LADCO | LAKE MICHIGAN AIR DIRECTORS CONSORTIUM

Attainment Demonstration Modeling for the 2015 Ozone National Ambient Air Quality Standard

Technical Support Document – Supplementary Materials

Lake Michigan Air Directors Consortium

4415 W Harrison Ave, Suite 548

Hillside, IL 60162

Please direct question/comments to adelman@ladco.org

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Contents

Figures

Tables

S1. 2015 O3 NAAQS NAA Model Performance Results

Additional LADCO CAMx 2022aaa2 simulation MPE plots are available on the LADCO website: https://www.ladco.org/technical/modeling-results/ladco-2022-modeling/#Air_Quality/2015_O3_NAAQS_Serious_TSD/CAMx_LADCO_2022aaa2

Table S 1. Model performance statistics for the LADCO 2022 4km CAMx simulation of high concentration (>60 ppb) MDA8 O_3 days at each AQS monitor in the 2015 O_3 NAAQS NAAs in the LADCO region

Area	Site Name	Site ID	State	Mean Obs (ppb)	Mean Model (ppb)	NMB (%)	NME (%)	Corr
Allegan	HOLLAND	260050003	MI	68.80	58.47	-15.02	15.42	0.84
Berrien	COLOMA	260210014	MI	68.26	58.44	-14.38	14.38	0.78
Chicago	ALSIP	170310001	IL	66.72	60.59	-9.19	10.87	0.51
Chicago	CHI_SWFP	170310032	IL	66.55	59.26	-10.96	12.59	0.29
Chicago	CHI_COM	170310076	IL	67.05	58.71	-12.44	13.29	0.52
Chicago	CHI_TAFT	170311003	IL	66.15	62.77	-5.11	7.16	0.67
Chicago	LEMONT	170311601	IL	65.70	59.39	-9.60	12.34	0.25
Chicago	SCHILPRK	170313103	IL	65.83	67.36	2.33	8.92	0.26
Chicago	CICERO	170314002	IL	65.77	60.53	-7.97	8.64	0.56
Chicago	DESPLNS	170314007	IL	65.69	62.20	-5.31	6.72	0.77
Chicago	NORTHBRK	170314201	IL	66.51	61.62	-7.36	8.60	0.73
Chicago	EVANSTON	170317002	IL	66.74	60.07	-10.00	10.51	0.73
Chicago	LISLE	170436001	IL	65.32	63.07	-3.45	7.94	0.43
Chicago	ELGIN	170890005	IL	65.94	62.12	-5.79	11.45	0.28
Chicago	ZION	170971007	IL	66.59	61.41	-7.77	9.63	0.65
Chicago	CARY	171110001	IL	66.65	60.22	-9.64	11.27	0.63
Chicago	BRAIDWD	171971011	IL	64.18	56.66	-11.72	11.72	0.62
Chicago	Gary-IITRI	180890022	IN	67.67	55.66	-17.75	17.86	0.28
Chicago	Hammond	180892008	IN	66.78	55.95	-16.21	16.38	0.15
Chicago	Ogden Dunes	181270024	IN	68.73	54.78	-20.30	20.60	0.04
Chicago	Valparaiso	181270026	IN	65.38	55.30	-15.43	15.43	0.33
Chicago	CHIWAUKEE	550590019	WI	66.92	59.70	-10.78	11.21	0.73
Chicago	Kenosha	550590025	WI	66.30	62.74	-5.37	10.37	0.43
Cleveland	6th District	390350034	OH	66.71	60.90	-8.71	11.00	0.48
Cleveland	G.T.Craig	390350060	OH	65.91	61.28	-7.01	10.54	0.47
Cleveland	Berea BOE	390350064	OH	65.26	61.31	-6.05	8.79	0.26

Cleveland	Mayfield	390355002	OH	65.04	60.44	-7.07	8.73	0.54
Cleveland	Notre Dame	390550004	OH	65.92	63.54	-3.61	7.86	0.37
Cleveland	Eastlake	390850003	OH	67.22	59.78	-11.07	12.46	0.53
Cleveland	Painesville - JFS	390850007	OH	65.60	65.92	0.49	5.43	0.21
Cleveland	Elyria - Sheffield	390930018	OH	65.57	63.26	-3.52	8.51	0.06
Cleveland	Chippewa Lake	391030004	OH	66.95	58.50	-12.62	12.71	0.36
Cleveland	Lake Rockwell	391331001	OH	66.68	59.15	-11.28	11.79	0.60
Detroit	NEW HAVEN	260990009	MI	65.06	59.42	-8.67	10.18	0.69
Detroit	WARREN	260991003	MI	64.79	59.34	-8.41	8.68	0.60
Detroit	OAK PARK	261250001	MI	64.62	60.22	-6.80	8.48	0.38
Detroit	PORT HURON	261470005	MI	65.49	58.72	-10.34	11.40	0.48
Detroit	YPSILANTI	261610008	MI	65.66	58.58	-10.79	10.79	0.77
Detroit	ALLEN PARK	261630001	MI	66.36	59.23	-10.73	10.73	0.73
Detroit	E 7 MILE	261630019	MI	66.49	60.88	-8.43	10.33	-0.05
Detroit	TRINITY	261630099	MI	65.42	60.82	-7.04	8.70	0.37
Milwaukee	16TH ST	550790010	WI	66.97	64.75	-3.31	7.36	0.62
Milwaukee	BAYSIDE	550790085	WI	66.84	60.65	-9.27	10.11	0.73
Milwaukee	GRAFTON	550890008	WI	66.77	60.59	-9.25	10.35	0.73
Milwaukee	HARRINGTON	550890009	WI	67.43	61.52	-8.77	9.77	0.70
Milwaukee	Racine	551010020	WI	66.75	61.11	-8.45	10.15	0.52
Milwaukee	WAUKESHA	551330027	WI	67.58	60.88	-9.91	9.91	0.87
Muskegon	MUSKEGON	261210039	MI	72.81	63.56	-12.70	13.28	0.79
Sheboygan	SHEBOYGAN	551170006	WI	69.38	62.02	-10.60	10.73	0.56
St. Louis	WOOD_WTP	171193007	IL	67.21	63.11	-6.11	9.71	0.53
St. Louis	East St. Louis	171630010	IL	64.22	61.85	-3.68	9.00	0.43

S1.1. Ozone Non-Attainment Area Model Performance Statistics

Table S 2. CAMx 4-km monthly MDA8 O_3 performance at AQS sites in the Chicago, IL/IN/WI NAA

