[15]

Local emission reduction programs have helped and will continue to help reduce ozone, but the large-scale regional NO_x reduction programs are what drove the noticeable improvements in ozone seen starting around 2003. Why?

Where Does Ozone in the Mid-Atlantic States Come From?

Ozone in the Mid-Atlantic is complicated. This issue can be understood by examining the two primary pieces of the problem: regional transport (i.e., ozone and ozone precursors from upwind sources across a large portion of the East) and local sources. In general terms, on bad ozone days in Baltimore, MD, approximately 70% of the problem is regional transport and approximately 30% is local.[16] As part of our research efforts, we measure "incoming" ozone levels with ozonesondes and airplanes that routinely approach or exceed the current 75 parts per billion (ppb) ozone standard.[17-20]

The regional transport component of our problem, builds up and collects in an "elevated reservoir" of ozone and ozone precursors that exists about

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1,000 m above the Mid-Atlantic and much of the East from May to September.[21,22] Ozone levels in the elevated reservoir can routinely be 70 ppb or greater on episode days.[23]

The influence of the elevated reservoir can best be seen by analyzing the morning "surge" of ozone reported in the ground-level monitoring data between 8:00 a.m. and 11:00 a.m. At night, ground-level monitors measure low ozone concentrations while monitors aloft measure much higher levels. At night, the elevated reservoir is separated from the surface by the nocturnal inversion. As the next day begins, temperatures increase, the inversion begins to collapse and the elevated ozone reservoir begins mixing down to the surface. In general, the ozone levels measured aloft at night mix down and create a regional transport contribution seen in ground-level monitors across the region. This "regional transport signal" can often approach or exceed 75 ppb. Local emissions begin to contribute to ozone production in the morning as well. Regional transport and local emissions combine to drive daily peak ozone levels in the late afternoon (see Figure 2).[24-27]

A classic, real-world case study helps demonstrate how regional NO_x reduction efforts can significantly lower ozone levels in the East. In 1997, 37 states and the District of Columbia participated in a collaborative effort, called the Ozone Transport Assessment Group (OTAG), to look at the transport of ozone in the East. Partially driven by that effort, in 1999 EPA adopted a federal program, called the NO_x State Implementation Plan (SIP) Call, to address ozone transport and help states satisfy the "good neighbor" requirements of the U.S. Clean Air Act (CAA). The NO_x SIP Call required a first round of meaningful NO_x reductions from EGUs in the 2003 to 2004 time frame. Around the same time, the federal Tier II vehicle standards also began to add NO_x reductions (volatile organic compounds [VOCs] were the focus of earlier federal standards).[28]

As Figure 3 shows, controls were added, regional NO_x emissions went down, ozone levels in the elevated reservoir were reduced, and ground-level ozone levels dropped dramatically.[10,29,30]

Filling the Reservoir

Which states and sources contribute to filling the elevated reservoir? The answer is that it varies from day to day. There are, however, some general observations that appear to be supported by Maryland's research and modeling.

Westerly transport is often a major factor when high pressure is located over the Southeast and the resulting aloft winds flow, clockwise, over the Ohio River Valley.[31,32] This classic ozone weather pattern often carries transported ozone and ozone precursors from power plants into the Mid-Atlantic region. This scenario can cover multiple days.

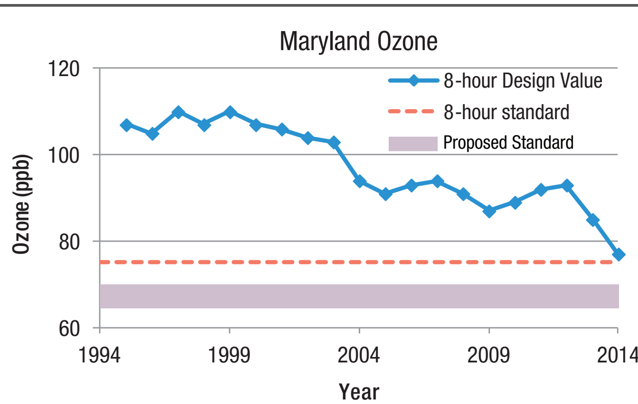

Figure 1. Trend chart for Maryland ozone.

Notes: Ozone design values in Maryland have steadily decreased since 1994 and in 2014 Maryland is close to meeting the current standard. Note the scale does not start at zero.

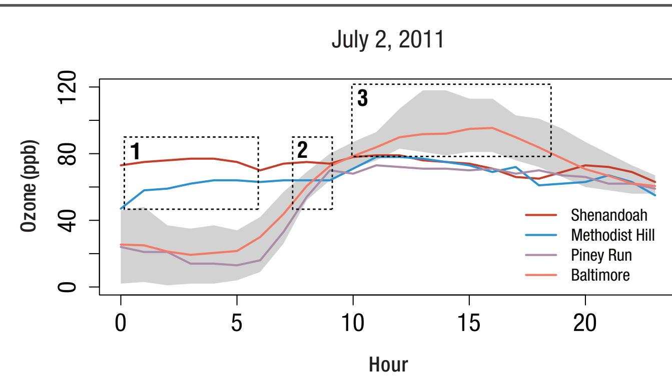

Figure 2. Daily evolution of ozone.

Notes: Hourly ozone collected on July 2, 2011. Box 1 highlights ozone measured in the elevated reservoir at night; Box 2 shows the regional transport signal and highlights the breakdown of the nocturnal inversion when the aloft ozone is mixed to the surface; and Box 3 highlights the contribution of locally produced ozone on top of the regional pollution.

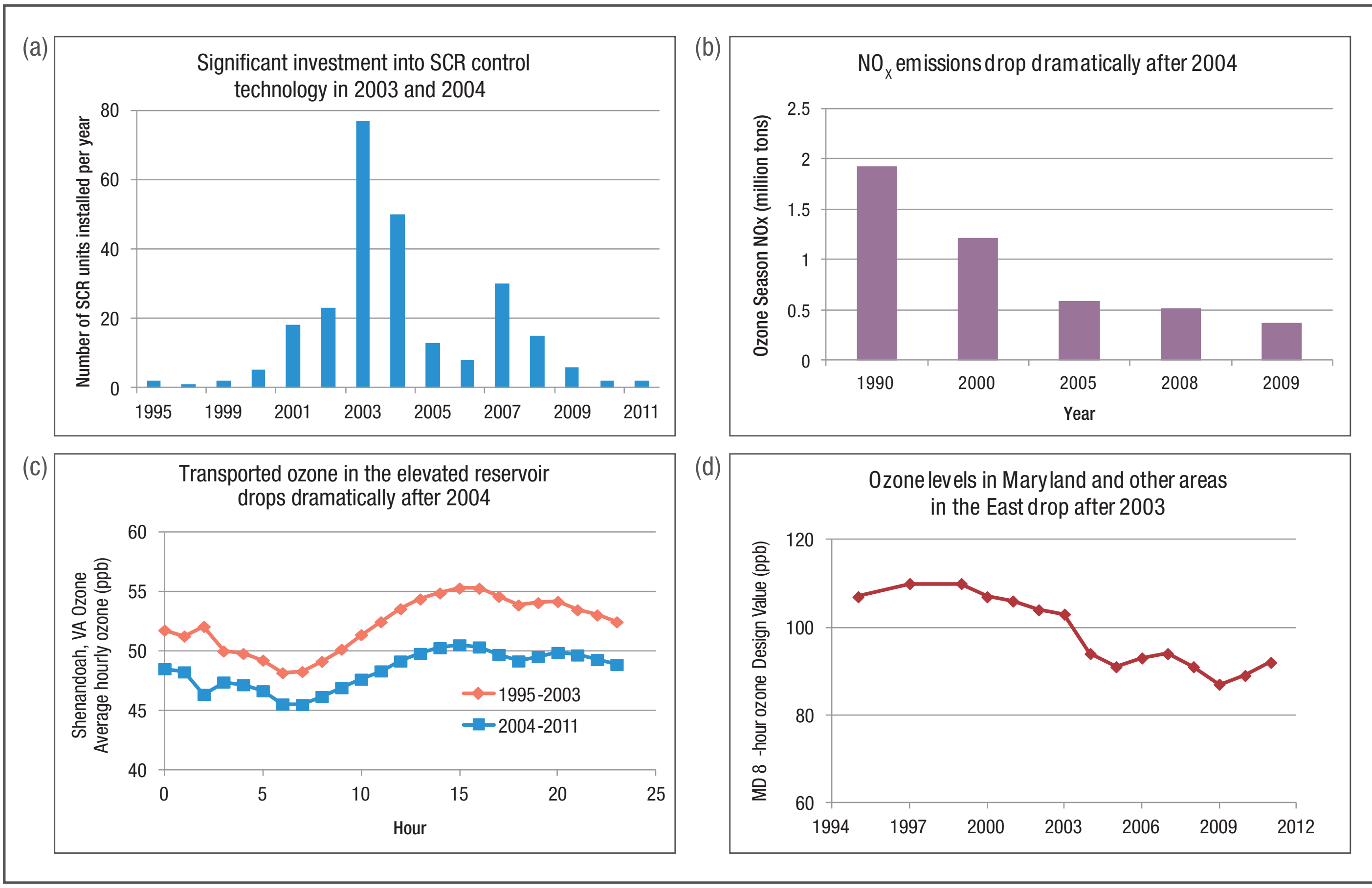

Figure 3. Why regional NO_x controls work.

Notes:

(a) NO_x SIP Call drives significant investment in selected catalytic reduction (SCR) NO_x control technology, 2003–2004;

(b) NO_x emissions in the area covered by the NO_x SIP Call drop dramatically around 2004;

(c) Transported ozone in the elevated reservoir drops dramatically after 2004. Note that the scale does not start at zero; and

(d) Ozone levels in Maryland and other areas in the East drop dramatically after 2003.

Southerly transport at night also appears to be important. On most bad ozone days, wind profilers along the East Coast show nighttime aloft winds moving from the south to the north funneled by the Appalachian Mountains on the west and the Atlantic Ocean on the east.

This nocturnal low level jet, measured by wind profilers, can reach wind speeds as high as 35 mph.[33,34] Nighttime ozonesonde launches show that ozone levels being carried by the nocturnal low level jet are routinely in the 50–70-ppb range and can get as high as 100 ppb.[35] It appears that this type of transport can move ozone for several hundred miles over night and has a significant mobile source fingerprint. In addition, the effects of a bay-breeze are often observed at monitoring stations near Baltimore. During the bay-breeze, air masses with both local and imported ozone pass from the western shore to the Chesapeake. Over the bay, ozone continues to form, until the winds reverse and ozone-enriched air returns to shore. During a 30-day aircraft and ozonesonde measurement campaign in July 2011, one monitoring site recorded eight ozone violations for which the bay-breeze was a factor.[36,37] The bottom line is that the contribution to the elevated ozone reservoir changes with weather. Westerly, southerly, sometimes northwesterly, and occasionally northeasterly flows are all important. EGUs, mobile sources, and other source sectors all appear to play a significant role in creating the elevated ozone reservoir.

The other type of important transport is city-to-city or short-range transport. For example, Baltimore's plume floating at ground level into Philadelphia and Washington's plume floating into Baltimore. This type of short-range transport is separate from the elevated ozone reservoir, but it is another significant way that emissions from close-by, upwind states contribute to downwind problem areas.[23]

The Path Forward

In the East, the formula is simple: Cost-effective regional NO_x control programs complimented by smart local efforts that target each area's unique

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Regional Transport

As states move forward and begin to develop plans to continue making progress with ground-level ozone, a new level of partnership with EPA will be needed. The CAA is often recognized as a good example of cooperative federalism where state and local governments work with EPA in partnership to provide clean air in a way that fosters economic prosperity. This partnership is now more important than ever.

Between 2005 and 2010, EPA and the states worked together to identify priority source categories that would have the largest eastern and national emissions of NO_x, sulfur dioxide (SO_2), and mercury (Hg) remaining in 2020. This effort identified six source categories that represented 75% of the remaining NO_x emissions that could be targeted for additional reductions. These categories included EGUs; on-road mobile sources; institutional, industrial, and commercial (ICI) boilers; cement kilns; marine engines; and locomotives. These six categories also represented 85% of the SO_2, and 75% of the Hg emissions left to control in 2020.[38-42] EPA has moved forward with initiatives to reduce national or regional NO_x emissions from many of these priority source categories and much of the recent progress on ozone reduction is linked to these actions. Earlier actions on marine and locomotive engines, the Tier 2 Vehicle Standards, and the NO_x SIP Call combined with more recent efforts like the Tier 3 Vehicle and Fuel Standards, the Mercury and Air Toxics Standard (MATS), Boiler MACT, and a series of mobile source actions on greenhouse gases that will provide ozone co-benefits have, and will continue to, help lower ozone levels.[43] It's clear that regional NO_x reductions drive down ozone across the East. So how do we continue to do more of that?

The state/EPA partnership on prioritizing important sectors by potential future multipollutant reductions provides a model to identify the next set of national or super-regional reduction programs that may be needed. The effort should be designed to analyze strategies to find the "biggest bang for the buck" and to look at multipollutant benefits. In many cases, at the national or super-regional level, a small set of source categories dominate emission contributions for ozone, fine particulates, SO_2, NO_2, Hg, haze, and greenhouse gases.

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One of the issues that continues to be discussed over the new ozone standard is that many new areas, particularly less populated areas, will be forced to try and solve a problem that they simply cannot solve alone because local emissions are relatively small. The need for regional controls is important for historically difficult nonattainment areas like Baltimore and New York, but they are actually much more important to new areas that may be nonattainment for ozone in the future.

Local Transport

Addressing the local contribution to ozone is important, but if done alone, without addressing the regional contribution, will fail. It is critical for local strategies to be "smart". What works in the Mid-Atlantic may not work in the South. As an example, Maryland and other Northeast states are working to drive down local mobile source emissions of NO_x along the I-95 corridor. Emissions for major point sources are accurately monitored, but substantial uncertainties remain in emissions for mobile sources.[44] Our research tells us that a focus on mobile sources is an important area to drive future progress.

Examples of the kind of local efforts being made in this area include the recent efforts by eight states on Zero Emission Vehicles (ZEVs), the OTC Aftermarket Catalyst model rule, and nontraditional initiatives to enhance SMARTWAYs efforts and to work with ports. The common thread in all of these is reducing NO_x, but all of these efforts also have multipollutant benefits.[44-48]

Maryland is also working with neighboring states to further reduce VOC emissions, which continue to be a meaningful contributor to ozone at our urban monitors. Recent efforts include updates to three model rules developed by the Ozone Transport Commission for consumer products, paints, and auto body shops. This is a good example of a strategy that would be smart for some areas, but less likely to be successful in other areas like the South where biogenic VOCs are dominant when compared to anthropogenic VOCs.

Enhanced Collaboration

Two more observations from the past 30 years: Legal challenges by the environmental community occasionally slow down environmental progress; and legal challenges by the private sector can lead to inefficient regulatory processes and a planning landscape for the business community that is impossible to navigate. Both hurt the nation's economy. This seems like an area that needs to be

It's clear that regional NO_x reductions drive down ozone across the East.

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explored and may be as important to future environmental and economic progress as the science giving us a clear technical path forward.

Having worked collaboratively with other government agencies, the environmental advocacy community and the private sector, we believe an enhanced effort to collaborate is critical and that such an effort could work. The CAA is a very powerful and functional legal framework to work from. Sometimes the solutions to the problems we struggle with lie within the gray areas of the law and require buy-in from multiple parties if they are to work. Clear environmental progress is essential. We cannot let perfection be the enemy of the very good.

Critical Emerging Ozone Research

One of the most policy-relevant, emerging research areas MDE is working on with the University of Maryland involves changes to the atmosphere over the past 15 years that may be affecting the chemistry of ozone production. These changes appear to support the hypothesis that we have reached a tipping point, where a ton of NO_x reduction in the 2015–2025 time frame will generate meaningfully more ozone reduction than it did just 15 years ago. This is a critical issue as we move toward a new standard. Stay tuned.

Evolving Markets

When markets change, market-based programs sometimes need to be tweaked. Over the past few years, changes in the electricity markets have created a situation where installed EGU control equipment for ozone does not need to be used effectively during bad ozone periods because of the flexibilities built into the market-based regulatory system under which many of these sources operate. This issue is already being discussed and appears to be moving toward resolution. That said, investing in billions of dollars worth of ozone controls and then not using them when it matters, is an issue that must be fixed.

Conclusion

Maryland is thoroughly convinced that continued significant progress on reducing ground-level ozone is within our grasp. The science linked to what else we need to do is solid. Continued progress in the future will, however, take a new level of partnership involving states and local agencies, EPA, the private sector, and the environmental advocacy community. **em**

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APPENDIX D

Photochemical Modeling and Other Analyses Supporting the 126 Petition

Part I – University of Maryland Modeling

I. Overview

At the University of Maryland, College Park (UMD) we have developed a state-of-the-art scientific research tool aimed at a more informed understanding of the influences controlling air quality over the mid-Atlantic States. The Regional Atmospheric Measurement, Modeling and Prediction Program (RAMMPP) involves a number of integrated research elements including measurements from the Earth's surface, aircraft, and space-borne satellites, air quality forecasts, and numerical models including CMAQ and CAMx (see reference list below).