Region	NMB (%)		NME (%)		r	
	All	> 60ppb	All	> 60ppb	All	> 60ppb
April	7.34		11.20		0.76	
May	1.60	-2.27	12.20	5.21	0.79	0.70
June	-4.91	-11.80	10.40	13.00	0.83	0.64
July	-0.88	-12.20	10.00	13.70	0.68	-0.14
August	6.50	-2.00	12.50	11.10	0.70	-0.41
September	6.06	-11.00	12.20	11.70	0.87	-0.35

Table S 3. CAMx 4-km monthly MDA8 O_3 performance at AQS sites in the St. Louis, IL/MO NAA

Region	NMB (%)		NME (%)		r	
	All	> 60ppb	All	> 60ppb	All	> 60ppb
April	2.73		6.89		0.79	
May	10.70	-0.22	14.60	4.68	0.75	0.45
June	1.45	-4.42	10.80	7.83	0.79	0.55
July	6.86	0.15	12.30	10.50	0.77	0.43
August	13.10	5.02	17.10	11.70	0.72	0.20
September	9.56	-6.05	12.50	7.99	0.85	-0.31

Table S 4. CAMx 4-km monthly MDA8 O_3 performance at AQS sites in the Allegan County, MI NAA

Region	NMB (%)		NME (%)		r	
	All	> 60ppb	All	> 60ppb	All	> 60ppb
April	2.63		7.22		0.82	
May	-0.79		12.10		0.83	
June	-11.30		14.90		0.92	
July	-8.28		10.90		0.86	
August	4.86		10.40		0.78	
September	3.74		13.10		0.88	

Table S 5. CAMx 4-km monthly MDA8 O_3 performance at AQS sites in the Berrien County, MI NAA

Region	NMB (%)		NME (%)		r	
	All	> 60ppb	All	> 60ppb	All	> 60ppb
April	1.80		7.71		0.75	
May	-0.93		11.80		0.79	
June	-10.80		12.60		0.91	
July	-0.57		7.19		0.89	
August	12.80		16.10		0.47	
September	5.42		14.80		0.83	

Table S 6. CAMx 4-km monthly MDA8 O_3 performance at AQS sites in the Muskegon County, MI NAA

Region	NMB (%)		NME (%)		r	
	All	> 60ppb	All	> 60ppb	All	> 60ppb
April	7.97		10.20		0.78	
May	2.32	-2.25	12.10	4.26	0.81	0.84
June	-3.93	-15.60	12.90	16.00	0.90	0.76
July	-1.05	-13.20	10.40	13.20	0.85	0.88
August	14.20		17.20		0.83	
September	17.60		21.00		0.88	

Table S 7. CAMx 4-km monthly MDA8 O_3 performance at AQS sites in the Detroit, MI NAA

Region	NMB (%)		NME (%)		r	
	All	> 60ppb	All	> 60ppb	All	> 60ppb
April	9.72		11.80		0.77	
May	4.40	-1.45	10.60	4.31	0.83	0.60
June	-1.96	-10.60	9.78	11.30	0.81	0.55
July	-1.82	-7.21	7.04	8.44	0.87	0.31
August	6.96	-2.95	14.00	4.53	0.61	-0.89
September	9.23	-10.90	14.50	10.90	0.89	0.21

Table S 8. CAMx 4-km monthly MDA8 O_3 performance at AQS sites in the Cleveland, OH NAA

Region	NMB (%)		NME (%)		r	
	All	> 60ppb	All	> 60ppb	All	> 60ppb
April	7.87	-9.90	10.90	9.90	0.76	0.96
May	8.30	-0.79	11.60	6.29	0.84	0.16
June	-1.46	-11.20	10.10	11.80	0.81	0.56
July	1.39	-7.43	9.64	10.50	0.76	0.24
August	5.98	-7.32	11.70	10.50	0.75	0.02
September	7.08	-18.90	11.30	18.90	0.89	

Table S 9. CAMx 4-km monthly MDA8 O_3 performance at AQS sites in the Milwaukee, WI NAA

Region	NMB (%)		NME (%)		r	
	All	> 60ppb	All	> 60ppb	All	> 60ppb
April	4.31		10.30		0.78	
May	-0.25	-6.19	9.50	7.24	0.90	0.81
June	-5.61	-11.00	9.86	12.30	0.87	0.70
July	-2.62	-4.50	8.11	5.83	0.86	0.49
August	7.08	-1.38	12.70	5.03	0.82	0.64
September	2.88	-12.60	12.30	12.70	0.91	0.19

Table S 10. CAMx 4-km monthly MDA8 O_3 performance at AQS sites in the Sheboygan County, WI NAA

Region	NMB (%)		NME (%)		r	
	All	> 60ppb	All	> 60ppb	All	> 60ppb
April	4.10		9.67		0.76	
May	-1.75	-5.20	7.81	5.20	0.92	0.75
June	-7.14	-14.50	10.60	14.50	0.90	0.71
July	-5.16	-8.00	8.53	8.00	0.91	0.84
August	3.47	-6.10	12.00	6.53	0.84	0.75
September	-0.88	-18.70	14.50	18.70	0.89	0.37

S2. Description of CART Nodes

Table S 11. Description of each high-ozone node for the different CART analyses, including its average ozone concentration and the meteorological characteristics of days within the node. Meteorological parameter abbreviations are explained in Table S12.