The Maryland Department of the Environment (MDE) contracted with the University of Maryland at College Park (UMD) Department of Atmospheric & Oceanic Science to perform photochemical modeling to demonstrate that emissions from 36 electric generating units (EGUs) in the five states of Indiana (IN), Kentucky (KY), Ohio (OH), Pennsylvania (PA) and West Virginia (WV) significantly contribute to ozone formation in Maryland (MD). The modeling completed will show the ozone concentration reduction if these EGUs had optimized running their SCR and SNCR controls. This document will describe the emissions and meteorological data used as input to the photochemical model, as well as the results in ozone concentrations based on the photochemical modeling completed.

II. Documented Evidence

Recent results relevant to this 126 Petition include CAMx modeling to show the impact of operating existing NOx control equipment at optimal levels (Vinciguerra et al., 2016) observations that demonstrate the role of the elevated reservoir in interstate transport of pollutant ozone and its precursors (Castellanos et al., 2011; He et al., 2014); the role of power plants on NOx and ozone formation especially on hot summer days (He et al., 2013); direct measurements and numerical studies to show that the air entering Maryland already contains substantial amounts of ozone and sufficient precursors (NOx) to form ozone between our western boarder and the cities of Baltimore and Washington, DC (Brent et al., 2013; Goldberg et al., 2015; 2016; Hains et al., 2008); and modeling results performed explicitly for this action.

An investigation of average ozone season NOx emission rates from coal-fired EGUs in the Eastern U.S. revealed several units where rates increased from 2004-2014 (McNevin, 2016). This trend suggested unit owners and operators found it cost-effective to limit operations of SCR or SNCR systems and instead use lenient regulatory or market mechanisms to legally meet their caps. This increase in NO_x emissions from not utilizing post-combustion controls can lead to increased ozone production locally and downwind. Alternatively, operating these controls at optimal rates could decrease ozone concentrations. Using a chemical transport model, Vinciguerra et al., (2016) quantified the regional impacts of EGU NOx controls on ozone formation.

In the Vinciguerra et al., 2016 study, several emissions scenarios were investigated. Rates can vary from unit to unit depending on multiple factors, such as installed controls, sequence of controls, gas temperature (which affects efficiency), and operational load. To capture some of these concerns, we use the average ozone season rates for each individual unit instead of simply applying only a single rate to every unit. The lowest, highest, and 2011 ozone season average NOx emission factors [lb/mmBtu] were found for each individual coal-fired unit equipped with SCR or SNCR controls.

The average ozone season historic CAMD NOx emission rates for each coal-fired unit from each year from 2005 through 2012 were compared to the rates from the 2018 IPM inventory files. For each unit, the ratio between lowest historic NOx rates and 2018 IPM NOx rates was calculated and used as a multiplier that was applied to the hourly and annual IPM emissions inventory files and reprocessed through the SMOKE model. These new EGU emissions representing coal-fired units operating at their lowest rates were combined with the other 2018 emissions to create 2018 Scenario A.

Using a similar approach, NOx rates for coal-fired units were adjusted to represent various different control optimization scenarios. Table D1 provides a brief description of each of the scenarios.

Table D1. Brief descriptions of the modeling scenarios.

Scenario Name	Brief Description
2011 Baseline	2011 EPA-provided emissions were used with no modifications
2018 Baseline	2018 EPA-provided, projected emissions were used with no modifications
2018 Scenario A	2018 SCR/SNCR EGU NOx emissions are reduced to match lowest rates observed in 2005-2012 historical data.
2018 Scenario B	2018 SCR/SNCR EGU NOx emissions are reduced to match highest rates observed in 2005-2012 historical data.
2018 Scenario C	2018 SCR/SNCR EGU NOx emissions are increased to match rates observed in 2011. Emission projections for 2018 in all other sectors remain unchanged.
2018 Scenario D	2018 SCR/SNCR EGU NOx emissions are reduced to match lowest rates observed in 2005-2012 historical data. And 2018 EGUs lacking post-combustion controls modeled to include SCR

NOx reductions.

These model runs with CMAQ demonstrated that running SCR and SNCR NOx control devices at optimal rates would have a substantial favorable impact on O_3, averaging up to 5 ppb (more on hot days), in the eastern US; see Figure D1.

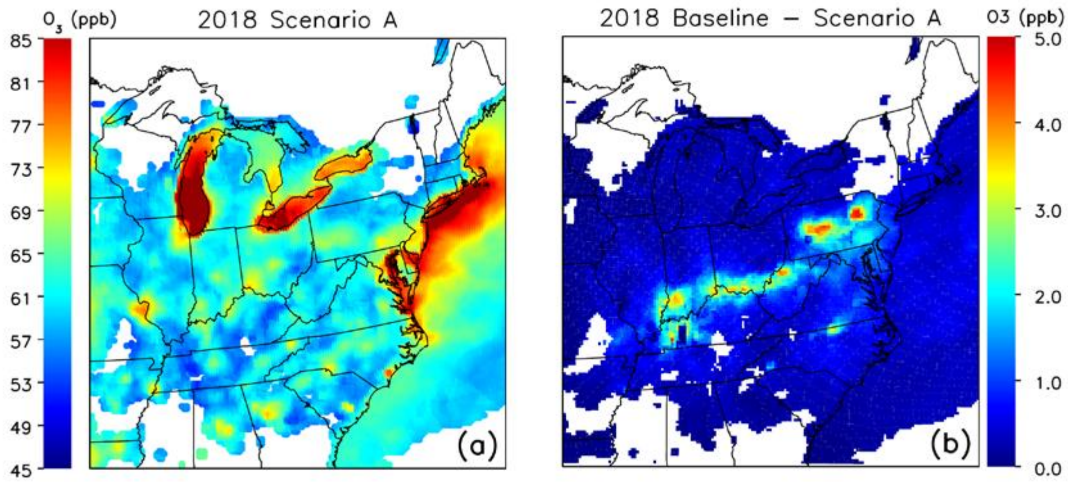


Figure D1. Left (a) Average 8-hour maximum surface ozone for the July 2018 Scenario A (historically best power plant NOx emission rates) run. Regions shown in red-orange to red exceed 75 ppb. Right (b) Difference plot between model surface 8-hour ozone concentrations from the 2018 Baseline and 2018 Scenario A runs showing the potential improvement from optimal operation of existing NOx control equipment (Vinciguerra et al., 2016).

This peer-reviewed, scientific journal article concluded: numerical simulations indicate that the substantial investment in SCR and SNCR units on power plants in the Eastern U.S. has provided an appreciable beneficial impact on air quality. Current regulations allow these units to be turned off for considerable periods as long as annual and ozone-season emissions caps are met. However, our model results indicate that the difference between the recorded least-effective NO_x removal rates and the rates from complete adoption and optimal utilization of NO_x removal systems on coal-fired power plants produces a calculated change in ozone that approaches 10 ppb. Even without new capital investment, predicted concentrations of ozone in 2018 could be improved by up to 5 ppb solely by running existing, operable technology at optimal rates.

Perhaps the most compelling evidence for substantial interstate transport of ozone and the pollutants that produce it comes from direct measurements from aircraft operated by the University of Maryland and NASA. Figures D2 and D3, taken from Brent et al. (2013) show that ozone is a regional problem and reservoir species extend the lifetime of NOx. NO_2 is high enough to generate new ozone at ~3 ppb/hr at midday even upwind of Baltimore and Washington.

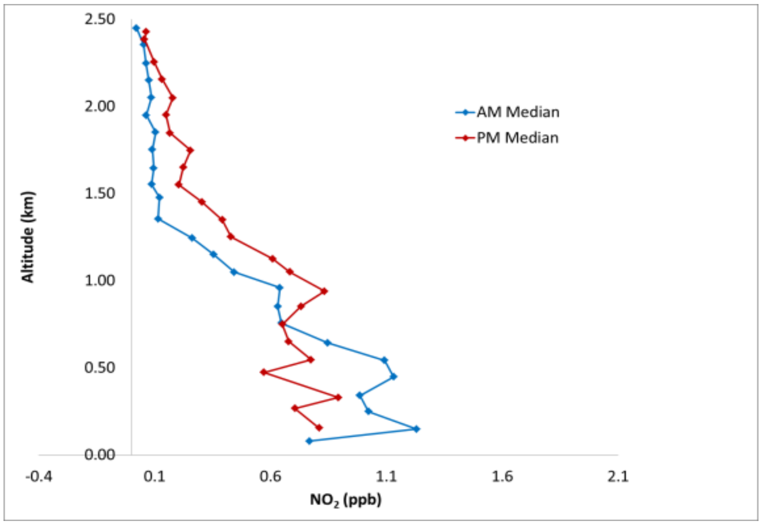


Figure D2. Mean ozone measured in July 2011 in the morning to the west and generally upwind of the Baltimore/Washington corridor (red) and in the afternoon, to the east and generally downwind. Air entering the urban airshed can already exceed the 75 ppb standard due to upwind emissions.

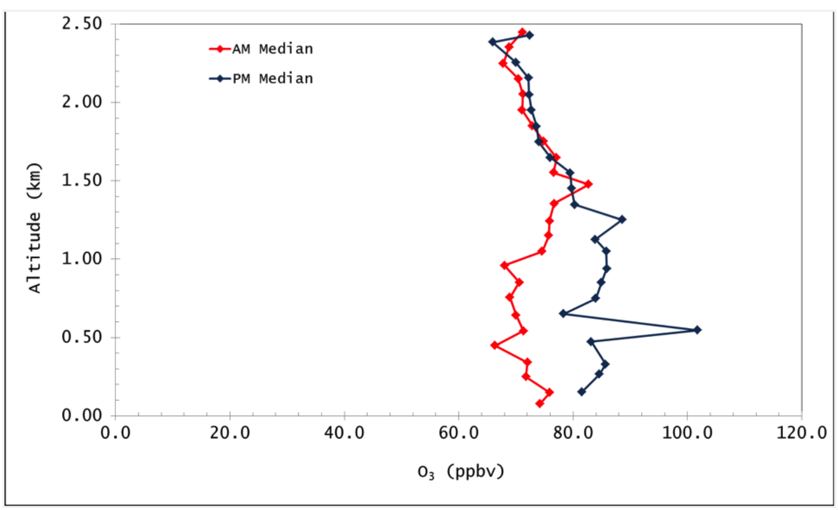


Figure D3. Mean NO_2 measured in July 2011 in the morning to the west and generally upwind of the Baltimore/Washington corridor (red) and in the afternoon, to the east and generally downwind. Air entering the urban airshed already contains sufficient NO_2 to produce ozone at several ppb per hour; see also Canty et al., (2015).

III. Emissions Processing Model

The Sparse Matrix Operator Kernel Emissions (SMOKE) Modeling System was selected for the proposed regulation modeling analysis. The SMOKE model was originally developed at the Microelectronics Center of North Carolina (MCNC) to integrate emissions data processing with high-performance computing (HPC) sparse –matrix algorithms. The SMOKE model is now under active development at the Institute for Environment and is partially supported by the Community Modeling and Analysis Systems (CMAS).

The SMOKE model is principally an emissions-processing system and not a true emissions inventory preparation system in which emissions are simulated from 'first principles'. This means that, with the exception of mobile and biogenic sources, its purpose is to provide an efficient, modern tool for converting emissions inventory data into the formatted gridded, speciated, hourly emissions files required by an air quality simulation model. For mobile emissions the on-road emissions model MOVES2014 was used. For biogenic emissions modeling, SMOKE uses the Biogenic Emission Inventory System, version 3.6.1 (BEIS3.6.1).

SMOKE is the fastest emissions processing tool currently available to the air quality modeling community. The sparse matrix approach used throughout SMOKE permits rapid and flexible processing of emissions data. The rapid processing is possible because SMOKE uses a series of matrix calculations rather than a less-efficient sequential approach used by previous systems. The process is flexible because the processing steps of temporal projection, controls, chemical speciation, temporal allocation, and spatial allocation have been separated into independent operations wherever possible. The results from these steps are merged together at a final stage of processing using vector-matrix multiplication. This means that individual steps (such as adding a new control strategy, or processing for a different grid) can be performed and merged without having to redo all of the other processing steps.

The SMOKE model supports area, mobile, fire, point, and biogenic sources emissions processing. For biogenic emissions, SMOKE supports both gridded land use and county total land use data.

SMOKE (Version 3.5.1) was used for the 126 Petition modeling demonstration. EPA provided a draft NEI2011v2 emissions (USEPA, August 2015) files to the Mid-Atlantic Regional Air Management Association (MARAMA). The stationary sources emissions were then grown using MARAMA created growth factors based on states' inputs and EPA's 2018/2028 Modeling Platform for mobile source emission projections. EPA released the NEI2018v1 on January 14, 2015. The EPA IPM (Integrated Planning Model) 5.13 EGU emissions were replaced with the Eastern Region Technical Advisory Committee (ERTAC)

2.3 EGU emissions (http://marama.org/2013-ertac-egu-forecasting-tool-documentation) in an effort to use the best emissions data available to complete this modeling demonstration.

IV. Meteorological Model

Meteorological inputs for the CMAQ modeling were developed by EPA for the 2011 modeling platform using version 3.4 of the Weather Research and Forecasting (WRF) numerical weather prediction model (Skamarock et al., 2008). The meteorological outputs from WRF include hourly varying winds, temperature, moisture, vertical diffusion rates, clouds, and rainfall rates. Additional details about this WRF simulation and its performance evaluation can be found in U.S. EPA (2014b).

V. Air Quality Model

The EPA's Models-3/Community Multi-scale Air Quality (CMAQ) model version 5.0.2 was used for this modeling analysis. The modeling system is a 'One-Atmosphere' photochemical grid model capable of addressing ozone and PM2.5 at a regional scale and is considered one of the preferred models for regulatory modeling applications. CMAQ is generally considered by the scientific community to meet the following prerequisites for photochemical modeling applications:

1. It has been received and been revised in response to a scientific peer review.
2. It is appropriate for the specific application on a theoretical basis.
3. It shall be used with a database that is adequate to support its application.
4. It has been shown to perform well in past ozone modeling applications.
5. It will be applied consistently with a protocol on methods and procedures.

Furthermore, several factors were considered as criteria for choosing the CMAQ model as a qualifying air quality model to support the proposed regulation and these factors are:

1. Documentation and past track record in similar applications;
2. Advanced science and technical features available in the modeling system;
3. Experience of staff; and
4. Required time and resources versus available time and resources.

For further documentation on the CMAQ model, see http://www.epa.gov/asmdnerl/CMAQ/CMAQscienceDoc.html.

VI. Modeling Scenarios

This section describes the modeling scenarios used to support this analysis. These scenarios simulate the effect of having 36 EGUs in the five states of IN, KY, OH, PA and WV fully optimize their SCR/SNCR controls and demonstrates the benefit of optimized controls on reducing ozone concentrations in Maryland. For all scenarios the meteorological period of July 1 – July 31, 2011 was simulated. This particular month was deemed an appropriate period to model since there were a high number of ozone exceedance days. During July 2011 Maryland experienced 17 ozone exceedance days (based on the 2008 ozone NAAQS of 75 ppb). In addition, 2011 National Emissions Inventory (NEI) was selected by EPA to be the base year for their modeling platform that will be used to support the development of the revised ozone NAAQS (US EPA, 2014a).

All scenarios consist of 2011 NEI v2 from EPA, ERTAC EGU emissions (replaced EPA's IPM EGU emissions) and EPA MOVES 2014 mobile sources. The base case model ready emissions were provided by the New York State Department of Environmental Conservation (NYSDEC) as part of an ongoing modeling effort of the Ozone Transport Commission (OTC) of which Maryland is a member. The 2011 emissions were grown by MARAMA to a future year of 2018 for the OTC. EGU 2018 projected emissions were developed from the ERTAC EGU 2.3 tool. The controls applied to the inventory were the following: On The Books (OTB)/On The Way (OTW) and Tier 3 mobile controls.

All modeling scenarios included three changes made to the base CMAQ model framework. The first two changes were motivated by analysis of NASA data products, specifically satellite observations of tropospheric column NO_2 from the Ozone Monitoring Instrument (OMI) as well as aircraft observations obtained during the NASA DISCOVER-AQ campaign which took place in the mid-Atlantic region during July 2011. The CB05 chemical mechanism used in the CMAQ model treats all organic nitrates as a single species called NTR. In the "off the shelf" version of CMAQ, NTR has a lifetime of about 10 days. Since the development of CB05 there has been increasing observational evidence that the lifetime of the main species that comprise NTR have lifetimes on the order of 1 day (Horowitz et al., 2007; Perring et al., 2009; Beaver et al., 2012). Comparison of baseline CMAQ output to observations of alkyl nitrates made during DISCOVER-AQ 2011 confirm that modeled NTR is roughly an order of magnitude greater than observed. To correct for this, the lifetime of NTR has been reduced by a factor of 10 (Canty et al, 2015). A comparison of CO/NO_y provided in the NEI 2011 emission inventories used by CMAQ to aircraft observations taken during DISCOVER-AQ 2011 indicates that emissions of NOx from mobile sources are roughly a factor of 2 too large (Anderson et al., 2014). A recent study of surface ozone in the Southeastern United States using the GEOS-Chem model further confirms this result (Travis et al., 2016). The third change is based on a recent study of emissions from C3 commercial marine vessels (C3MV; ships with ~3,000 to 100,000 hp engines) that has determined an apparent discrepancy in the treatment of this source category. While off shore, modeled C3MV stack emissions have a vertical distribution peaking at ~80m, the typical height of a C3MV smoke stack. The near-shore (including Chesapeake and Delaware Bays, Great Lakes, etc.) emissions inventories have all C3MV emissions only at the surface. A consequence of this is that pollution from C3MV sources near places like

Edgewood, MD is kept very local. The vertical representation of near-shore C3MV ship emissions has been modified to match the offshore C3MV emissions that are treated as point sources (Ring et al., in preparation).

These changes, termed "best science model", provide a better representation of the chemical pre-cursors to ozone formation and the actual state of the atmosphere, in general. Compared to the baseline simulation, a CMAQ run using these changes leads to considerably better simulation of tropospheric column NO_2 and other nitrogen-containing pollutants in both urban and rural areas and improves agreement with in-situ aircraft observations in the mid-Atlantic region.

Descriptions of the specific modeling scenarios used for this study are as follows:

Scenario 4-126-1

This scenario consists of starting from the 2018 base case and for each of the identified units; the ERTAC2.3 ozone season NO_X mass was either adjusted up or down based on the mass percentage adjustment calculated for each of the units to reflect 2015 rates. This scenario is representative of power plant units operating their controls at 2015 ozone season NOx rates; generally, this is consistent with units not optimizing their controls.

The purpose of this scenario is to make the 2018 ozone season rates consistent with the 2015 ozone season rates so that when an optimized control scenario is applied, the percent reduction in NOx mass will be equal to the reduction in NOx mass had the units fully optimized their controls in the 2015 ozone season. The EGUs and adjustment percentages are provided in Table D2.

Scenario 4-126-2

This scenario consists of starting from scenario 4-126-1and for each of the 36 identified units, ozone season NO_X mass was adjusted down based on the mass percentage adjustment calculated for each of the units to reflect optimized rates. The EGUs and adjustment percentages are provided in Table D2.

The difference between scenarios 4-126-1 and 4-126-2 is the impact associated with the EGU units identified in Table D2 fully optimizing their SCR and SNCR controls.

Table D2. Modeling Adjustment Values for Scenarios S4-126-1 and S4-126-2

Unit Level Data for Units with SCR and SNCR						Modeling Adjustment Values - Scenario's	
Plant ID (ORISPL)	State	Facility Name	Unit ID	Post Combustion Control Type	Control Installation Year (Year)	Scenario 4-126A-1 (adjust to 2015 rates) Adjust ERTAC 2.3 Reference Case 2018 OS Mass Up or Down by X % (%)	Scenario 4-126A-2 (adjust to optimized rates) Adjust ERTAC 2.3 Reference Case 2018 OS Mass Up or Down by X % (%)
ERTAC	ERTAC	ERTAC	ERTAC	CAMD/ERTAC	CAMD/ERTAC	Calculated	Calculated
6705	IN	Alcoa Allowance Management Inc	4	SCR	2004	103.0635%	-31.8810%
983	IN	Clifty Creek	1	SCR	2003	127.6000%	-26.5000%
983	IN	Clifty Creek	2	SCR	2003	129.0000%	-25.0000%
983	IN	Clifty Creek	3	SCR	2003	128.7000%	-25.8000%
6113	IN	Gibson	3	SCR	2002	15.9538%	-61.9075%
6113	IN	Gibson	5	SCR	2004	177.1545%	-51.4634%
994	IN	Petersburg	2	SCR	2004	15.4460%	-71.2372%
994	IN	Petersburg	3	SCR	2004	122.7927%	-61.4334%
6018	KY	East Bend	2	SCR	2002	57.7107%	-62.1085%
1374	KY	Elmer Smith	1	SCR	2003	18.3030%	-59.2047%
1378	KY	Paradise	3	SCR	2004	-53.4843%	-69.8431%
6031	OH	Killen Station	2	SCR	2003	44.6881%	-46.8897%
2876	OH	Kyger Creek	1	SCR	2003	38.0729%	-48.9195%
2876	OH	Kyger Creek	2	SCR	2003	30.4940%	-48.7345%
2876	OH	Kyger Creek	3	SCR	2003	61.6703%	-50.2407%
2876	OH	Kyger Creek	4	SCR	2003	85.2413%	-48.2772%
2876	OH	Kyger Creek	5	SCR	2003	92.7096%	-48.7544%
6019	OH	W H Zimmer Generating Station	1	SCR	2004	5.0309%	-74.1222%
6094	PA	Bruce Mansfield	1	SCR	2003	78.8174%	-39.4340%
10641	PA	Cambria Cogen	1	SNCR	1999	34.3113%	-25.2947%
10641	PA	Cambria Cogen	2	SNCR	1999	28.3383%	-26.8071%
8226	PA	Cheswick	1	SCR	2003	7.6458%	-61.7401%
3122	PA	Homer City	1	SCR	2001	75.2500%	-66.6500%
3122	PA	Homer City	2	SCR	2000	75.4500%	-58.7000%
3122	PA	Homer City	3	SCR	2001	40.9500%	-56.4000%
3136	PA	Keystone	1	SCR	2003	16.0000%	-78.4500%
3136	PA	Keystone	2	SCR	2003	21.2500%	-78.3500%
3149	PA	Montour	1	SCR	2001	54.6000%	-70.9500%
3149	PA	Montour	2	SCR	2000	68.1000%	-71.1000%
10151	WV	Grant Town Power Plant	1A	SNCR	2003	27.0786%	-73.2486%
10151	WV	Grant Town Power Plant	1B	SNCR	2003	28.7425%	-72.6370%
3944	WV	Harrison Power Station	1	SCR	2001	66.4055%	-66.7818%
3944	WV	Harrison Power Station	2	SCR	2003	81.0219%	-67.1050%
3944	WV	Harrison Power Station	3	SCR	2003	60.1537%	-69.2228%
6004	WV	Pleasants Power Station	1	SCR	2003	56.2881%	-71.8181%
6004	WV	Pleasants Power Station	2	SCR	2003	190.6732%	-69.4111%

VII. Modeling Results

In Figure D4.A is a difference plot of scenario 4-126-1 (2015 EGUs emissions) and scenario 4-126-2 (optimized EGUs emissions) and it demonstrates the impact of non-optimized power plant controls. Much of Maryland would have seen as much as an approximately 2.5 ppb reduction in ozone concentrations on 29 July if the 36 126 petition EGUs had run their SCR/SNCR controls at optimized rates July 29th.

In Figure D4.B is a difference plot of scenario 4-126-1 (2015 EGU emissions) and scenario 4-126-2 (optimized EGU emissions) and it demonstrates parts of Maryland would have seen as much as a 5 ppb reduction in ozone concentrations on 30 July if all 36 EGU units had run their SCR/SNCR controls at optimized rates.

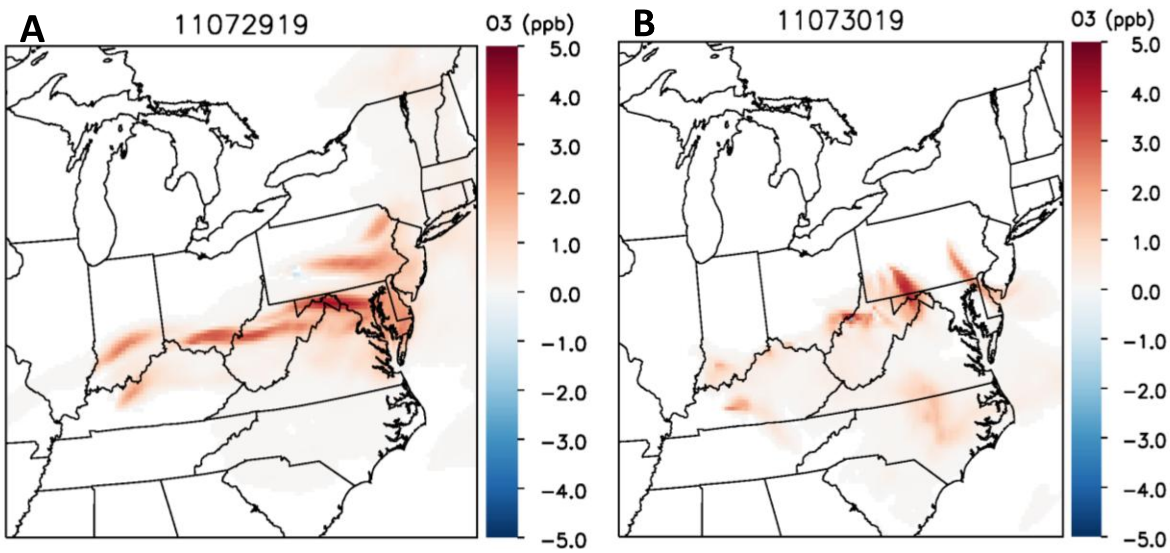


Figure D4. Difference Plot of Scenarios S4-126-1 and S4-126-2 on **A)** July 29th and **B)** July 30th

Based on the July modeling analysis of the 36 EGUs running their SCR/SNCR controls Maryland would have seen an ozone reduction of approximately 1 – 6 ppbv across the state. The maximum ozone reduction results for each Maryland monitor is in Table D3.

Table D3. Maximum Ozone Reduction (ppbv) in July if the 36 EGU units had run their SCR/SNCR Controls

Maryland Monitor	**Max Ozone Reduction if 126 Petition Power Plants had Run Their SCR/SNCR Controls (ppb)**
Davidsonville	2.22
Padonia	2.32
Essex	1.79
Calvert	2.55
South Carroll	2.95
Fairhill	1.85
Southern Maryland	2.60
Blackwater NWR	2.25
Frederick Airport	3.05
Piney Run	6.06
Edgewood	1.66
Aldino	1.80
Millington	1.79
Rockville	2.23
HU-Beltsville	2.24
PG Equest Center	2.50
Beltsville	2.20
Hagerstown	2.96
Furley	1.73

Design values for 2018 have been calculated for monitors in Maryland and key sites outside of Maryland following the EPA guidance with one caveat. Normally, the top 10 days above the ozone standard are used in the calculation of relative reduction factors at surface monitoring sites. However, requiring 10 days above a standard is too restrictive when evaluating one month simulations so this has been relaxed to a required 6 days above the standard. Table D4 shows the 2011 observed design values, the 2018 base model, Scenarios S4-126-1 and S4-126-2 design values for Maryland monitors. Similarly, table D5 shows design values for monitors outside of Maryland.

Table D4. Design Values for Maryland monitors. Calculations of 2018 design values are based on CMAQ output for July 2011.

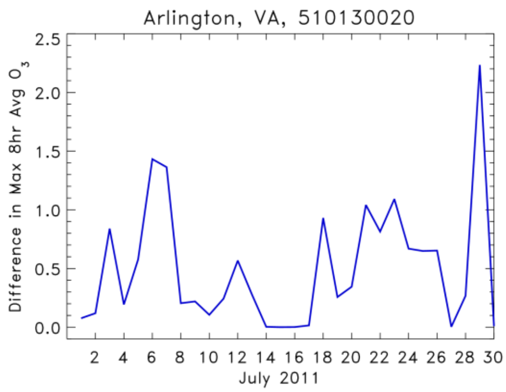
Site	DV 2011	DV 2018	2018 126-1	2018 126-2
Davidsonville	83	74.3	74.7	74.0
Padonia	79	72.3	72.7	71.8
Essex	80.7	73.5	73.7	73.2
Calvert	79.7	74.0	74.4	73.7
South Carroll	76.3	70.3	71.0	69.7
Fair Hill	83	76.8	77.3	76.3
S.Maryland	79	72.3	72.8	71.9
Blackwater	**75**	69.2	69.6	68.9
Frederick Airport	76.3	70.1	70.8	69.4
Piney Run	72	62.9	64.0	62.1
Edgewood	90	83.3	83.5	82.9
Aldino	79.3	72.8	73.1	72.4
Millington	78.7	72.7	73.1	72.3
Rockville	**75.7**	67.5	68.0	67.1
HU-Beltsville	79	69.7	70.1	69.4
PG Equest.	82.3	73.7	74.1	73.3
Beltsville	80	71.5	71.9	71.1
Hagerstown	72.7	66.0	66.6	65.3
Furley	73.7	66.8	67.0	66.5

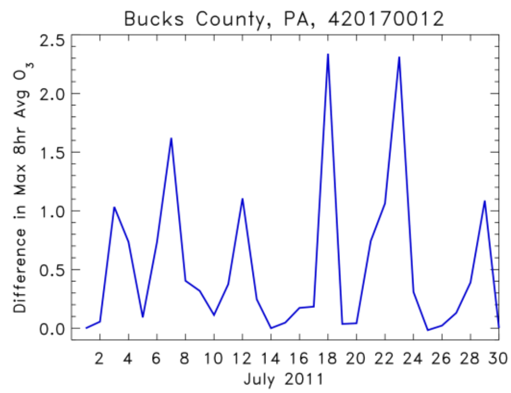
Table D5. Design Values for monitors outside of Maryland. Calculations of 2018 design values are based on CMAQ output for July 2011.

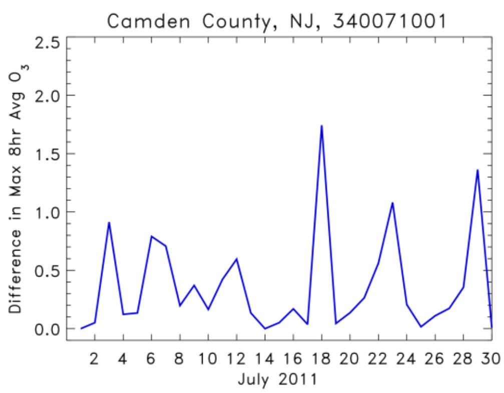
County, State	AQS #	DV 2011	DV 2018	2018 126-1	2018 126-2
Attainment Problems – 2018					
Harford, MD	240251001	90.0	83.3	83.5	82.9
Fairfield, CT	090013007	84.3	75.9	76.1	75.8
Fairfield, CT	090019003	83.7	77.7	77.8	77.6
Suffolk, NY	361030002	83.3	74.4	74.5	74.3
Maintenance Problems - 2018					
Fairfield, CT	090010017	80.3	72.0	72.0	71.9
New Haven, CT	090099002	85.7	76.9	76.9	76.9
Camden, NJ	340071001	82.7	75.0	75.4	74.6
Gloucester, NJ	340150002	84.3	77.3	77.8	76.9
Richmond, NY	360850067	81.3	76.6	76.7	76.3
Philadelphia, PA	421010024	83.3	75.8	76.3	75.2

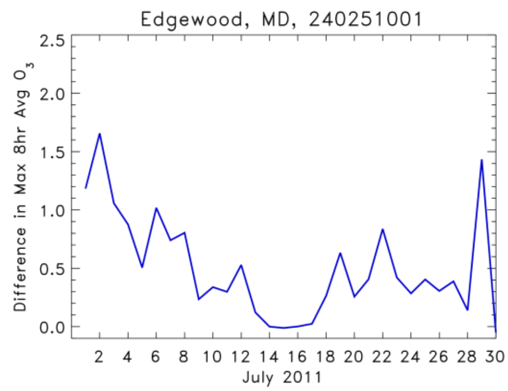
Table D4 shows that surface monitors could expect up to 2 ppb reduction in the 2018 design values if optimized controls were utilized by upwind power plants. Similar results, though not as large, would be expected for some sites outside of the Maryland area though the complicated chemistry around monitors near the Long Island Sound may mitigate this improvement.

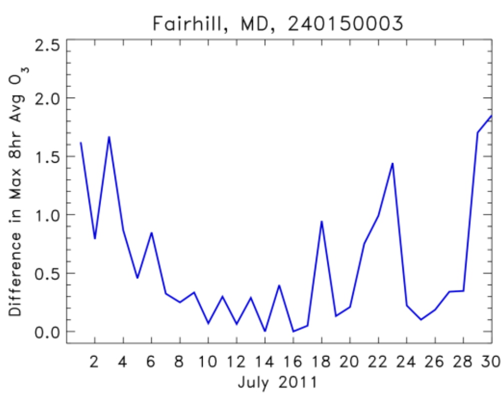
Design values indicate the “average” expected change in ozone on the most polluted days. While useful, this calculate does not indicate day-to-day changes. The panels of figure D5 present time series of the differences in daily maximum 8hr ozone between Scenarios S4-126-1 and S4-126-2 for July 2011. Expected decreases in surface ozone if upwind power plants run optimized controls are very dependent upon prevailing daily meteorology as can also be seen in Figure D4.

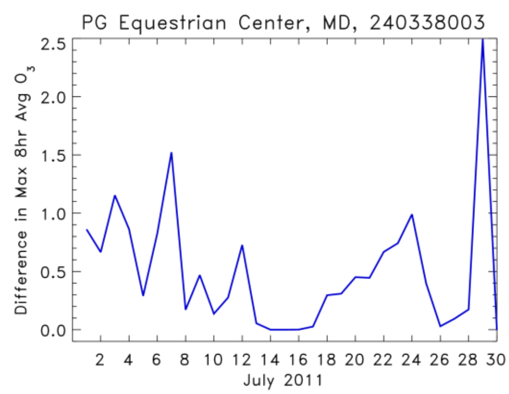












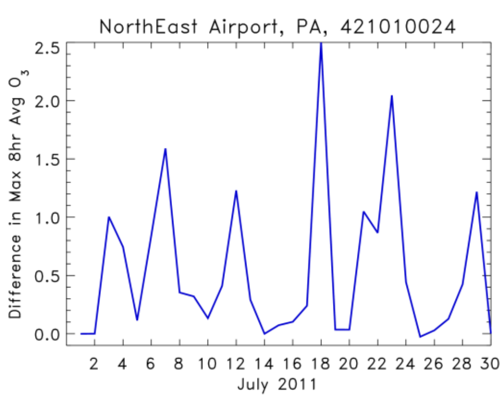


Figure D5. Differences in daily maximum average 8-hour ozone between scenarios S4-126-1 and S4-126-2 at various surface monitors.