		Mean Ozone (ppb)						
Area	**node**	**2001-10**	**2011-23**	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**
Chicago - Kenosha-Lake	23	63.4	58.7	tavgpm > 80.4	tavgpm ≤ 84.9	lagstpavg > 992.4	rhavg ≤ 66.8	
Chicago - Kenosha-Lake	27	66.5	61.0	tavgpm > 80.4	tavgpm > 84.9	tranwest ≤ 219.6	avg_W_am ≤ 0.37	
Chicago - Kenosha-Lake	28	77.7	66.9	tavgpm > 80.4	tavgpm > 84.9	tranwest ≤ 219.6	avg_W_am > 0.37	
Chicago - Kenosha-Lake	30	66.5	61.6	tavgpm > 80.4	tavgpm > 84.9	tranwest > 219.6	ws2day ≤ 3.5	
Chicago - Cook Co.	20	56.4	54.3	tavgpm > 78.8	tavgpm ≤ 85.6	lagstpavg > 995.3		
Chicago - Cook Co.	23	58.4	59.3	tavgpm > 78.8	tavgpm > 85.6	trandis ≤ 629.3	lagstpavg ≤ 992.2	
Chicago - Cook Co.	24	67.7	63.7	tavgpm > 78.8	tavgpm > 85.6	trandis ≤ 629.3	lagstpavg > 992.2	
Chicago - Cook Co.	25	53.0	55.6	tavgpm > 78.8	tavgpm > 85.6	trandis > 629.3		
Chicago - Lake-Porter	24	58.2	49.7	tmax > 79.1	tmax ≤ 85.0	lagstpavg > 994.4	lag_S_wn > -0.14	
Chicago - Lake-Porter	27	58.1	53.9	tmax > 79.1	tmax > 85.0	rhavgmid ≤ 59.8	lagstpavg ≤ 991.6	
Chicago - Lake-Porter	28	68.9	56.3	tmax > 79.1	tmax > 85.0	rhavgmid ≤ 59.8	lagstpavg > 991.6	
Detroit	22	64.4	56.3	tavgpm > 80.1	tavgpm ≤ 86.1	lagstpavg > 996.2		
Detroit	24	72.3	60.8	tavgpm > 80.1	tavgpm > 86.1	wndrun≤ 443.1		
Detroit	25	62.3	56.6	tavgpm > 80.1	tavgpm > 86.1	wndrun > 443.1		
Cleveland	21	63.2	53.5	tavgpm > 77.1	tavgpm ≤ 83.8	trandis ≤ 213.8	transouth > 2.1	
Cleveland	27	66.5	59.3	tavgpm > 77.1	tavgpm > 83.8	wndrun ≤ 406.8	tavgpm ≤ 86.6	
Cleveland	28	80.1	62.7	tavgpm > 77.1	tavgpm > 83.8	wndrun ≤ 406.8	tavgpm > 86.6	
Cleveland	30	64.5	60.0	tavgpm > 77.1	tavgpm > 83.8	wndrun > 406.8	rhavgmid ≤ 53.0	

Table S 11 (cont'd)

Area	node	Mean Ozone (ppb) 2001-10	2011-23	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
St. Louis	17	63.6	56.4	tavgpm > 79.8	rhavgmid ≤ 50.4	trandis ≤ 450.5	tavgpm ≤ 87.8	tranwest ≤ -48.7
St. Louis	20	66.3	61.1	tavgpm > 79.8	rhavgmid ≤ 50.4	trandis ≤ 450.5	tavgpm > 87.8	lagstpavg ≤ 991.3
St. Louis	21	73.8	58.7	tavgpm > 79.8	rhavgmid ≤ 50.4	trandis ≤ 450.5	tavgpm > 87.8	lagstpavg > 991.3
St. Louis	29	60.4	49.8	tavgpm > 79.8	rhavgmid > 50.4	wndrun ≤ 516.6	rhavgmid ≤ 62.8	lagstpavg > 992.1
Louisville	9	59.9	54.3	rhavgmid ≤ 60.2	tavgpm > 79.8	wndrun ≤ 544.2	tavgpm ≤ 85.0	rhavgmid ≤ 46.5
Louisville	12	68.0	57.7	rhavgmid ≤ 60.2	tavgpm > 79.8	wndrun ≤ 544.2	tavgpm > 85.0	rhavgmid ≤ 47.3
Louisville	13	60.6	50.6	rhavgmid ≤ 60.2	tavgpm > 79.8	wndrun ≤ 544.2	tavgpm > 85.0	rhavgmid > 47.3
Cincinnati	18	65.5	59.4	tavgpm > 82.3	trandis ≤ 399.4	tavgpm <= 87.6	rhavgmid ≤ 56.8	
Cincinnati	21	70.8	64.2	tavgpm > 82.3	trandis ≤ 399.4	tavgpm > 87.6	stpavg ≤ 1000.4	
Cincinnati	22	77.6	58.1	tavgpm > 82.3	trandis ≤ 399.4	tavgpm > 87.6	stpavg > 1000.4	
Cincinnati	24	60.7	58.1	tavgpm > 82.3	trandis > 399.4	rhavgmid ≤ 53.8		
Door	16	58.0	52.9	avg_S_win > 1.82	tavgam ≤ 72.1	avg_S_win > 3.1		
Door	17	70.8	58.8	avg_S_win > 1.82	tavgam > 72.1			
Manitowoc	18	55.3	53.4	transouth > 53.4	avg_S_pm > 3.71	tem2day ≤ 75.3		
Manitowoc	19	68.6	63.0	transouth > 53.4	avg_S_pm > 3.71	tem2day > 75.3		
Sheboygan	20	64.4	57.5	transouth > -147.3	tmax > 73.5	avg_S_pm ≤ 4.7	tavgam > 74.4	
Sheboygan	21	73.0	64.0	transouth > -147.3	tmax > 73.5	avg_S_pm > 4.7		
North Milwaukee	22	72.4	61.3	tmax > 78.9	avg_S_pm > 2.39	avg_W_pm ≤ -1.9		
North Milwaukee	25	64.9	57.6	tmax > 78.9	avg_S_pm > 2.39	avg_W_pm > -1.9	tmax > 84.3	
Downtown Milwaukee	26	68.8	61.2	tmax > 78.2	avg_S_pm > 2.49	tavgam > 77.4	avg_W_pm ≤ -1.9	
Downtown Milwaukee	27	56.2	52.1	tmax > 78.2	avg_S_pm > 2.49	tavgam > 77.4	avg_W_pm > -1.9	

Table S 11 (cont'd)

Area	node	Mean Ozone (ppb) 2001-10	2011-23	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Racine	24	60.1	54.6	tmax > 78.2	tavgam ≤ 79.3	lagstpavg > 993.1		
Racine	26	73.9	63.4	tmax > 78.2	tavgam > 79.3	tranwest ≤ 242.9		
Racine	27	60.9	55.9	tmax > 78.2	tavgam > 79.3	tranwest > 242.9		
Muskegon	24	64.7	57.0	avg_S_win > 0.33	tavgpm > 78.8	tavgpm ≤ 83.3		
Muskegon	25	76.8	65.5	avg_S_win > 0.33	tavgpm > 78.8	tavgpm > 83.3		
Allegan	22	65.6	56.6	tmax > 76.0	avg_S_pm > 0.717	tavgpm > 78.9	avg_W_am ≤ 0.45	
Allegan	23	76.6	63.9	tmax > 76.0	avg_S_pm > 0.717	tavgpm > 78.9	avg_W_am > 0.45	
Berrien	18	62.9	56.4	tavgpm > 79.2	tavgpm ≤ 85.0	lagstpavg > 988.0	tavgpm > 81.8	
Berrien	20	76.0	67.0	tavgpm > 79.2	tavgpm > 85.0	rhavg ≤ 64.1		
Berrien	21	67.3	56.8	tavgpm > 79.2	tavgpm > 85.0	rhavg > 64.1		

S3. Description of CART Analysis

We applied a simple form of machine learning to adjust O_3 data for meteorological factors to simplify interpretation of the remaining trends in O_3. A classification and regression tree (CART) analysis is a statistical tool to classify data. We applied CART to 8-hour ozone (O_3) and daily meteorological data to determine the meteorological conditions most commonly associated with high-O_3 days in O_3 nonattainment and maintenance areas in the LADCO region. Once days are classified by their unique, shared meteorological characteristics, O_3 concentration trends among days with similar local meteorological conditions can be examined. We use CART to normalize the influence of year-to-year local meteorological variability on O_3 concentrations at surface monitors within designated O_3 NAAQS nonattainment and maintenance areas. We interpret the remaining trend in O_3 concentrations after controlling for meteorology to be the result of non-meteorological factors. The most likely driver of the residual trend is the change in emissions of O_3 precursors over time. Other drivers may include changes in the long-range transport of precursors, biomass burning smoke, or long-term average weather conditions.

S3.1. Meteorological and O_3 Data

The CART analysis processed dozens of meteorological variables for each day to determine which variables are the most effective at predicting daily maximum 8-hour (MDA8) O_3 concentrations. The analysis focused on warm season months (May to September). EPA processed surface meteorological data at all airports in the U.S. for the years 2001 through 2023 and provided these data to LADCO.[1] Meteorological parameters related to transport of air masses (southerly transport distance, transport direction, etc.) were determined based on EPA and LADCO runs of the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model. EPA processed HYSPLIT data for the years 2001 through 2019; LADCO processed the HYSPLIT data for 2020 through 2023 because EPA stopped processing these data. Comparisons of 2019 HYSPLIT data prepared by EPA and LADCO demonstrated that LADCO's analysis exactly

[1] Upper air observations were not included in this analysis because EPA is no longer processing this data.

reproduced EPA's analysis for the variables used here. The meteorological parameters used in the analysis are listed in Table S12. LADCO dropped all 2015 meteorological data because of apparent issues with the temperature data provided by EPA. This analysis does not include data for 2024 because the meteorological data for this year were not yet complete.[2]

LADCO downloaded MDA8 O_3 concentrations for regulatory monitors from EPA's Air Data website (https://aqs.epa.gov/aqsweb/airdata/download_files.html). Ozone data were only included for monitors with long-term records, defined as monitors that had at least 75% data completeness in 19 out of 23 years (from 2001 to 2023).

S3.2. CART Analysis

LADCO conducted the CART analyses in *R* using the *ctree* function from the package *partykit*. *Ctree* is a non-parametric class of regression tree that avoids overfitting data by applying a statistical approach using a significance test (using a p-value) for each split. We pruned the regression trees using the *ctree_control* options: *maxdepth, minsplit,* and *minbucket*, with *maxsurrogate* set to 3; these options control the maximum depth of the tree, the minimum number of days in a node to allow it to be further split, the minimum number of days in a terminal node, and the number of surrogate splits allowed in case of missing data, respectively. The aim was to produce a tree that met the following objectives:

(1) had at least one node with relatively high average O_3 concentrations (65 to greater than 70 parts per billion, ppb), such that days in this node would impact attainment of the 2015 O_3 NAAQS;
(2) was not too complicated; ideally, the trees would contain 14 or fewer terminal nodes, however, some trees contained up to 17 terminal nodes;

[2] The meteorological data used in the CART analysis require significant processing by the National Oceanic and Atmospheric Administration (NOAA), the National Weather Service, the Environmental Protection Agency (EPA) and LADCO. This processing is time-consuming and results in a lag between the end of the year and when the data are available for use.

(3) contained relatively complete records, ideally with data for each node in every year, but minimally missing just a few year-node combinations.

Data for nodes with fewer than 3 days in a year were dropped from the trends figures for that year.

We used O_3 and meteorological data from the years 2001-2010 to determine the meteorological conditions that lead to high O_3 concentrations via the CART analysis. We limited analysis to data from a single decade to minimize the confounding impacts of changing emissions of O_3 precursors over time on O_3 concentrations.[3] We then applied the model to meteorological data from the years 2011-2023 to identify the nodes for each day during this period. After running the CART analysis, we selected the meteorologically similar days ("nodes") that had average MDA8 values greater than 60 ppb in either 2001-2010 or 2011-2023 for most areas. We applied a lower threshold of 55 ppb to define high-O_3 nodes for areas with very low O_3 (such as Chicago Cook County or Chicago Lake-Porter). These day types are considered to be "O_3-conducive" and are listed in Table S11.

[3] CART works by identifying "decision rules" that split the data into sets of days with similar meteorological conditions that have relatively similar O_3 concentrations. Building the model based on the whole 23 years of data would blur the relationships between meteorology and O_3 because it would appear that the same weather conditions could lead to very different O_3 outcomes in early versus later years. (For example, reductions in O_3 precursors over time may have caused identical meteorological conditions to create 80 ppb O_3 in 2001 but only 70 ppb O_3 in 2023.) These changes would confuse the model and make it harder to define the relationships between meteorology and O_3.

Table S 12. Daily meteorological parameters used in the CART analysis.