VIII. Conclusion

Based on extensive evidence including photochemical modeling of 36 EGUs in the five states of IN, KY, OH, PA and WV, emissions from these 36 units significantly contribute to ozone formation in MD and interfere with the maintenance and contribute to nonattainment of the 8-hour ozone NAAQS. Based on this modeling analysis EPA should immediately and quickly take action to require the 36 EGUs to run their existing control equipment in an optimal manner during the ozone season.

IX. References

A. EPA documents

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Part II – Sonoma Technology Incorporated Modeling

Analysis conducted by Sonoma Technology to support Connecticut's recent Section 126 Petition was also used to supplement the University of Maryland modeling described in Part 1 of this Appendix. The Sonoma Technology modeling for Connecticut also included analysis for 10 of the 19 plants where the 36 EGUs targeted in the Maryland Section 126 petition ort the Maryland Section 126 petition.

The technical support documents for the Sonoma Technology modeling from the Connecticut Section 126 petition are provided below.

Sonoma Technology, Inc.
Environmental Science and Innovative Solutions

Technical Memorandum

August 6, 2015 STI-915046-6329

To: Zachary Fabish, Josh Berman, and Josh Stebbins, Sierra Club

From: Kenneth J. Craig and Stephen B. Reid

Re: **Ozone Impacts from Brunner Island Power Plant in 2011**

Executive Summary

Sonoma Technology, Inc. (STI) performed source apportionment modeling to analyze impacts of emissions from the Brunner Island power plant in York County, Pennsylvania, in 2011 on air quality in Pennsylvania and neighboring states. The results of this analysis showed that emissions from Brunner Island contribute significantly to ozone formation in Pennsylvania during the modeled ozone season. Modeled 8-hr ozone impacts were as large as about 10 ppb in Pennsylvania. In addition, impacts considered significant (>1% of the current ozone National Ambient Air Quality Standards [NAAQS]) were modeled on as many as 50 days at a single Pennsylvania monitor during the single ozone season. Significant ozone impacts were modeled at one or more Pennsylvania monitors on 66% (100 out of 152) of modeled days during the entire ozone season, and almost every day (86%) during June, July, and August. Peak modeled 8-hr ozone impacts from Brunner Island, depicted in **Figure 1**, show large impacts in southeastern Pennsylvania near Brunner Island (star). Significant ozone impacts occur in several states from North Carolina to the Canadian border.

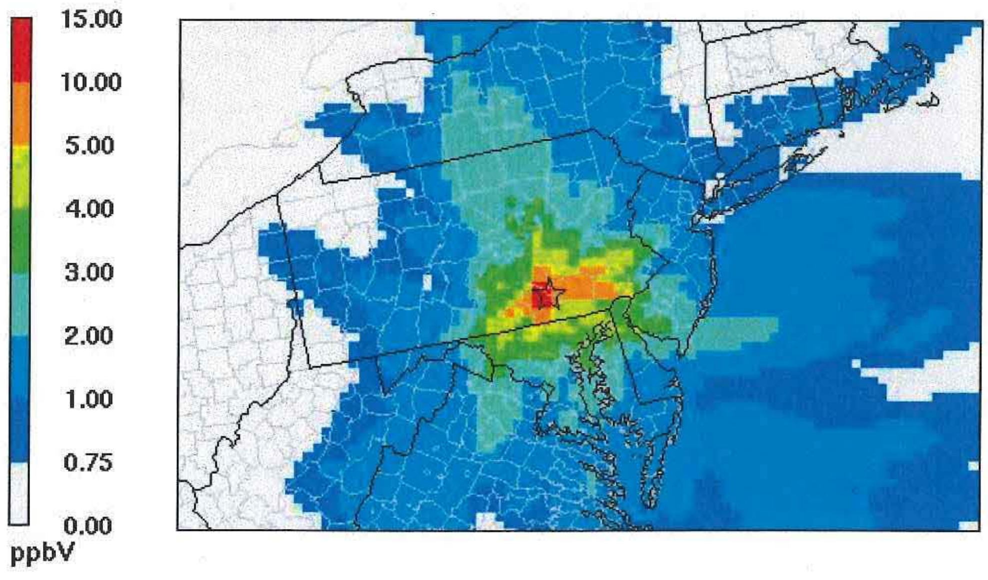

Figure 1. Peak modeled 8-hr ozone impacts from Brunner Island power plant.

Introduction

STI performed source apportionment modeling using the Comprehensive Air Quality Model with Extensions (CAMx) with Ozone Source Apportionment Technology (OSAT) to support the Sierra Club and state air agencies to evaluate ozone impacts from coal-fired power plants and other emission sources on downwind receptors in non-attainment areas. The source apportionment modeling was conducted for the 2011 ozone season (May to September) for a domain covering the continental United States at 12-km spatial resolution (**Figure 2**), and results were compiled into a series of databases that can be used for future data mining and analysis. Additional details on the models, data, and methods used can be found in **Appendix A**.

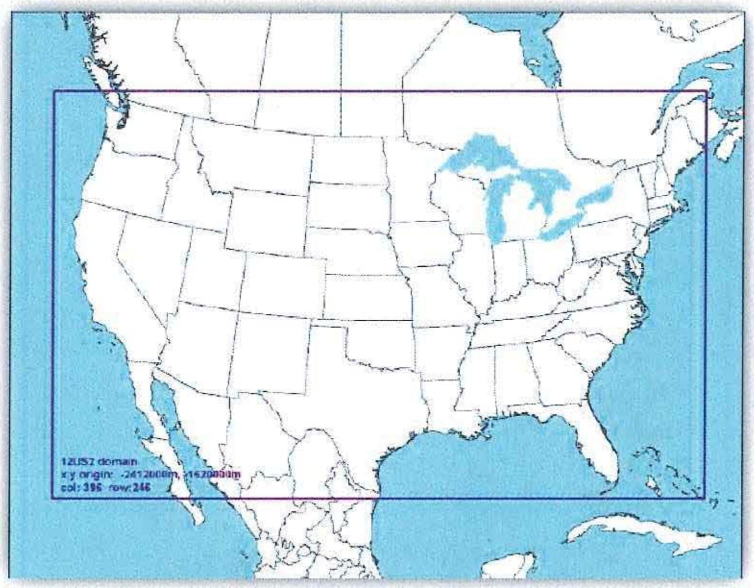

Figure 2. Modeling domain for the source apportionment model simulations. Source: U.S. Environmental Protection Agency (2015).

STI used the results from this source apportionment modeling to analyze impacts of emissions from the Brunner Island power plant (Brunner Island) in York County on air quality monitor locations in Pennsylvania and neighboring states. In summary, the modeling results showed that emissions from Brunner Island contribute significantly to ozone formation downwind in Pennsylvania during the 2011 ozone season. Modeled daily 8-hr average ozone impacts were as large as 10.58 ppb at Pennsylvania monitors, and were significant (>0.75 ppb) on as many as 50 days at a single Pennsylvania monitor. Significant ozone impacts were modeled at one or more Pennsylvania monitors on 66% of modeled days (100 out of 152) during the ozone season, where 86% (79 of 92) of those days occurred during the June–August summer season. On several days during the ozone season, significant ozone contributions from Brunner Island coincided with days when monitored ozone concentrations exceeded the current ozone National Ambient Air Quality Standards (NAAQS) (75 ppb).

Brunner Island Ozone Contributions in Pennsylvania

Brunner Island is a coal-fired electrical generating facility along the Susquehanna River in York County. The plant has three major boiler units, built in the 1960s, with approximately 1,500+ Megawatts of capacity.[1] In 2011, the total NO_x emissions from Brunner Island were about 16,800 tons, making Brunner Island the fourth highest NO_x emitter of all tagged power plants in the source apportionment modeling.

Figure 3 shows a map of Brunner Island's location (orange star), and nearby ozone monitoring stations (blue dots). The Sipe Avenue ozone monitoring station in the Harrisburg area is about 12 miles north of Brunner Island, while the Little Buffalo State Park (Little Buffalo SP) ozone monitor is further to the northwest, about 35 miles from Brunner Island. To the east in the Lancaster area, the Abraham Lincoln Junior High and Newport Road ozone monitoring stations are 22 and 31 miles from the Brunner Island, respectively. The Hill Street ozone monitor in York County is the nearest monitor to Brunner Island, about 9 miles south of the facility.

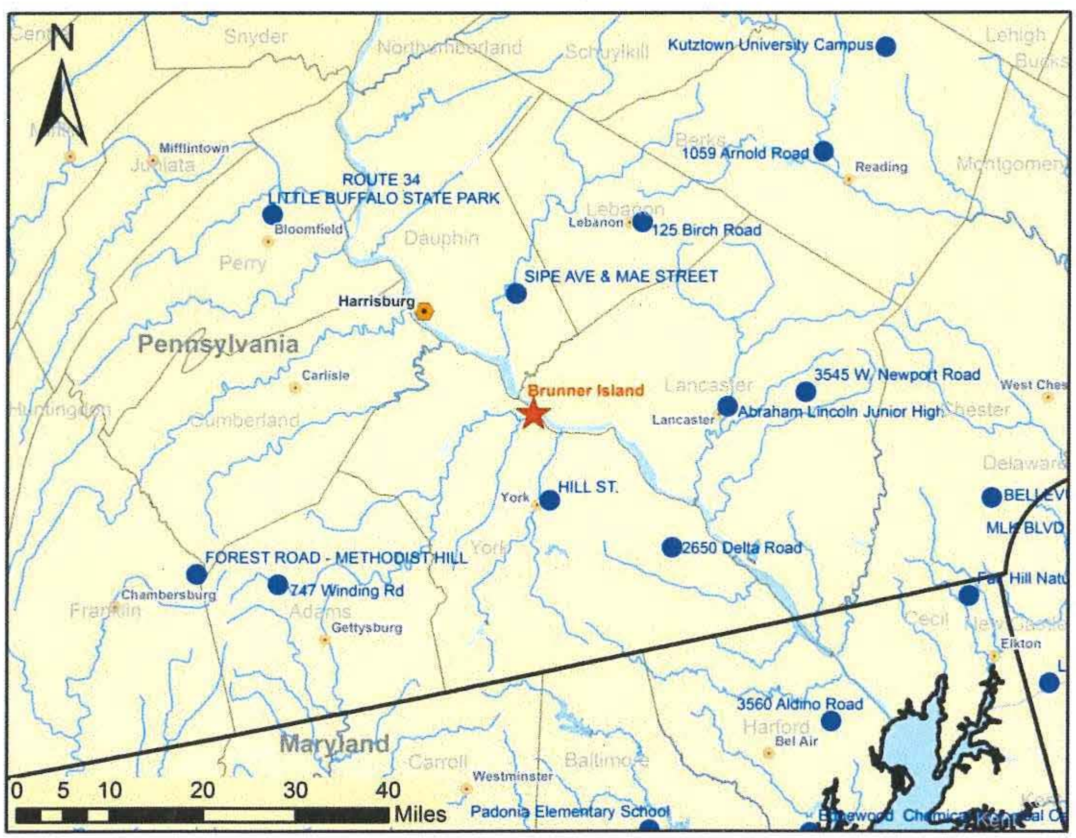

Figure 3. The Brunner Island power plant in York County and nearby air quality monitoring sites.

[1] http://www.sourcewatch.org/index.php/Brunner_Island_Power_Station

For this analysis, modeled 8-hr ozone impacts greater than 1% of the NAAQS are considered significant. For the current ozone NAAQS, this significance threshold is 0.75 ppb. This type of significance threshold is consistent with how the U.S. Environmental Protection Agency (EPA) has previously defined significant interstate contributions for ozone and $PM_{2.5}$.[2]

Starting with results at monitors relatively close to Brunner Island, for example, Figure 4 shows a time-series plot of the daily modeled 8-hr average ozone impacts from Brunner Island at two air quality monitoring sites near Harrisburg, Pennsylvania. The Sipe Avenue monitor (blue line) is closer to Brunner Island than Little Buffalo SP (red line); as a result, the modeled impacts were larger at Sipe Avenue on most days. Modeled impacts were significant (>0.75 ppb) on 34 days (22% of days modeled) at Sipe Avenue and on 12 days (8% of days modeled) at Little Buffalo SP, and exceeded 2 ppb on 14 days at Sipe Avenue and 2 days at Little Buffalo SP. The peak modeled ozone impacts were 6.70 ppb and 3.15 ppb at Sipe Avenue and Little Buffalo SP, respectively. The Harrisburg monitors are most impacted by Brunner Island emissions when winds are blowing from the south or southeast directions.

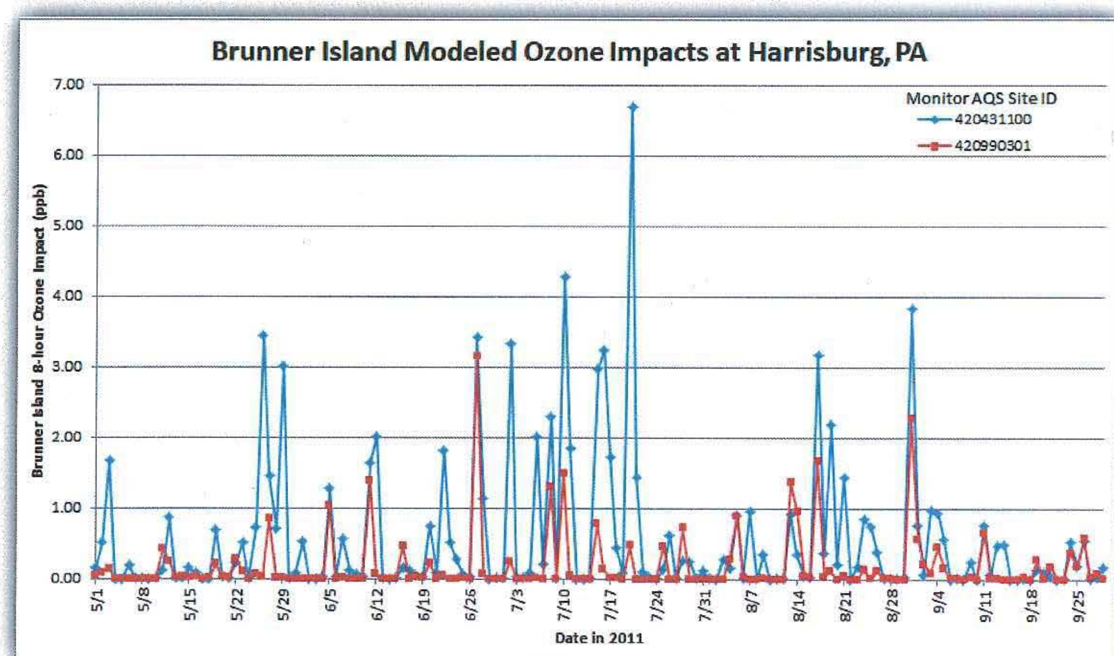

Figure 4. Time series of modeled daily 8-hr ozone impacts from Brunner Island at air quality monitors near Harrisburg.

[2] See 75 Federal Register (August 2, 2010) and 76 Federal Register (August 8, 2011), 40 CFR Parts 51, 52, 72, 78, and 97.

Figure 5 shows a time-series plot of the daily modeled 8-hr average ozone impacts from Brunner Island at two air quality monitoring sites near Lancaster, Pennsylvania. The monitoring site at Abraham Lincoln Junior High (blue line) is about 9 miles closer to Brunner Island than the Newport Road monitor (red line). As a result, the modeled impacts were generally larger at Abraham Lincoln Junior High than at Newport Road, although the reverse was true on a few days. Modeled impacts were significant on 36 days (24% of days modeled) at Abraham Lincoln Junior High, and 31 days (20% of days modeled) at Newport Road. Impacts exceeded 2 ppb on 19 days at Abraham Lincoln Junior High and 13 days at the Newport Road monitor. The peak modeled ozone impacts were 5.56 ppb and 5.17 ppb at Abraham Lincoln Junior High and Newport Road, respectively. The Lancaster monitors are most impacted by Brunner Island emissions when winds are blowing from the west.