Parameter	Description	Units
avg_S_am	Average Morning Wind South (v) Vector	meters/second (m/s)
avg_S_pm	Average Morning Wind South (v) Vector	meters/second (m/s)
avg_S_win	Average Wind South (v) Vector	meters/second (m/s)
avg_W_am	Average Morning Wind West (u) Vector	meters/second (m/s)
avg_W_pm	Average Afternoon Wind West (u) Vector	meters/second (m/s)
avg_W_win	Average Wind West (u) Vector	meters/second (m/s)
dpavg	Average Daily Dew Point Temperature	Degrees Fahrenheit (°F)
dpmax	Maximum Daily Dew Point Temperature	Degrees Fahrenheit (°F)
foghrs	Hours of Fog	Hours
hazehrs	Hours of Haze	Hours
lag_S_wn	Previous Day Wind South (V) Vector	meters/second (m/s)
lag_W_wn	Previous Day Wind West (U) Vector	meters/second (m/s)
lagstpavg	Previous Day Station Pressure	millibars (mb)
lagtmax	Previous Day Max Temp	Degrees Fahrenheit (°F)
lagwsavg	Previous Day Avg Wind Speed	meters/second (m/s)
mrmax	Maximum Water Vapor Mixing Ratio	grams/kilogram (g/kg)
precip	24-hour Precipitation	inches
presschange	24-hour Pressure Change	millibars (mb)
rainhrs	Hours of Rain	hours
rhavg	Average Daily Relative Humidity	Percent (%)
rhavgmid	Average Midday Relative Humidity	Percent (%)
rhavgnight	Average Nighttime Relative Humidity	Percent (%)
slpavg	Average Sea Level Pressure	millibars (mb)
stpavg	Average Station Pressure	millibars (mb)
taavg	Average Apparent Temperature	Degrees Fahrenheit (°F)
tamax	Maximum Apparent Temperature	Degrees Fahrenheit (°F)
tamin	Minimum Apparent Temperature	Degrees Fahrenheit (°F)
tavgam	Average Morning Temperature	Degrees Fahrenheit (°F)
tavgpm	Average Afternoon Temperature	Degrees Fahrenheit (°F)
tem2day	Average 2-day Temperature	Degrees Fahrenheit (°F)
tem3day	Average 3-day Temperature	Degrees Fahrenheit (°F)
tempchange	24-hr Temperature Change"	Degrees Fahrenheit (°F)
tmax	Maximum Daily Temperature	Degrees Fahrenheit (°F)
trandir	24-hr Transport Direction	Degrees (°)
trandis	24-hr Transport Distance	kilometers (km)
transouth	Southerly (v) Component of 24-hr Transport Vector	kilometers (km)
tranw	Vertical (z) Component of 24-hr Transport Vector	kilometers (km)
tranwest	Westerly (u) Component of 24-hr Transport Vector	kilometers (km)

Table S 12 (continued).

Parameter	Description	Units
wdavg	Average Daily Wind Direction	Degrees (°)
wdavgam	Average Morning Wind Direction	Degrees (°)
wdavgpm	Average Afternoon Wind Direction	Degrees (°)
weekday	Day of Week	
wndrun	24-hr Scalar Wind Run	kilometers (km)
ws2day	Average 2-day Wind Speed	meters/second (m/s)
ws3day	Average 3-day Wind Speed	meters/second (m/s)
wsavg	Average Daily Wind Speed	meters/second (m/s)
wsavgam	Average Morning Wind Speed	meters/second (m/s)
wsavgpm	Average Afternoon Wind Speed	meters/second (m/s)

S4. ERTAC 22.1 Electricity Generating Unit Shutdowns

The table below shows the electricity generating units (EGU) that operated in 2022 but were excluded from the LADCO 2026 CAMx modeling because they are scheduled to shut down before the end of 2026. The ERTAC EGU model considers shut downs that are scheduled in 2026, only discontinuing the emissions after the scheduled retirement date. If the offline end date was a year then it was assumed it was January 1st of that year.

ORIS id	CAMD unit id	FIPS code	County Code	County Name	State	Facility Name	ERTAC Region	Online Start Date	Offline End Date	Primary Fuel
856	2	17143	17143	Peoria	IL	E D Edwards	MISC	1968	1/1/2023	Coal
856	3	17143	17143	Peoria	IL	E D Edwards	MISC	1972	1/1/2023	Coal
883	7	17097	17097	Lake	IL	Waukegan	PJMC	1958	1/1/2023	Coal
883	8	17097	17097	Lake	IL	Waukegan	PJMC	1962	1/1/2023	Coal
884	3	17197	17197	Will	IL	Will County	PJMC	1957	1/1/2023	Coal
884	4	17197	17197	Will	IL	Will County	PJMC	1963	1/1/2023	Coal
887	1	17127	17127	Massac	IL	Joppa Steam	MISC	1953	2025	Coal
887	2	17127	17127	Massac	IL	Joppa Steam	MISC	1953	2025	Coal
887	3	17127	17127	Massac	IL	Joppa Steam	MISC	1954	2025	Coal
887	4	17127	17127	Massac	IL	Joppa Steam	MISC	1954	2025	Coal
887	5	17127	17127	Massac	IL	Joppa Steam	MISC	1955	2025	Coal
887	6	17127	17127	Massac	IL	Joppa Steam	MISC	1955	2025	Coal
889	1	17157	17157	Randolph	IL	Baldwin Energy Complex	MISC	1970	2025	Coal
889	2	17157	17157	Randolph	IL	Baldwin Energy Complex	MISC	1973	2025	Coal
963	33	17167	17167	Sangamon	IL	Dallman	MISC	1950	2023	Coal
994	2	18125	18125	Pike	IN	IPL - Petersburg Generating Station	MISC	1950	2023	Coal
994	3	18125	18125	Pike	IN	IPL - Petersburg Generating Station	MISC	1950	2025	Coal

994	4	18125	18125	Pike	IN	IPL - Petersburg Generating Station	MISC	1986	2025	Coal
1012	2	18173	18173	Warrick	IN	F B Culley Generating Station	MISC	1966	12/30/2025	Coal
6085	17	18073	18073	Jasper	IN	R M Schahfer Generating Station	MISC	1983	12/31/2025	Coal
6085	18	18073	18073	Jasper	IN	R M Schahfer Generating Station	MISC	1986	12/31/2025	Coal
6137	1	18129	18129	Posey	IN	A B Brown Generating Station	MISC	1979	12/30/2023	Coal
6137	2	18129	18129	Posey	IN	A B Brown Generating Station	MISC	1986	12/30/2023	Coal
1702	1	26017	26017	Bay	MI	Dan E Karn	MISE	1950	12/31/2023	Coal
1702	2	26017	26017	Bay	MI	Dan E Karn	MISE	1950	12/31/2023	Coal
1710	1	26139	26139	Ottawa	MI	J H Campbell	MISE	1962	12/31/2025	Coal
1710	2	26139	26139	Ottawa	MI	J H Campbell	MISE	1967	12/31/2025	Coal
1710	3	26139	26139	Ottawa	MI	J H Campbell	MISE	1980	12/31/2025	Coal
1743	2	26147	26147	Saint Clair	MI	St. Clair	MISE	1953	1/1/2023	Coal
1743	3	26147	26147	Saint Clair	MI	St. Clair	MISE	1954	1/1/2023	Coal
1743	6	26147	26147	Saint Clair	MI	St. Clair	MISE	1961	1/1/2023	Coal
1743	7	26147	26147	Saint Clair	MI	St. Clair	MISE	1969	1/1/2023	Coal
1745	9A	26163	26163	Wayne	MI	Trenton Channel	MISE	1948	1/1/2023	Coal
1832	1	26045	26045	Eaton	MI	Erickson	MISE	1973	1/1/2023	Coal
6034	1	26147	26147	Saint Clair	MI	Belle River	MISE	1950	12/31/2025	Coal
50835	1	26101	26101	Manistee	MI	TES Filer City Station	MISE	1990	2025	Coal
50835	2	26101	26101	Manistee	MI	TES Filer City Station	MISE	1990	2025	Coal
1913	1	27037	27037	Dakota	MN	Inver Hills	MISW	2012	2026	Nat Gas
1913	2	27037	27037	Dakota	MN	Inver Hills	MISW	2012	2026	Nat Gas
1913	3	27037	27037	Dakota	MN	Inver Hills	MISW	2012	2026	Nat Gas
1913	4	27037	27037	Dakota	MN	Inver Hills	MISW	2012	2026	Nat Gas
1913	5	27037	27037	Dakota	MN	Inver Hills	MISW	2012	2026	Nat Gas
1913	6	27037	27037	Dakota	MN	Inver Hills	MISW	2012	2026	Nat Gas
6090	2	27141	27141	Sherburne	MN	Sherburne County	MISW	1977	12/31/2023	Coal
8027	1	27139	27139	Scott	MN	Blue Lake Generating Plant	MISW	04/26/1974	2023	Diesel
8027	2	27139	27139	Scott	MN	Blue Lake Generating Plant	MISW	04/26/1974	2023	Diesel

8027	3	27139	27139	Scott	MN	Blue Lake Generating Plant	MISW	04/26/1974	2023	Diesel
8027	4	27139	27139	Scott	MN	Blue Lake Generating Plant	MISW	04/26/1974	2023	Diesel
10075	1	27031	27031	Cook	MN	Taconite Harbor Energy Center	MISW	1950	1/1/2023	Coal
10075	2	27031	27031	Cook	MN	Taconite Harbor Energy Center	MISW	1950	1/1/2023	Coal
10849	PB1	27075	27075	Lake	MN	Northshore Mining Silver Bay Power	CONUS	1955	1/1/2023	Coal
10849	PB2	27075	27075	Lake	MN	Northshore Mining Silver Bay Power	CONUS	1963	1/1/2023	Coal
2832	6	39061	39061	Hamilton	OH	Miami Fort Power Station	PJMW	1960	1/1/2023	Coal
2836	12	39093	39093	Lorain	OH	Avon Lake Power Plant	PJMW	1950	1/1/2023	Coal
2836	CT10	39093	39093	Lorain	OH	Avon Lake Power Plant	PJMW	1950	1/1/2023	Diesel
2837	6	39085	39085	Lake	OH	Eastlake	PJMW	1973	1/1/2023	Diesel
2866	1	39081	39081	Jefferson	OH	W H Sammis	PJMW	1959	1/1/2023	Coal
2866	2	39081	39081	Jefferson	OH	W H Sammis	PJMW	1960	1/1/2023	Coal
2866	3	39081	39081	Jefferson	OH	W H Sammis	PJMW	1961	1/1/2023	Coal
2866	4	39081	39081	Jefferson	OH	W H Sammis	PJMW	1962	1/1/2023	Coal
2866	5	39081	39081	Jefferson	OH	W H Sammis	PJMW	1967	7/1/2023	Coal
2866	6	39081	39081	Jefferson	OH	W H Sammis	PJMW	1969	7/1/2023	Coal
2866	7	39081	39081	Jefferson	OH	W H Sammis	PJMW	1971	7/1/2023	Coal
6019	A	39025	39025	Clermont	OH	W H Zimmer Generating Station	CONUS	1991	1/1/2023	
6019	B	39025	39025	Clermont	OH	W H Zimmer Generating Station	CONUS	1991	1/1/2023	
6019	1	39025	39025	Clermont	OH	W H Zimmer Generating Station	PJMW	1990	1/1/2023	Coal
4041	5	55079	55079	Milwaukee	WI	South Oak Creek	MISW	1959	2025	Coal
4041	6	55079	55079	Milwaukee	WI	South Oak Creek	MISW	1961	2025	Coal
4041	7	55079	55079	Milwaukee	WI	South Oak Creek	MISW	1965	2026	Coal
4041	8	55079	55079	Milwaukee	WI	South Oak Creek	MISW	1967	2026	Coal

4078	2	55073	55073	Marathon	WI	Weston	MISW	06/01/2015	2023	Natural Gas

S5. Summer 2026 ERTAC Projected Daily EGU Emissions By Fuel type for the LADCO States.

Power sector emissions have significant variability by day. Daily variability is impacted when fuel types used to respond to peak loads like simple cycle gas are shown. In the chart when there is no color that indicated that there are no units in the state with that fuel type.