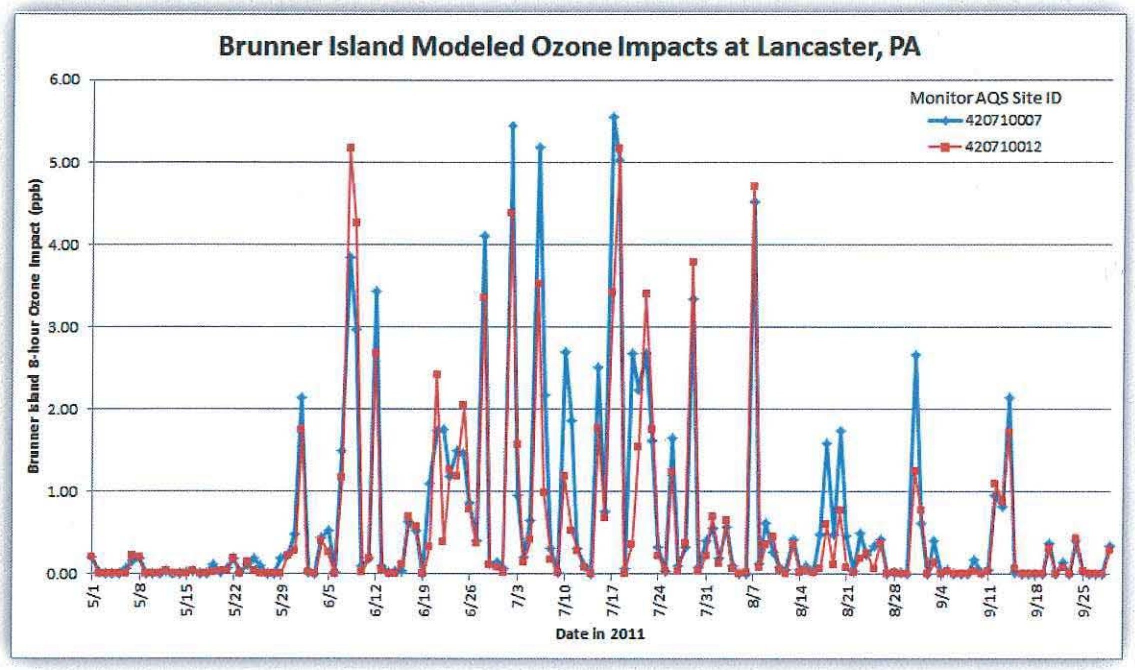

Figure 5. Time series of modeled 8-hour average ozone impacts from Brunner Island at air quality monitors in Lancaster.

Brunner Island ozone impacts from the CAMx OSAT modeling were analyzed at 53 air quality monitoring sites throughout Pennsylvania, including the four sites discussed above. Table 1 shows the highest significant (>0.75 ppb) modeled ozone contributions for the 2011 ozone season, as well as the number of days with significant modeled ozone impacts. The largest overall modeled ozone impact was 10.58 ppb at Hill Street in York, which is the closest monitor to Brunner Island. Significant impacts occurred on 33% (50 out of 152) of modeled days at that site. A significant contribution was modeled at least once during the ozone season at 75% (40 of 53) of Pennsylvania monitoring sites.

The largest impacts generally occurred at monitors closest to Brunner Island, particularly those in southeast Pennsylvania. However, monitors throughout Pennsylvania, including those in Pittsburgh and in counties bordering Ohio, were also significantly impacted on at least one day during the 2011 ozone season. The OSAT modeling predicted significant impacts from Brunner Island on multiple days as far away as Indiana, Pennsylvania (135 miles). Significant ozone impacts from Brunner Island were modeled at one or more Pennsylvania monitors on 66% of modeled days (100 out of 152) during the 2011 ozone season, and 86% (79 of 92) of days during June through August summer season.

The electronic attachment provided with this memorandum includes a full listing of days and monitors in Pennsylvania when modeled The 8-hr ozone impacts were greater than 1% of the ozone NAAQS.

Table 1. Peak modeled 8-hr average ozone impacts and number of days with significant (>0.75 ppb) modeled 8-hr average ozone impacts at Pennsylvania monitors due to Brunner Island emissions during the 2011 ozone season, ranked by peak modeled impact. Only monitors with a significant modeled impact are shown.

AQS Site ID	Monitor County	Core Based Statistical Area	Maximum Modeled Contribution (ppb)	Number of Significant Impact Days
421330008	York	York-Hanover, PA	10.58	50
420431100	Dauphin	Harrisburg-Carlisle, PA	6.70	31
420710007	Lancaster	Lancaster, PA	5.56	36
420710012	Lancaster	Lancaster, PA	5.17	31
420019991	Adams	Gettysburg, PA	5.01	14
420750100	Lebanon	Lebanon, PA	4.78	33
421330011	York	York-Hanover, PA	4.65	48
420110011	Berks	Reading, PA	3.93	22
420290100	Chester	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	3.85	26
420550001	Franklin	Chambersburg, PA	3.85	7
420450002	Delaware	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	3.74	14

AQS Site ID	Monitor County	Core Based Statistical Area	Maximum Modeled Contribution (ppb)	Number of Significant Impact Days
420910013	Montgomery	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	3.36	16
420990301	Perry	Harrisburg-Carlisle, PA	3.15	12
420810100	Lycoming	Williamsport, PA	2.82	9
420950025	Northampton	Allentown-Bethlehem-Easton, PA-NJ	2.46	12
420110006	Berks	Reading, PA	2.36	21
421010004	Philadelphia	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	2.25	8
421010048	Philadelphia	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	2.25	8
420770004	Lehigh	Allentown-Bethlehem-Easton, PA-NJ	1.99	13
421174000	Tioga	N/A	1.88	7
420958000	Northampton	Allentown-Bethlehem-Easton, PA-NJ	1.76	10
421011002	Philadelphia	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	1.75	10
421010024	Philadelphia	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	1.75	10
420690101	Lackawanna	Scranton--Wilkes-Barre, PA	1.62	8
420692006	Lackawanna	Scranton--Wilkes-Barre, PA	1.60	8
420279991	Centre	State College, PA	1.45	3
420170012	Bucks	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	1.41	9
420270100	Centre	State College, PA	1.40	3
420630004	Indiana	Indiana, PA	1.08	4
420210011	Cambria	Johnstown, PA	1.02	3
421290008	Westmoreland	Pittsburgh, PA	0.94	1
421290006	Westmoreland	Pittsburgh, PA	0.90	1
420730015	Lawrence	New Castle, PA	0.89	1
420850100	Mercer	Youngstown-Warren-Boardman, OH-PA	0.87	1
420031005	Allegheny	Pittsburgh, PA	0.85	1
420031008	Allegheny	Harrison Township	0.85	1
420070014	Beaver	Pittsburgh, PA	0.81	1
420030008	Allegheny	Pittsburgh, PA	0.77	1
420030010	Allegheny	Pittsburgh, PA	0.77	1

To illustrate how emissions from Brunner Island contribute to ozone concentrations throughout the region, **Figure 6** shows a spatial plot of maximum modeled 8-hr ozone impacts from Brunner Island on July 20, 2011.[3] This day had the highest modeled ozone impact at monitors in Pennsylvania (10.58 ppb at York). Significant ozone impacts (>0.75 ppb) on this day extend from Scranton, Pennsylvania, to Washington, D.C. A wind shift that occurred on July 20 caused ozone contributions to extend in two different directions from Brunner Island on that day.

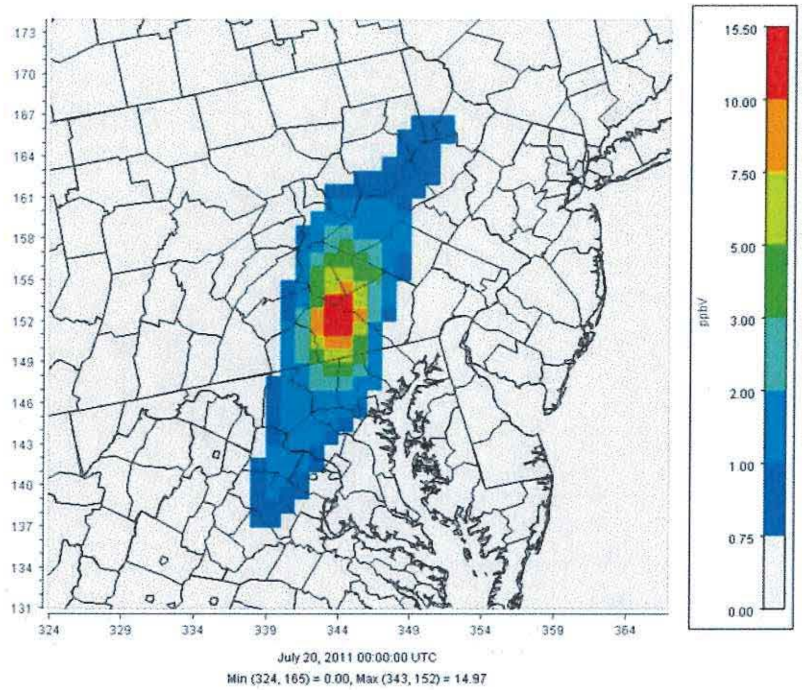

Figure 6. Spatial plot of maximum modeled 8-hr average ozone contribution from Brunner Island on July 20, 2011.

[3] This figure shows the *maximum* modeled 8-hr ozone contributions from Brunner Island, which were computed without regard to the time period when the maximum modeled 8-hr average ozone concentrations occurred. Therefore, the data represented in this figure may differ slightly from the corresponding data found in the Access databases provided to the Sierra Club.

We also analyzed days during the 2011 ozone season when significant (>0.75 ppb) modeled ozone impacts from Brunner Island coincided with days when the monitored maximum 8-hr average ozone concentration exceeded the current ozone NAAQS (>75 ppb). Figures 7 and 8 show these occurrences with incremental monitored concentrations above the current 8-hr ozone NAAQS at ozone monitors in Harrisburg and Lancaster, respectively. For example, at the Sipe Avenue monitor in Harrisburg on July 20 (Figure 7), the observed maximum 8-hr ozone concentration of 81 ppb exceeded the current ozone NAAQS by 6 ppb. The modeled 8-hr ozone impact from Brunner Island on this day was 6.70 ppb.

At the Sipe Avenue monitor in Harrisburg (Figure 7), significant modeled impacts from Brunner Island coincided with monitored NAAQS exceedances three times during the 2011 ozone season. On those days, monitored ozone concentrations ranged from 5 to 10 ppb over the NAAQS, and modeled ozone contributions from Brunner Island ranged from 1.44 to 6.70 ppb. In Lancaster (Figure 8), modeled impacts from Brunner Island were significant at the Abraham Lincoln Junior High monitor (blue bars) on five days, and the Newport Avenue monitor (red bars) on six days, when the NAAQS was exceeded at these monitors. On those days, monitored ozone concentrations exceeded the NAAQS by 1 to 15 ppb, and modeled ozone contributions from Brunner Island ranged from 1.00 to 5.45 ppb. The electronic attachment provided with this memorandum includes a full listing of days and monitors in Pennsylvania for which modeled 8-hr ozone impacts coincided with days when monitored ozone concentrations exceeded the current ozone NAAQS.

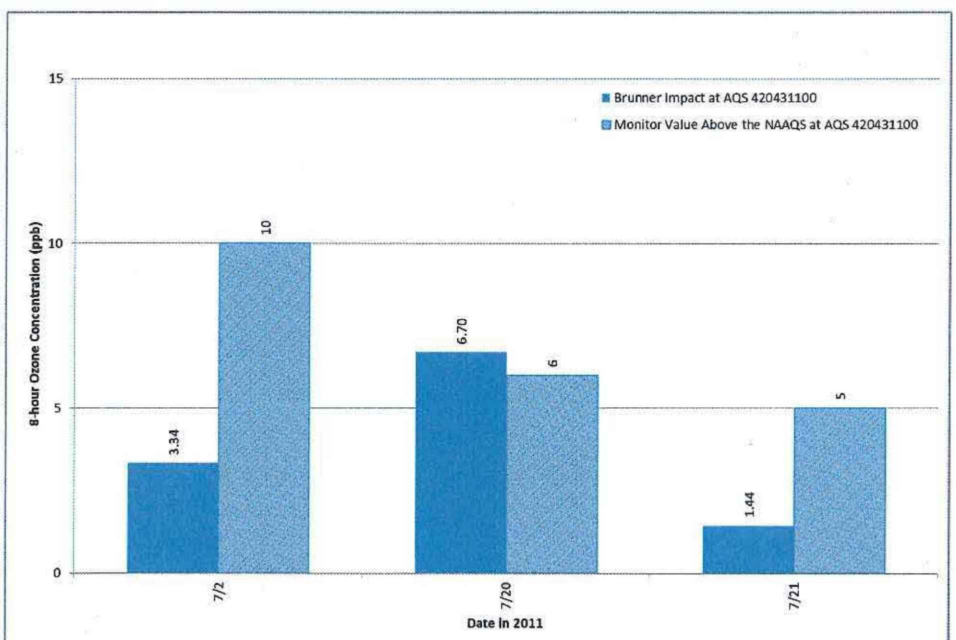

Figure 7. Modeled 8-hr ozone impacts from Brunner Island exceeding 1% of the ozone NAAQS, and incremental monitored ozone concentrations above the ozone NAAQS on days when the NAAQS was exceeded at the Sipe Avenue ozone monitor near Harrisburg.

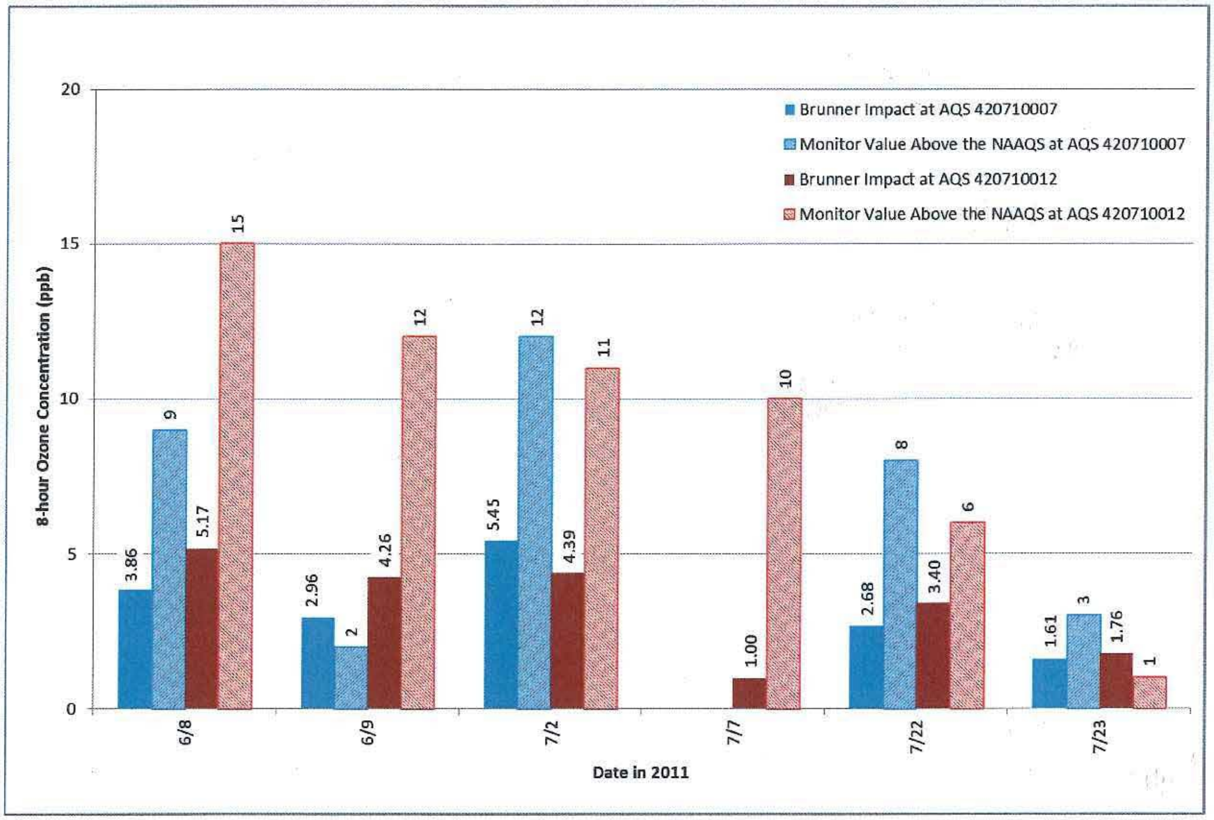

Figure 8. Modeled 8-hr ozone impacts from Brunner Island exceeding 1% of the ozone NAAQS, and incremental monitored ozone concentrations above the ozone NAAQS on days when the NAAQS was exceeded at air quality monitors near Lancaster.

Brunner Island Ozone Contributions on Neighboring States

In addition to analyzing the modeled ozone contributions due to Brunner Island emissions at receptors within Pennsylvania, we also analyzed contributions at air quality monitors in five neighboring downwind states: New York, New Jersey, Delaware, Maryland, and Connecticut.

Table 2 summarizes the number of times during the 2011 ozone season in which Brunner Island was a significant contributor to the total 8-hr ozone concentration at air quality monitors in each state. The table also includes the peak modeled contributions at monitors in each state, as well as the average and 75th percentile of *significant* modeled ozone contributions from Brunner Island at monitors in each state.

The electronic attachment provided with this memorandum includes a full listing of days when modeled ozone contributions from Brunner Island exceeded 1% of the ozone NAAQS (0.75 ppb) at monitors in all six states (PA, CT, DE, MD, NJ, and NY), along with the matching *monitored* maximum 8-hr ozone concentration on those days. Coincident occurrences of significant modeled ozone contributions from Brunner Island and high (>75 ppb) monitored maximum 8-hr average ozone concentrations at a monitor are highlighted and color-coded to indicate the attainment status of the monitor with respect to the 1997 and 2008 ozone NAAQS. The table is grouped by state (Pennsylvania first), and then sorted by the highest to lowest significant 8-hr ozone contribution from Brunner Island.