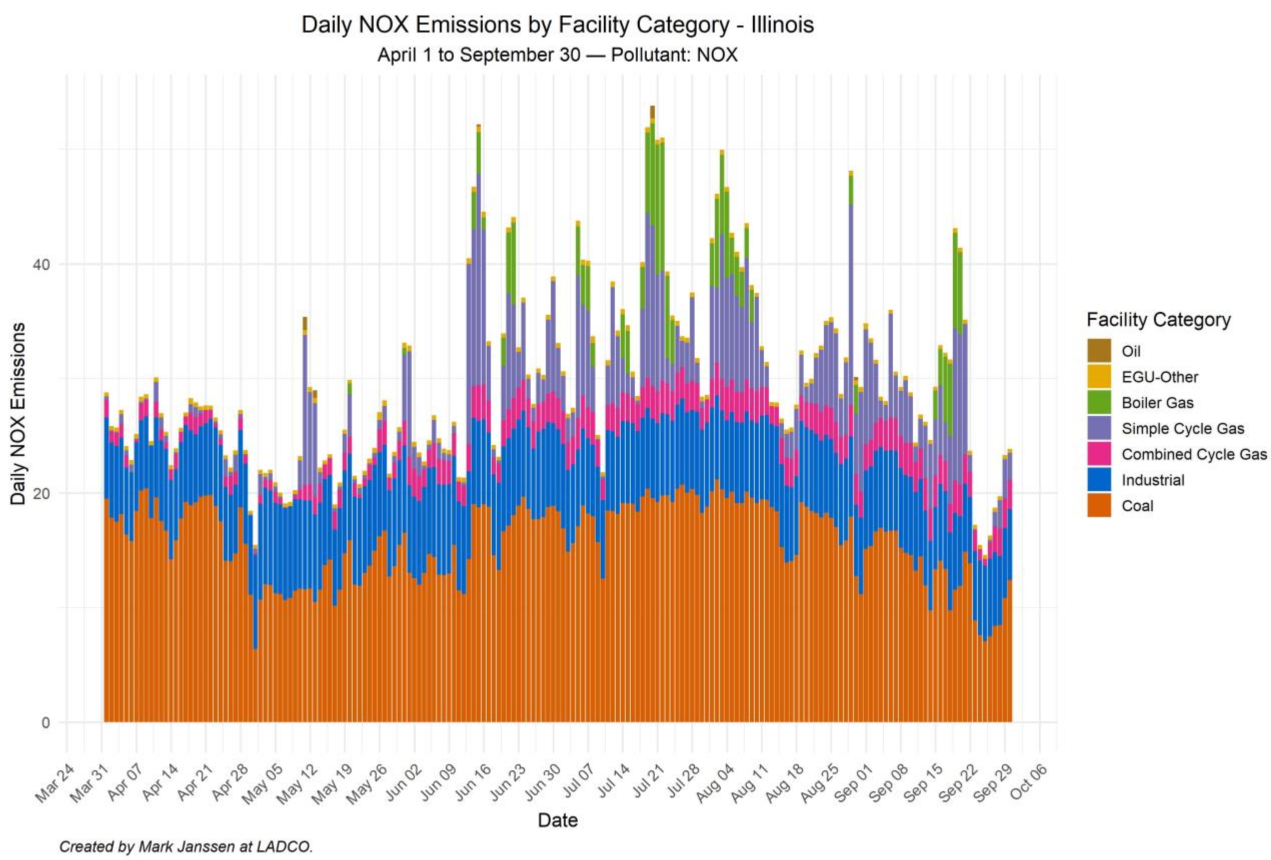

Figure S5-1. Daily NOx emissions for Illinois Electricity Generating Units by fuel category

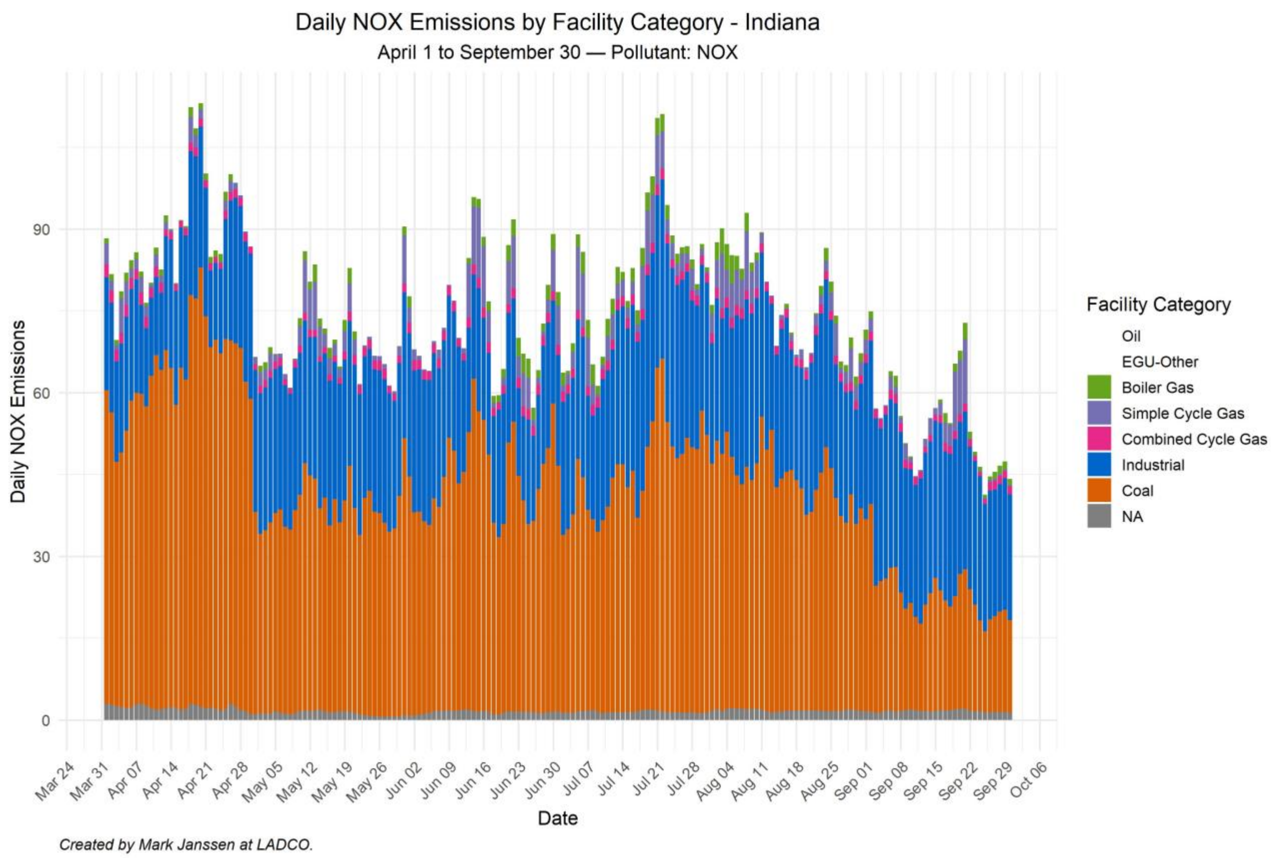

Figure S5-2. Daily NOx emissions for Indiana Electricity Generating Units by fuel category