Table 2. Summary of significant (>0.75 ppb) modeled 8-hr ozone contributions from Brunner Island at monitoring stations in Pennsylvania and neighboring states. A "monitor-day" refers to one occurrence of a significant ozone contribution at one monitor. Peak modeled contributions at ozone monitors in each state, as well as the average and 75th percentile of significant contributions in each state, are also included.

State	Monitors with Significant Ozone Contributions	Maximum Number of Days any One Monitor had a Significant Ozone Contribution	Monitor-Days with Significant Ozone Contributions	Peak Ozone Contribution (ppb)	Average of Significant Ozone Contributions (ppb)	75th Percentile of Significant Ozone Contributions (ppb)
Pennsylvania	40	50	495	10.58	1.63	2.23
Connecticut	6	2	8	0.93	0.85	0.89
Delaware	7	28	118	4.83	1.69	2.10
Maryland	20	35	336	4.06	1.56	1.97
New Jersey	17	15	133	3.12	1.29	1.47
New York	16	6	45	2.31	1.00	1.02

Appendix A. Modeling Methods

Photochemical Grid Model and Source Apportionment

To quantify the ozone impacts due to precursor emissions from individual power plants and other source groups, STI performed CAMx OSAT source apportionment model simulations for the 2011 ozone season (May to September). The modeling domain and configurations used were based on those developed by EPA in recent ozone transport assessments using CAMx OSAT (U.S. Environmental Protection Agency, 2014a), and included the use of the carbon-bond 6 revision 2 gas phase chemistry mechanism.

The Comprehensive Air Quality Model with Extensions (CAMx version 6.1) (ENVIRON International Corporation, 2014) is a publically available, peer-reviewed, state-of-the-science three-dimensional grid-based (Eulerian) photochemical air quality model designed to simulate the emission, transport, diffusion, chemical transformation, and removal of gaseous and particle pollutants in the atmosphere over spatial scales ranging from continental to urban. CAMx was designed to approach air quality as a whole by including capabilities for modeling multiple air quality issues, including tropospheric ozone, fine particles, visibility degradation, acid deposition, air toxics, and mercury. The ability of photochemical grid models such as CAMx to treat a large number of sources and their chemical interactions makes them well suited for assessing the impacts of natural and anthropogenic emissions sources on air quality. CAMx is widely used to support regulatory air quality assessments and air quality management policy decisions in the United States In recent years, the EPA has used CAMx to support the NAAQS designation process (U.S. Environmental Protection Agency, 2014a) and evaluate interstate pollutant transport (U.S. Environmental Protection Agency, 2005).

CAMx also includes Ozone Source Apportionment Technology (OSAT), which can be used to estimate the contributions of individual sources, groups of sources, or source regions to ozone concentrations at a given receptor location (Yarwood et al., 1996). Source apportionment modeling is useful for understanding model performance, designing emission control strategies, and performing culpability assessments to identify emission sources that contribute significantly to pollution (ENVIRON International Corporation, 2010). The key precursor species for ozone production are volatile organic compounds (VOC) and oxides of nitrogen (NO_x). OSAT uses reactive tracers to track the fate of these precursor emissions and the ozone formation resulting from them within a CAMx simulation. The ozone and precursors are tracked and apportioned by OSAT without perturbing the host model chemistry; therefore the OSAT results are fully consistent with the host model results for total concentrations. OSAT can efficiently estimate source contributions from multiple emission sources within a single model simulation. Importantly, while source apportionment modeling can be used to estimate source contributions to ozone concentrations for a given set of emission inputs, sensitivity modeling approaches such as brute-force modeling[4] or the direct decoupled method (DDM)[5] are

[4] The brute-force modeling method involves running the model both with and without emission controls applied to the source(s) of interest. The difference in pollutant concentrations between the two simulations yields the impact of the emission control scenario.
[5] DDM provides sensitivity coefficients that relate emissions changes to model outcomes. These sensitivity coefficients can be used to evaluate how pollutant concentrations would respond to a range of changes in emissions from a source or group of sources.

needed to quantify the effect of a given emission control scenario (e.g., 90% NO_x reduction at power plants) on ozone concentrations.

In this work, the Anthropogenic Precursor Culpability Assessment (APCA) extension of OSAT was used. APCA is based on OSAT, but calculates source contributions a little differently to recognize the fact that biogenic (or non-anthropogenic) emissions are not controllable. For example, when ozone is formed by reactions between biogenic VOC and anthropogenic NO_x, APCA apportions the ozone contribution entirely to the anthropogenic source. APCA only apportions ozone contributions to biogenic sources when both the VOC and NO_x precursors are from biogenic sources. APCA is useful for determining which source controls might have the greatest effect at reducing ozone concentrations.

2011 EPA Modeling Platform

The CAMx OSAT simulations were based on EPA's 2011 modeling platform. A modeling platform consists of a structured system of connected data and models that provide a consistent and transparent basis for assessing the air quality impact of anticipated changes in emissions. EPA develops and evaluates a new modeling platform each time the National Emissions Inventory (NEI) is updated (every three years). EPA has used the 2011 modeling platform to support development of revised ozone NAAQS (U.S. Environmental Protection Agency, 2014a) and to quantify future-year interstate contributions to ozone concentrations to help states address their obligations under the "Good Neighbor" provision of the Clean Air Act for the 2008 ozone NAAQS (U.S. Environmental Protection Agency, 2015).

The CAMx OSAT simulations relied on EPA's 2011v6.1 modeling platform, which was based on the 2011 NEI, Version 1 (2011NEIv1). The NEI is compiled by EPA on a triennial basis, primarily from data submitted by state, local, and tribal air agencies, and the 2011 NEI includes emissions from five source sectors: point sources, nonpoint (or area) sources, onroad mobile sources, nonroad mobile sources, and fire events.

For air quality modeling purposes, the 2011 NEI data was augmented by EPA to include biogenic emissions and data from Canadian and Mexican emissions inventories. In addition, the annualized point source data for electrical generating units (EGUs) in the 2011 NEI were replaced with hourly 2011 continuous emissions monitoring (CEMS) data for SO_2 and NO_x. Annual emissions for pollutants were converted to an hourly basis using CEMS input data (U.S. Environmental Protection Agency, 2011).

Source Apportionment Tagging

After obtaining the 2011 modeling platform from EPA, STI worked with the Sierra Club and state air agencies in Connecticut, Delaware, and Maryland to identify sources and source groups to be tagged for ozone attribution analysis. Tagged sources fell into one of the following general categories:

- Individual coal-fired power plants (in some cases, specific coal-fired EGUs within a single facility were tagged separately);
- Groups of coal-fired power plants within a state or sub-state region (e.g., downstate New York);
- Groups of other (non-EGU) point sources within a state or sub-state region; and
- Non-point source sectors (e.g., biogenic sources and onroad mobile sources) within a state, sub-state, or multi-state region (e.g., states in the Southeast States Air Resources Managers [SESARM] consortium).

A total of 52 EGUs were individually tagged, while several dozen additional EGUs were tagged within 61 state and sub-state regions. Point sources that were tagged individually were not included in any of the state- or sub-state-level tag groups. In addition, each non-point source sector was tagged within 15 state, sub-state, or multi-state regions. Because of the large number of tags modeled, the processing was divided in to three separate CAMx OSAT simulations. Brunner Island is represented by source tag I7 in Simulation 1. More detailed information on sources tagged in the CAMx OSAT simulations is provided in **Appendix B**.

Meteorology

Meteorological inputs for the CAMx-OSAT simulations were developed by EPA for the 2011 modeling platform using version 3.4 of the Weather Research and Forecasting (WRF) numerical weather prediction model (Skamarock et al., 2008). The meteorological outputs from WRF include hourly varying winds, temperature, moisture, vertical diffusion rates, clouds, and rainfall rates. Additional details about this WRF simulation and its performance evaluation can be found in U.S. Environmental Protection Agency (2014b).

Initial and Boundary Conditions

Initial and lateral boundary conditions were developed from three-dimensional global atmospheric chemistry simulations with GEOS-Chem standard version 8-03-02 with 8-02-01 chemistry (http://geos-chem.org) provided with the EPA 2011 platform. The GEOS-Chem predictions were translated into CAMx-ready initial and boundary conditions using code and procedures developed by Henderson et al. (2014), and modifications provided to STI by the Lake Michigan Air Directors Consortium (LADCO) to accommodate carbon-bond 6 chemistry species. OSAT tracks ozone transported through the boundaries, as well as ozone formation resulting from precursor emissions transported through the boundaries.

Post-Processing

The raw result from a CAMx OSAT simulation is hourly ozone contributions from each source tag at each grid cell in the modeling domain for the 2011 ozone season. These hourly contributions were extracted and post-processed for several hundred receptor sites, listed in the electronic attachment provided with this memorandum. The receptors correspond to quality monitoring sites across the eastern half of the United States, and include sites of specific interest to northeastern states, as well as monitors with current ozone design values exceeding 65 ppb. At each receptor and for each day, the 8-hr average ozone contribution was calculated for all source tags using the averaging period corresponding to the period of highest modeled 8-hr average concentration at the receptor location. Although this analysis approach may not capture the largest ozone contributions modeled during the day, it does reflect contributions during time periods when ozone concentrations are highest. This analysis approach also ensures that ozone contributions from all source tags[6] sum to total modeled 8-hr ozone concentration each day. The post-processed OSAT results were compiled into Microsoft Access databases to facilitate future data mining and analysis.

Model Performance Evaluation

EPA evaluated its 2011 modeling platform using statistical assessments of model predictions versus observations paired in time and space. Overall, the model performance statistics for ozone were within or close to the ranges found in other peer-reviewed applications (Simon et al., 2012) and were found to be suitable for use in a regulatory context (U.S. Environmental Protection Agency, 2014a).

As an example of how the 2011 modeling platform was performing in southeast Pennsylvania, **Figure 9** shows a time-series comparison between modeled and monitored peak 8-hr ozone concentrations at the Sipe Avenue monitor in Harrisburg. The modeled ozone concentrations will not typically show perfect agreement with observed concentrations. For the Sipe Avenue monitor, the model performs well and captures observed ozone trends throughout the 2011 ozone season quite well, but tends to under-predict ozone concentrations when monitored concentrations are highest.

[6] Including a leftover residual contribution from all untagged sources calculated by CAMx.

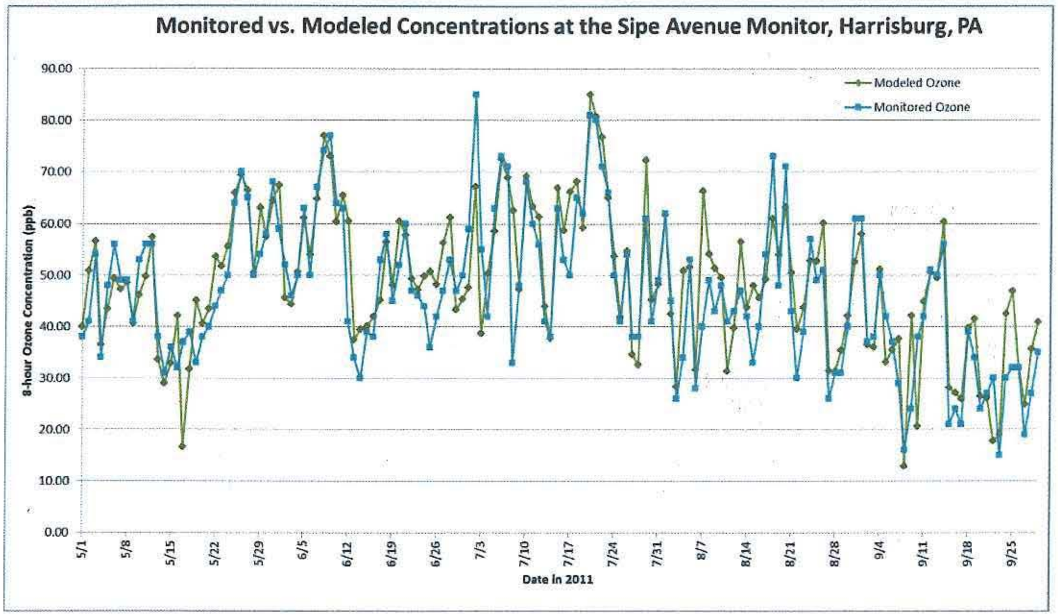

Figure 9. Monitored vs. modeled 8-hr ozone concentrations at the Sipe Avenue monitor near Harrisburg.

Appendix B. OSAT Source Tags

This information is also included in the Access database of OSAT results provided to the Sierra Club. Point source state groups (e.g., PA1, MDALL, and CTOTH) do not include point sources that were already tagged individually or point sources included in other state groupings from the same state.

Simulation 1

Tag Name	State	Tag Description
IC	N/A	Initial Conditions
BC	N/A	Boundary Conditions
biog	N/A	Biogenics
I2	CT	Bridgeport Station
I5	PA	Conemaugh
I6	PA	Homer City Station
I7	PA	PPL Brunner Island
I10	PA	Bruce Mansfield
I11	PA	Keystone
I12	PA	PPL Montour
I17	VA	Chesterfield
I19	WV	Pleasants Power Station
I23	IL	E D Edwards
I28	WV	Harrison Power Station
I30	WV	Fort Martin Power Station
I32	WV	John E Amos
I33	MI	St Clair
I34	MI	Trenton Channel
I35	IN	Clifty Creek
I36	IL	Wood River
I37	IL	Waukegan
I38	OH	Kyger Creek
I39	IL	Will County
I40	OH	Cardinal
I41	MI	J H Campbell
I43	OH	General James M Gavin
I44	OH	W H Sammis
I45	IL	Powerton
I46	MI	River Rouge

Tag Name	State	Tag Description
I49	PA	Cheswick Power Plant
IL1	IL	Illinois point group 1
IL2	IL	Illinois point group 2
IN1	IN	Indiana point group 1
IN2	IN	Indiana point group 2
MD	MD	Maryland point group
MI	MI	Michigan point group
NJ1	NJ	Illinois point group 1
NJ2	NJ	Illinois point group 2
NY	NY	New York point group
OH1	OH	Ohio point group 1
OH2	OH	Ohio point group 2
PA1	PA	Pennsylvania point group 1
PA2	PA	Pennsylvania point group 2
VA1	VA	Virginia point group 1
VA2	VA	Virginia point group 2
WV	WV	West Virginia point group
NYEGU	NY	New York EGUs not individually tagged
NYUOTH	NY	Non-EGU point sources in upstate New York
NYDCMB	NY	New York "downstate" combustion sources
NYDOTH	NY	New York "downstate" point sources
PAEGU	PA	Pennsylvania EGUs not individually tagged
PAOTH	PA	Other Pennsylvania sources
NJCMB	NJ	New Jersey CMB sources
NJOTH	NJ	Other New Jersey point sources
CTCMB	CT	Connecticut combustion sources
CTOTH	CT	Other Connecticut point sources
MDALL	MD	Other Maryland point sources
VAALL	VA	Other Virginia point sources
OHALL	OH	Other Ohio point sources
INALL	IN	Other Indiana point sources
OTHER	N/A	CAMx "residual" contribution
total	N/A	Total ozone concentration

Simulation 2

Tag Name	Tag Description
IC	Initial conditions
BC	Boundary conditions
biog_oth	Biogenic emissions from states not included in tagging
biog_CT	Connecticut biogenics
biog_DC	Washington D. C. biogenics
biog_IL	Illinois biogenics
biog_IN	Indiana biogenics
biog_MD	Maryland biogenics
biog_MI	Michigan biogenics
biog_NJ	New Jersey biogenics
biog_NYD	New York "downstate" biogenics
biog_NYU	New York "update" biogenics
biog_OH	Ohio biogenics
biog_PA	Pennsylvania biogenics
biog_SESARM	Biogenics from SESARM states
biog_VA	Virginia biogenics
biog_WV	West Virginia biogenics
biog_DE	Delaware biogenics
nonr_oth	Non-road emissions from states not included in tagging
nonr_CT	Connecticut non-road
nonr_DC	Washington D. C. non-road
nonr_IL	Illinois non-road
nonr_IN	Indiana non-road
nonr_MD	Maryland non-road
nonr_MI	Michigan non-road
nonr_NJ	New Jersey non-road
nonr_NYD	New York "downstate" non-road
nonr_NYU	New York "update" non-road
nonr_OH	Ohio non-road
nonr_PA	Pennsylvania non-road
nonr_SESARM	non-road from SESARM states
nonr_VA	Virginia non-road
nonr_WV	West Virginia non-road
nonr_DE	Delaware non-road

Tag Name	Tag Description
onr_oth	Onroad emissions from states not included in tagging
onr_CT	Connecticut onroad
onr_DC	Washington D. C. onroad
onr_IL	Illinois onroad
onr_IN	Indiana onroad
onr_MD	Maryland onroad
onr_MI	Michigan onroad
onr_NJ	New Jersey onroad
onr_NYD	New York "downstate" onroad
onr_NYU	New York "update" onroad
onr_OH	Ohio onroad
onr_PA	Pennsylvania onroad
onr_SESARM	onroad from SESARM states
onr_VA	Virginia onroad
onr_WV	West Virginia onroad
onr_DE	Delaware onroad
othr_oth	Other emissions (not addressed by the onroad, non-road, and biogenic tags) from states not included in tagging
othr_CT	Other emissions from Connecticut
othr_DC	Other emissions from Washington, DC
othr_IL	Other emissions from Illinois
othr_IN	Other emissions from Indiana
othr_MD	Other emissions from Maryland
othr_MI	Other emissions from Michigan
othr_NJ	Other emissions from New Jersey
othr_NYD	Other emissions from downstate New York
othr_NYU	Other emissions from upstate New York
othr_OH	Other emissions from Ohio
othr_PA	Other emissions from Pennsylvania
othr_SESARM	Other emissions from SESARM states
othr_VA	Other emissions from Virginia
othr_WV	Other emissions from West Virginia
othr_DE	Other emissions from Delaware
total_icbc	Total initial and boundary conditions
total_biog	Total biogenic emissions
total_nonr	Total nonroad emissions

Tag Name	Tag Description
total_onr	Total onroad emissions
total_othr	Total other emissions
total	Total ozone concentration

Simulation 3

Tag Name	State	Plant Name
IC	N/A	Initial conditions
BC	N/A	Boundary conditions
biog	N/A	Biogenics
OTHER	N/A	CAMx "residual" contribution
total	N/A	Total ozone concentration
I1	DE	Indian River Generating Station
I3	AR	White Bluff
I4	AR	Independence
I6	TX	Big Brown
I8	GA	Hammond
I9	KS	Tecumseh Energy Center
I13	TX	W A Parish
I14	TX	Coleto Creek
I15	TX	Monticello
I16	TX	Fayette Power Project (a.k.a. Sam Seymour)
I18	TX	Martin Lake
I20	TX	Pirkey
I21	TN	Kingston
I22	KY	Kenneth C Coleman
I24	TN	Gallatin
I25	KY	Elmer Smith
I26	KY	E W Brown
I27	KY	Shawnee
I29	MO	Thomas Hill
I31	MO	Sioux
I42	NC	G G Allen
I47	GA	Scherer
I48	NC	Marshall
I50	OK	Muskogee

Tag Name	State	Plant Name
I51	OK	GRDA
AL1	AL	Alabama point group 1
AL2	AL	Alabama point group 2
AR	AR	Arkansas point group
FL1	FL	Florida point group 1
FL2	FL	Florida point group 2
GA	GA	Georgia point group
IA1	IA	Iowa point group 1
IA2	IA	Iowa point group 2
KS	KS	Kansas point group
KY1	KY	Kentucky point group 1
KY2	KY	Kentucky point group 2
LA	LA	Louisiana point group
MA	MA	Massachusetts point group
MN1	MN	Minnesota point group 1
MN2	MN	Minnesota point group 2
MO	MO	Missouri point group
MS1	MS	Mississippi point group 1
MS2	MS	Mississippi point group 2
NC	NC	North Carolina group
NE1	NE	Nebraska group
NH	NH	New Hampshire point group
OK1	OK	Oklahoma point group 1
OK2	OK	Oklahoma point group 2
SC1	SC	South Carolina point group 1
SC2	SC	South Carolina point group 2
TN1	TN	Tennessee point group 1
TN2	TN	Tennessee point group 2
TX1	TX	Texas point group 1
TX2	TX	Texas point group 2
WI1	WI	Wisconsin point group 1
WI2	WI	Wisconsin point group 2

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APPENDIX E

Specific Language Recommended by Maryland for EPA to Include in Federal Orders by May 1, 2017 for the 36 EGUs

Facility: Alcoa Allowance Management Inc
Unit ID: 4
State: IN
ORIS ID: 6705

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.104 lb/mmBtu during the ozone season.

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Facility: Clifty Creek
Unit ID: 1
State: IN
ORIS ID: 983

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.090 lb/mmBtu during the ozone season.

Facility: Clifty Creek
Unit ID: 2
State: IN
ORIS ID: 983

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.090 lb/mmBtu during the ozone season.

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Facility: Clifty Creek
Unit ID: 3
State: IN
ORIS ID: 983

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.084 lb/mmBtu during the ozone season.

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Facility: Gibson
Unit ID: 3
State: IN
ORIS ID: 6113

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's’ specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.088 lb/mmBtu during the ozone season.

Facility: Gibson
Unit ID: 5
State: IN
ORIS ID: 6113

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.084 lb/mmBtu during the ozone season.

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Facility: Petersburg
Unit ID: 2
State: IN
ORIS ID: 994

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.062 lb/mmBtu during the ozone season.

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Facility: Petersburg
Unit ID: 3
State: IN
ORIS ID: 994

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.061 lb/mmBtu during the ozone season.

Facility: East Bend
Unit ID: 2
State: KY
ORIS ID: 6018

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.067 lb/mmBtu during the ozone season.

Facility: Elmer Smith
Unit ID: 1
State: KY
ORIS ID: 1374

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.159 lb/mmBtu during the ozone season.

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Facility: Paradise
Unit ID: 3
State: KY
ORIS ID: 1378

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.120 lb/mmBtu during the ozone season.

Facility: Killen Station
Unit ID: 2
State: OH
ORIS ID: 6031

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.097 lb/mmBtu during the ozone season.

Facility: Kyger Creek
Unit ID: 1
State: OH
ORIS ID: 2876

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.085 lb/mmBtu during the ozone season.

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Facility: Kyger Creek
Unit ID: 2
State: OH
ORIS ID: 2876

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.084 lb/mmBtu during the ozone season.

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Facility: Kyger Creek
Unit ID: 3
State: OH
ORIS ID: 2876

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.084 lb/mmBtu during the ozone season.

Facility: Kyger Creek
Unit ID: 4
State: OH
ORIS ID: 2876

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.084 lb/mmBtu during the ozone season.

Facility: Kyger Creek
Unit ID: 5
State: OH
ORIS ID: 2876

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's’ specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.084 lb/mmBtu during the ozone season.

Facility: W H Zimmer Generating Station
Unit ID: 1
State: OH
ORIS ID: 6019

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.094 lb/mmBtu during the ozone season.

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Facility: Bruce Mansfield
Unit ID: 1
State: PA
ORIS ID: 6094

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.089 lb/mmBtu during the ozone season.

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Facility: Cambria Cogen
Unit ID: 1
State: PA
ORIS ID: 10641

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.115 lb/mmBtu during the ozone season.

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Facility: Cambria Cogen
Unit ID: 2
State: PA
ORIS ID: 10641

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.115 lb/mmBtu during the ozone season.

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Facility: Cheswick
Unit ID: 1
State: PA
ORIS ID: 8226

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.097 lb/mmBtu during the ozone season.

Facility: Homer City
Unit ID: 1
State: PA
ORIS ID: 3122

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.072 lb/mmBtu during the ozone season.

Facility: Homer City
Unit ID: 2
State: PA
ORIS ID: 3122

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.093 lb/mmBtu during the ozone season.

Facility: Homer City
Unit ID: 3
State: PA
ORIS ID: 3122

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.105 lb/mmBtu during the ozone season.

Facility: Keystone
Unit ID: 1
State: PA
ORIS ID: 3136

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.048 lb/mmBtu during the ozone season.

Facility: Keystone
Unit ID: 2
State: PA
ORIS ID: 3136

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.046 lb/mmBtu during the ozone season.

Facility: Montour
Unit ID: 1
State: PA
ORIS ID: 3149

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.100 lb/mmBtu during the ozone season.

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Facility: Montour
Unit ID: 2
State: PA
ORIS ID: 3149

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.088 lb/mmBtu during the ozone season.

Facility: Grant Town Power Plant
Unit ID: 1A
State: WV
ORIS ID: 10151

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.077 lb/mmBtu during the ozone season.

Facility: Grant Town Power Plant
Unit ID: 1B
State: WV
ORIS ID: 10151

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.077 lb/mmBtu during the ozone season.

Facility: Harrison Power Station
Unit ID: 1
State: WV
ORIS ID: 3944

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.066 lb/mmBtu during the ozone season.

Facility: Harrison Power Station
Unit ID: 2
State: WV
ORIS ID: 3944

y Ma Specific requirements that EPA must include in a federal order that is effective on or before
May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.085 lb/mmBtu during the ozone season.

Facility: Harrison Power Station
Unit ID: 3
State: WV
ORIS ID: 3944

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.083 lb/mmBtu during the ozone season.

Facility: Pleasants Power Station
Unit ID: 1
State: WV
ORIS ID: 6004

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.046 lb/mmBtu during the ozone season.

Facility: Pleasants Power Station
Unit ID: 2
State: WV
ORIS ID: 6004

Specific requirements that EPA must include in a federal order that is effective on or before May 1, 2017:

Requirement #1: Beginning on May 1, 2017, for each operating day during the ozone season, the owner or operator shall minimize NOx emissions by operating and optimizing the use of all installed pollution control technology and combustion controls consistent with the technological limitations, manufacturer's' specifications, good engineering and maintenance practices, and good air pollution control practices for minimizing emissions (as defined in 40 C.F.R. § 60.11(d)) for such equipment and the unit at all times the unit is in operation while burning any coal.

Requirement #2: Beginning on May 1, 2017, the owner or operator shall not exceed a 30-day rolling average NOx emission rate of 0.045 lb/mmBtu during the ozone season.

APPENDIX F

Cost Analyses

Part I – Cost Analysis for the 36 Units

Introduction

To evaluate the cost savings incurred by the 126 petitioned power plants, Maryland used the capital expenses, fixed and variable operation and maintenance costs for installing and fully operating emission controls researched by Sargent & Lundy, a nationally recognized architect/engineering firm (A/E firm) familiar with the EGU sector.[1]

Cost Estimate for Existing SCR

Maryland sought to examine costs for full operation of SCR. SCR are post-combustion controls that reduce NOx emissions by reacting the NOx with either ammonia or urea. The SCR technology utilizes a catalyst and produces a high conversion of NOx to nitrogen. Fully operating an SCR includes maintenance costs, labor, auxiliary power, catalyst, and reagent cost. The chemical reagent (typically ammonia or urea) is a signification portion of the operating cost of these controls.

Maryland examined three of the variable operations and maintenance (VOM) costs: reagent, catalyst and auxiliary power. Depending on circumstances, SCR operators may operate the system while achieving less that "full" removal efficiency by using less reagent, and/ or not replacing degraded catalyst which allows the SCR to perform at lower reduction capabilities. Maryland considered the cost of both additional reagent and catalyst maintenance and replacement in representing the cost of optimizing existing and operating SCR systems.

In contrast, Maryland found that units running their SCR systems have incurred the complete set of fixed and operating maintenance (FOM) costs. In addition, Maryland found that the auxiliary power component of VOM is also largely indifferent to the NOx removal. That is, auxiliary power is indifferent to reagent consumption, catalyst degradation or NOx removal rate. Thus, the FOM and auxiliary power VOM cost components are not included in the cost estimate to achieve "full" operation for units that are already operating.

Only the VOM reagent and catalyst replacement costs should be included in cost estimates to ensure an operating SCR operates fully.

Maryland identified the cost for returning a partially operating SCR to full operation by applying the Sargent & Lundy cost equations for the coal fired units mentioned in this 126 petition based on their operation in 2014 based on a per ton of NOx removed (had the units ran at full capacity). In all 31 of the 36 units were modeled, the 5 non-modeled units were missing kw-hr data.

Maryland was able to identify the costs of individual VOM and FOM cost components, including reagent and catalyst cost. Some of these expenses, as modeled by the Sargent &

[1] IPM Model – Updates to Cost and Performance for APC Technologies -SCR Cost Development Methodology (

Lundy cost tool, vary depending on factors such as units size, NOx generated from the combustion process, and reagent utilized. The key input parameters in the cost equations are the size of the unit, the uncontrolled, or "input", NOx rate, the NOx removal efficiency, the type of coal and the capacity factor. For the input NOx rate, each unit's ozone season emissions rate from the period 2003 though 2012 was examined to determine the best operation of the SCR. This emissions rate best (Er) in Lbs NOx/MMBtu was assumed to be the best rate achievable at 100 per cent operation of the controls. This optimum best emissions rate was divided by 0.08 to calculate a totally uncontrolled emissions rate. The totally uncontrolled emissions rate was multiplied by a .70 factor to account for low NOx burner and other emissions control reductions to yield a pre SCR emissions rate. To project the cost to return the partially operating SCR's to full operation Maryland examined only the sum of the VOM reagent and catalyst cost components for the additional tons of NOx removed assuming 100 per cent operation of the SCR compared to the actual tons removed in 2014. A factor called "petal to the metal" which represented how hard the emissions controls were run was calculated by the following equation 1-[(actual Er-best Er)/(pre SCR Er-best Er)]. The cost savings for not running controls was calculated for each unit by taking the VOM reagent and catalyst cost for the additional tons times the number of additional tons to reach 100% operation.[2]

Cost estimates on a per ton basis

Cost Estimates for Fully Operating Existing SCR that operate to some extent[3].

EPA ranked the quantified VOM costs for each unit and identified the cost on the 90th percentile level rank, which rounded to $800 per ton of NOx removed. EPA also identified the average cost, which rounded to $670 per ton of NOx removed. EPA selected the 90th percentile value because a substantial portion of units had combined reagent and catalyst cost at or less than this $800/ton of NOx removed.

Cost Estimate for Restarting Idled (Mothballed) Existing SCR

EPA did an additional cost estimate since SCR which are bypassed could incur some additional costs including the auxiliary fan power VOM component and all of the FOM components along with the reagent and catalyst VOM components. EPA again ranked the sum of the VOM and FOM costs for each unit and identified the 90^{th} percentile cost. When rounded, this was $ 1,400/ton of NOx removed. EPA also identified the average cost at $1,000/ton of NOx removed.

[2] Pivot table chart attached

[3] EGU NOx Mitigation Strategies Final Rule TSD - Technical Support Document (TSD) for the Cross-State Air Pollution Rule Update for the 2008 Ozone NAAQS Docket ID No. EPA-HQ-OAR-2015-0500

Summary

The cost savings incurred in 2014 by the units in this 126 petition by not fully running their controls was at least $24 million. Conversely, the cost to the units in this 126 petition to fully run their controls would be about $24 million per ozone season.

In 2014 the units ran with average capacity factors of 0.56 and only used their controls at about 54% efficiency (petal to the metal). The average ozone season emissions rate emitted by these plants was 0.29 Lbs NOx/MMBtu compared to the EPA selected 0.10 lbs NOx/mmBtu as a reasonable representation for full operational capability of an SCR. In this study EPA noted that over half of the EGU's achieved a rate of 0.076 lbs NOx/mmBtu over their third-best entire ozone season 2002 – 2014.

The Cost per ton basis in the EPA study of 255 units ranges from $800 - $1,400 per ton at the 90th percentile ranking and $670 to $1,000 per ton on average depending if the SCR are in partial operation or totally idled "mothballed". Five of the units modeled for this 126 petition, Cheswick 1, Elmer Smith 1, Montour 1 & 2 and Pleasants Power 2 exhibited such low "petal to the metal" factors in 2014 that they were probably mothballed and the cost per ton to reactivate them would be at the top of the range. The remainder of the units seemed to run their SCR to some extent and would experience costs at the bottom of the range.

Row Labels	Sum of Assoc. EIA Gen Nameplate (MW)	Average of 2014 Ozone Season Emission Rate	Sum of 2014 Ozone Season Emission Tons	Sum of 2014 Estimated OS Nox Mass Emissions Reduction (tons)	Average of Lowest 2003 - 2012 O.S. Avg. NOx Rate (lb/MMBTU)	Average of Cost to control $(2012)/Ton	Average of Pedal to the Metal (how close to 100% are they running controls)	Sum of Cost Savings from not running controls OS 2104	Average of 2014 O.S. Heat Input Capacity Factor
Bruce Mansfield	**914**	**0.22**	**2,617**	**1,705**	**0.08**	**442**	**69%**	**$753,606**	**0.77**
1	914	0.22	2,617	1,705	0.08	442	69%	$753,606	0.77
Cheswick	**637**	**0.40**	**2,193**	**1,863**	**0.06**	**412**	**32%**	**$767,725**	**0.50**
1	637	0.40	2,193	1,863	0.06	412	32%	$767,725	0.50
Clifty Creek	**652**	**0.22**	**1,403**	**925**	**0.07**	**574**	**75%**	**$530,561**	**0.42**
1	217	0.21	505	331	0.07	574	75%	$190,076	0.46
2	217	0.22	488	324	0.08	573	74%	$185,959	0.42
3	217	0.22	411	269	0.07	574	75%	$154,526	0.37
East Bend	**669**	**0.24**	**1,471**	**1,157**	**0.05**	**475**	**52%**	**$549,441**	**0.42**
2	669	0.24	1,471	1,157	0.05	475	52%	$549,441	0.42
Elmer Smith	**163**	**1.07**	**2,042**	**1,809**	**0.12**	**1,582**	**0%**	**$2,861,056**	**0.19**
1	163	1.07	2,042	1,809	0.12	1,582	0%	$2,861,056	0.19
Gibson	**1,336**	**0.23**	**3,206**	**2,317**	**0.06**	**511**	**65%**	**$1,205,181**	**0.55**
3	668	0.16	1,176	705	0.07	486	81%	$342,691	0.53
5	668	0.29	2,030	1,613	0.06	535	50%	$862,489	0.57
Harrison Power Station	**2,052**	**0.36**	**9,741**	**7,988**	**0.07**	**509**	**41%**	**$4,059,585**	**0.67**
1	684	0.35	3,120	2,555	0.06	548	42%	$1,400,244	0.64
2	684	0.36	2,986	2,438	0.07	485	43%	$1,182,392	0.66
3	684	0.37	3,636	2,995	0.07	493	40%	$1,476,949	0.72
Homer City	**2,012**	**0.38**	**8,372**	**6,628**	**0.08**	**481**	**54%**	**$3,196,564**	**0.58**
1	660	0.37	2,978	2,448	0.07	488	45%	$1,195,114	0.64
2	660	0.38	2,029	1,586	0.08	474	57%	$751,033	0.43
3	692	0.38	3,365	2,594	0.09	482	60%	$1,250,417	0.66
IPL - Petersburg Generating Station	**1,194**	**0.18**	**2,326**	**1,743**	**0.04**	**371**	**61%**	**$641,313**	**0.75**
2	523	0.21	1,328	1,055	0.04	358	50%	$377,964	0.85
3	671	0.15	998	688	0.05	383	71%	$263,349	0.65
Keystone	**1,872**	**0.22**	**5,442**	**4,388**	**0.04**	**446**	**50%**	**$1,958,203**	**0.75**
1	936	0.20	2,291	1,795	0.04	443	57%	$795,209	0.72
2	936	0.24	3,151	2,593	0.04	448	44%	$1,162,993	0.78
Killen Station	**661**	**0.28**	**2,153**	**1,471**	**0.09**	**495**	**74%**	**$728,728**	**0.60**
2	661	0.28	2,153	1,471	0.09	495	74%	$728,728	0.60
Kyger Creek	**1,087**	**0.15**	**1,809**	**886**	**0.08**	**547**	**88%**	**$483,480**	**0.49**
1	217	0.14	402	180	0.08	555	90%	$100,096	0.58
2	217	0.14	275	120	0.08	562	91%	$67,669	0.40
3	217	0.16	330	166	0.08	540	88%	$89,478	0.43
4	217	0.16	381	199	0.08	539	87%	$107,425	0.48
5	217	0.17	421	221	0.08	538	87%	$118,813	0.53
Montour	**1,625**	**0.41**	**4,463**	**3,964**	**0.05**	**448**	**0%**	**$1,768,959**	**0.40**
1	806	0.41	1,856	1,656	0.04	455	1%	$753,947	0.33
2	819	0.41	2,607	2,308	0.05	440	0%	$1,015,012	0.47
Paradise	**1,150**	**0.16**	**2,140**	**783**	**0.10**	**573**	**93%**	**$448,731**	**0.50**
3	1,150	0.16	2,140	783	0.10	573	93%	$448,731	0.50
Pleasants Power Station	**1,368**	**0.30**	**5,461**	**4,762**	**0.04**	**576**	**29%**	**$2,732,711**	**0.61**
1	684	0.23	1,885	1,557	0.04	581	39%	$904,834	0.56
2	684	0.38	3,576	3,205	0.04	570	19%	$1,827,878	0.65
W H Zimmer Generating Station	**1,426**	**0.29**	**4,639**	**3,753**	**0.06**	**453**	**49%**	**$1,700,604**	**0.66**
1	1,426	0.29	4,639	3,753	0.06	453	49%	$1,700,604	0.66
Grand Total	**18,817**	**0.29**	**59,480**	**46,143**	**0.07**	**534**	**56%**	**$24,386,447**	**0.55**

Part II – Sargent and Lundy Cost Development Methodology

Cost estimates for the units identified in this petition were calculated using the methodology developed by Sargent and Lundy. The documentation for this methodology is provided below.

IPM Model – Updates to Cost and Performance for APC Technologies

SCR Cost Development Methodology

Final

March 2013

Project 12847-002

Systems Research and Applications Corporation

Prepared by

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SCR Cost Development Methodology

Establishment of Cost Basis

The 2004 to 2006 industry cost estimates for SCR units from the "Analysis of MOG and Ladco's FGD and SCR Capacity and Cost Assumptions in the Evaluation of Proposed EGU 1 and EGU 2 Emission Controls" prepared for Midwest Ozone Group (MOG) were used by Sargent & Lundy LLC (S&L) to develop the SCR cost model. In addition, S&L included data from "Current Capital Cost and Cost-effectiveness of Power Plant Emissions Control Technologies" prepared by J. E. Cichanowicz for the Utility Air Regulatory Group (UARG) in 2010. The published data was significantly augmented by the S&L in-house database of recent SCR projects. The current industry trend is to retrofit high-dust hot-side SCRs. The cold-side tail-end SCRs encompass a small minority of units and as such were not considered in this evaluation.

The data was converted to 2012 dollars based on the Chemical Engineering Plant Index (CEPI) data. Additional proprietary S&L in-house data from 2007 to 2012 were included to confirm the index validity. Finally, the cost estimation tool was benchmarked against recent SCR projects to confirm the applicability to the current market conditions.

The available data was analyzed in detail regarding project specifics such as coal type, NOx reduction efficiency and air pre-heater requirements. The data was refined by fitting each data set with a least squares curve to obtain an average $/kW project cost as a function of unit size. The data set was then collectively used to generate an average least-squares curve fit. The curve fit indicated all the data sets produced similar average costs (within 4%) at the 200 MW range, but deviate as the unit size increases to approximately 11% at 600 MW and 13% at 900 MW.

The costs for retrofitting a plant smaller than 100 MW increase rapidly due to the economy of size. The older units which comprise a large proportion of the plants in this range generally have more compact sites with very short flue gas ducts running from the boiler house to the chimney. Because of the limited space, the SCR reactor and new duct work can be expensive to design and install. Additionally, the plants might not have enough margins in the fans to overcome the pressure drop due to the duct work configuration and SCR reactor and therefore new fans may be required.

The least squares curve fit was based upon an average of the SCR retrofit projects in recent years. Retrofit difficulties associated with an SCR may result in significant capital cost increases. A typical SCR retrofit was based on:

- Retrofit Difficulty =1 (Average retrofit difficulty);
- Gross Heat Rate = 9500 Btu/kWh;
- SO_2 Rate = < 3.0 lb/MMBtu;
- Type of Coal = Bituminous; and
- Project Execution = Multiple lump sum contracts.

SCR Cost Development Methodology

Methodology

Inputs

To predict SCR retrofit costs several input variables are required. The unit size in MW is the major variable for the capital cost estimation followed by the type of fuel (Bituminous, PRB, or Lignite) which will influence the flue gas quantities as a result of the different typical heating values. The fuel type also affects the air pre-heater costs if ammonium bisulfate or sulfuric acid deposition poses a problem. The unit heat rate factors into the amount of flue gas generated and ultimately the size of the SCR reactor and reagent preparation. A retrofit factor that equates to difficulty in construction of the system must be defined. The NO_x rate and removal efficiency will impact the amount of catalyst required and size of the reagent handling equipment.

The cost methodology is based on a unit located within 500 feet of sea level. The actual elevation of the site should be considered separately and factored into the cost due to the effects on the flue gas volume. The base SCR and balance of plant costs are directly impacted by the site elevation. These two base cost modules should be increased based on the ratio of the atmospheric pressure between sea level and the unit location. As an example, a unit located 1 mile above sea level would have an approximate atmospheric pressure of 12.2 psia. Therefore, the base SCR and balance of plant costs should be increased by:

14.7 psia/12.2 psia = 1.2 multiplier to the base SCR and balance of plant costs

The NOx removal efficiency specifically affects the SCR catalyst, reagent and steam costs. The lower level of NOx removal is recommended as:

- 0.07 NOx lb/MMBtu – Bituminous
- 0.05 NOx lb/MMBtu – PRB
- 0.05 NOx lb/MMBtu – Lignite

Outputs

Total Project Costs (TPC)

First the installed costs are calculated for each required base module. The base module installed costs include:

- All equipment;
- Installation;
- Buildings;
- Foundations;
- Electrical; and
- Average retrofit difficulty.

SCR Cost Development Methodology

The base modules are:

BMR =	Base SCR cost
BMF =	Base reagent preparation cost
BMA =	Base air pre-heater cost
BMB =	Base balance of plant costs including: ID or booster fans, ductwork reinforcement, piping, etc…
BM =	BMR + BMF + BMA + BMB

The total base module installed cost (BM) is then increased by:

- Engineering and construction management costs at 10% of the BM cost;
- Labor adjustment for 6 x 10 hour shift premium, per diem, etc., at 10% of the BM cost; and
- Contractor profit and fees at 10% of the BM cost.

A capital, engineering, and construction cost subtotal (CECC) is established as the sum of the BM and the additional engineering and construction fees.

Additional costs and financing expenditures for the project are computed based on the CECC. Financing and additional project costs include:

- Owner's home office costs (owner's engineering, management, and procurement) at 5% of the CECC; and
- Allowance for Funds Used During Construction (AFUDC) at 6% of the CECC and owner's costs. The AFUDC is based on a two-year engineering and construction cycle.

The total project cost is based on a multiple lump sum contract approach. Should a turnkey engineering procurement construction (EPC) contract be executed, the total project cost could be 10 to 15% higher than what is currently estimated.

Escalation is not included in the estimate. The total project cost (TPC) is the sum of the CECC and the additional costs and financing expenditures.

SCR Cost Development Methodology

Fixed O&M (FOM)

The fixed operating and maintenance (O&M) cost is a function of the additional operations staff (FOMO), maintenance labor and materials (FOMM), and administrative labor (FOMA) associated with the SCR installation. The FOM is the sum of the FOMO, FOMM, and FOMA.

The following factors and assumptions underlie calculations of the FOM:

- All of the FOM costs were tabulated on a per kilowatt-year (kW yr) basis.

- In general, half of an operator's time is required to monitor a retrofit SCR. The FOMO is based on that ½ time requirement for the operations staff.

- The fixed maintenance materials and labor is a direct function of the process capital cost at 0.5% of the BM for units less than 300 MW and 0.3% of the BM for units greater than or equal to 300 MW and.

- The administrative labor is a function of the FOMO and FOMM at 3% of (FOMO + 0.4FOMM).

Variable O&M (VOM)

Variable O&M is a function of:

- Reagent use and unit costs;
- Catalyst replacement and disposal costs;
- Additional power required and unit power cost; and
- Steam required and unit steam cost.

The following factors and assumptions underlie calculations of the VOM:

- All of the VOM costs were tabulated on a per megawatt-hour (MWh) basis.

- The reagent consumption rate is a function of unit size, NOx feed rate and removal efficiency.

- The catalyst replacement and disposal costs are based on the NOx removal and total volume of catalyst required.

- The additional power required includes increased fan power to account for the added pressure drop and the power required for the reagent supply system. These requirements are a function of gross unit size and actual gas flow rate.

SCR Cost Development Methodology

- The additional power is reported as a percent of the total unit gross production. In addition, a cost associated with the additional power requirements can be included in the total variable costs.

- The steam usage is based upon reagent consumption rate.

Input options are provided for the user to adjust the variable O&M costs per unit. Average default values are included in the base estimate. The variable O&M costs per unit options are:

- Urea cost in $/ton;
- Catalyst costs that include removal and disposal of existing catalyst and installation of new catalyst in $/cubic meter;
- Auxiliary power cost in $/kWh;
- Steam cost in $/1000 lb; and
- Operating labor rate (including all benefits) in $/hr.

The variables that contribute to the overall VOM are:

VOMR = Variable O&M costs for urea reagent

VOMW = Variable O&M costs for catalyst replacement & disposal

VOMP = Variable O&M costs for additional auxiliary power

VOMM = Variable O&M costs for steam

The total VOM is the sum of VOMR, VOMW, VOMP, and VOMM. Table 1 is a complete capital and O&M cost estimate worksheet.

SCR Cost Development Methodology

Table 1. Example Complete Cost Estimate for an SCR System

Variable	Designation	Units	Value	Calculation
Unit Size	A	(MW)	500	<--- User Input
Retrofit Factor	B		1	<--- User Input (An "average" retrofit has a factor = 1.0)
Heat Rate	C	(Btu/kWh)	9500	<--- User Input
NOx Rate	D	(lb/MMBtu)	0.3	<--- User Input
SO2 Rate	E	(lb/MMBtu)	3	<--- User Input
Type of Coal	F		Bituminous	<--- User Input
Coal Factor	G		1	Bit=1.0, PRB=1.05, Lig=1.07
Heat Rate Factor	H		0.95	C/10000
Heat Input	I	(Btu/hr)	4.75E+09	A*C*1000
NOx Removal Efficiency	K	(%)	75	<--- User Input
NOx Removal Factor	L		0.9375	K/80
NOx Removed	M	(lb/hr)	1069	D*I/10^6*K/100
Urea Rate (100%)	N	(lb/hr)	747	M*0.525*60/46*1.01/0.99
Steam Required	O	(lb/hr)	845	N*1.13
Aux Power **Include in VOM?** ☑	**P**	**(%)**	**0.55**	0.56*(G*H)^0.43
Urea Cost (50% wt solution)	R	($/ton)	310	<--- User Input
Catalyst Cost	S	($/m3)	8000	<--- User Input (Includes removal and disposal of existing catalyst and installation of new catalyst)
Aux Power Cost	T	($/kWh)	0.06	<--- User Input
Steam Cost	U	($/klb)	4	<--- User Input
Operating Labor Rate	V	($/hr)	60	<--- User Input (Labor cost including all benefits)

Costs are all based on 2012 dollars

Capital Cost Calculation		Example	Comments
Includes - Equipment, installation, buildings, foundations, electrical, and retrofit difficulty.			
BMR ($) =	270000*(B)*(L)^0.2*(A*G*H)^0.92	$ 77,324,000	SCR (Inlet Ductwork, Reactor, Bypass) Island Cost
BMF ($) =	490000*(M)^0.25	$ 2,802,000	Base Reagent Preparation Cost
BMA ($) =	IF E ≥ 3 AND F=Bituminous, THEN 69000*(B)*(A*G*H)^0.78, ELSE 0	$ 8,446,000	Air Heater Modification / SO3 Control (Bituminous only & > 3lb/mmBtu)
BMB ($) =	460000*(B)*(A*G*H)^0.42	$ 6,123,000	ID or booster fans & Auxiliary Power Modification Costs
BM ($) =	BMR + BMF + BMA + BMB	$ 94,695,000	Total bare module cost including retrofit factor
BM ($/KW) =		189	Base cost per kW
Total Project Cost			
A1 = 10% of BM		$ 9,470,000	Engineering and Construction Management costs
A2 = 10% of BM		$ 9,470,000	Labor adjustment for 6 x 10 hour shift premium, per diem, etc…
A3 = 10% of BM		$ 9,470,000	Contractor profit and fees
CECC ($) = BM+A1+A2+A3		**$ 123,105,000**	Capital, engineering and construction cost subtotal
CECC ($/kW) =		**246**	Capital, engineering and construction cost subtotal per kW
B1 = 5% of CECC		$ 6,155,000	Owners costs including all "home office" costs (owners engineering, management, and procurement activities)
TPC' ($) - Includes Owner's Costs = CECC + B1		$ 129,260,000	Total project cost without AFUDC
TPC' ($/kW) - Includes Owner's Costs =		**259**	Total project cost per kW without AFUDC
B2 = 6% of CECC + B1		$ 7,756,000	AFUDC (Based on a 2 year engineering and construction cycle)
TPC ($) = CECC + B1 + B2		**$ 137,016,000**	Total project cost
TPC ($/kW) =		**274**	Total project cost per kW

SCR Cost Development Methodology

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Coal Factor	G		1	Bit=1.0, PRB=1.05, Lig=1.07
Heat Rate Factor	H		0.95	C/10000
Heat Input	I	(Btu/hr)	4.75E+09	A*C*1000
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Steam Cost	U	($/klb)	4	<--- User Input
Operating Labor Rate	V	($/hr)	60	<--- User Input (Labor cost including all benefits)

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Fixed O&M Cost

FOMO ($/kW yr) = (1/2 operator time assumed)*2080*V/(A*1000)	$	0.13	Fixed O&M additional operating labor costs
FOMM ($/kW yr) = (IF A < 300 then 0.005*BM ELSE 0.003*BM)/(B*A*1000)	$	0.57	Fixed O&M additional maintenance material and labor costs
FOMA ($/kW yr) = 0.03*(FOMO+0.4*FOMM)	$	0.01	Fixed O&M additional administrative labor costs
FOM ($/kW yr) = FOMO + FOMM	**$**	**0.71**	Total Fixed O&M costs

Variable O&M Cost

VOMR ($/MWh) = N*R/(A*1000)	$	0.46	Variable O&M costs for Urea
VOMW ($/MWh) = (0.4*(G^2.9)*(L^0.71)*S)/(8760)	$	0.35	Variable O&M costs for catalyst: replacement & disposal
VOMP ($/MWh) =P*T*10	$	0.33	Variable O&M costs for additional auxiliary power required including additional fan power
VOMM ($/MWh) = O*U/A/1000	$	0.01	Variable O&M costs for steam
VOM ($/MWh) = VOMR + VOMW + VOMP + VOMM	**$**	**1.14**	