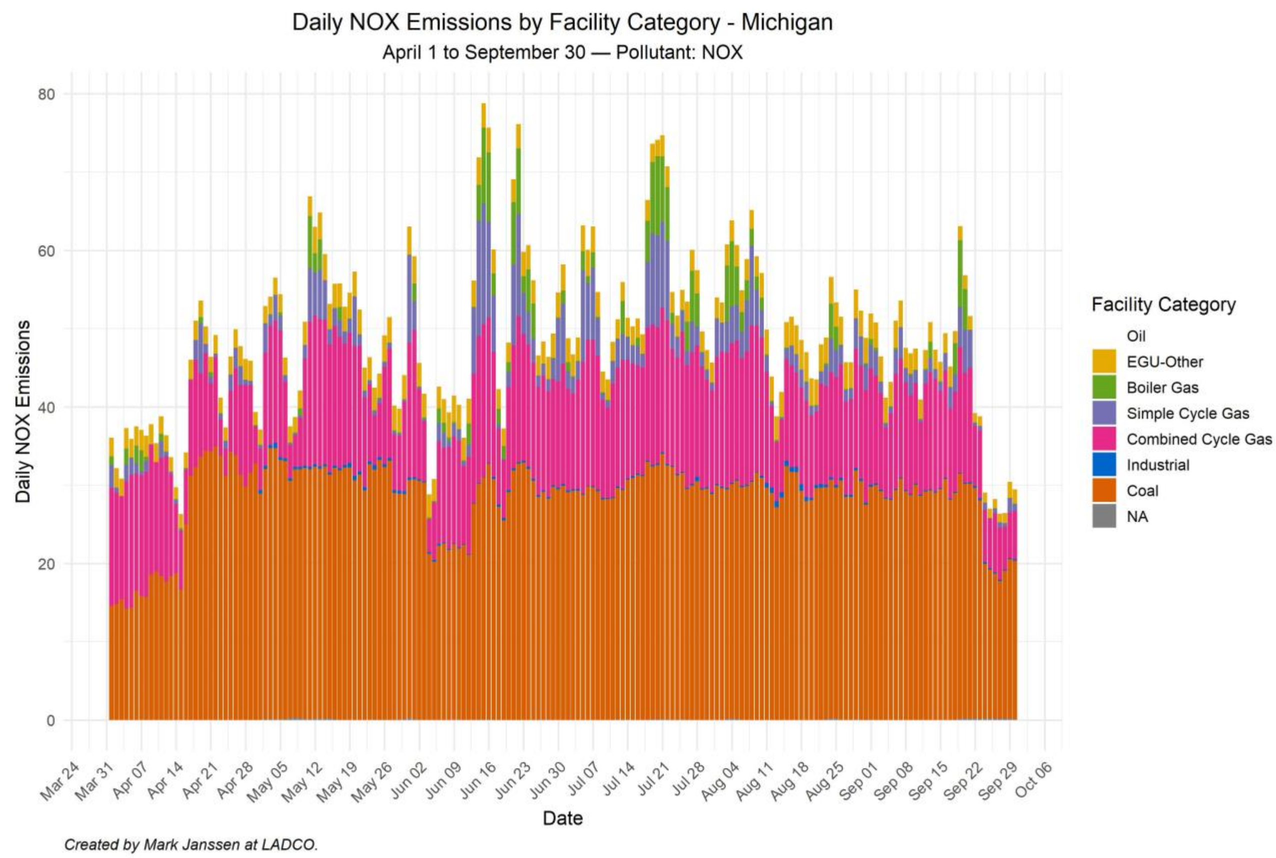

Figure S5-3. Daily NOx emissions for Michigan Electricity Generating Units by fuel category

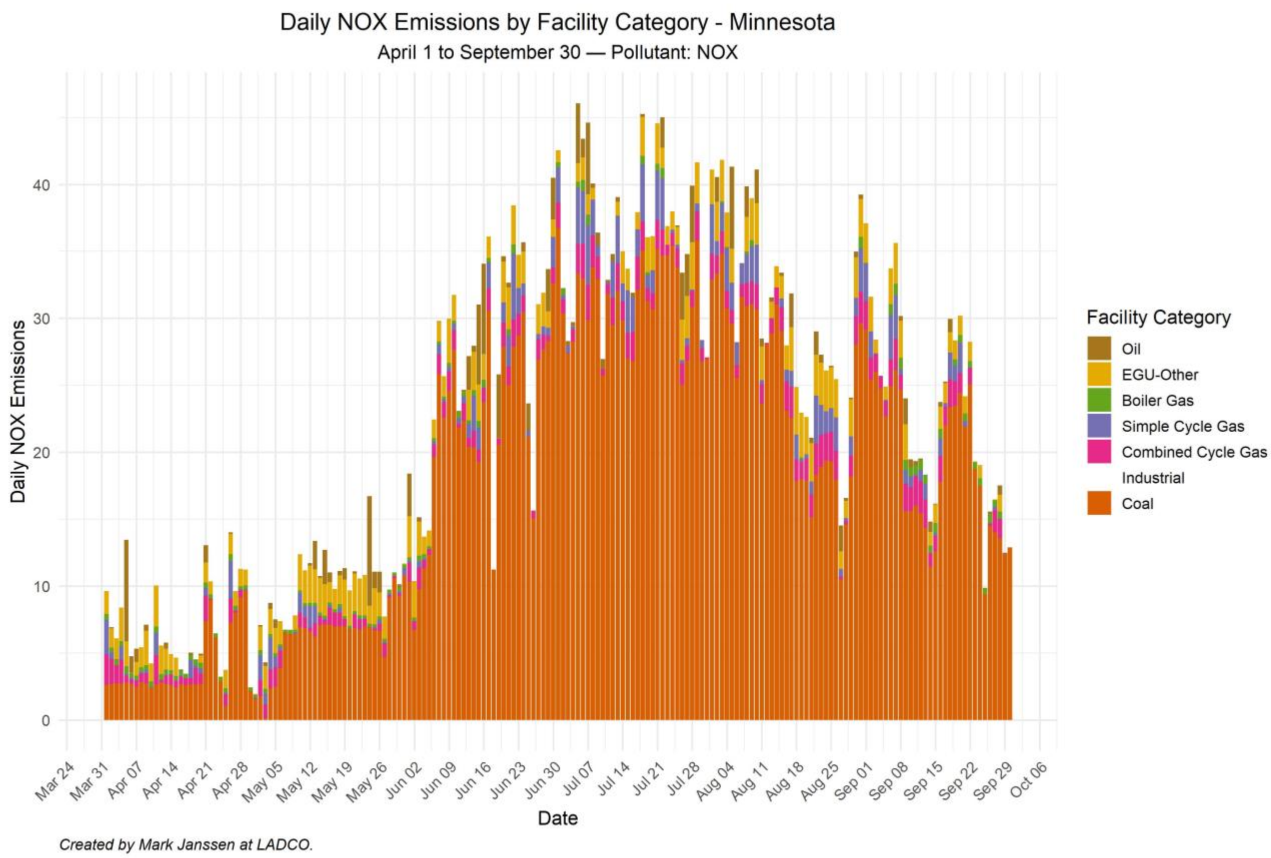

Figure S5-4. Daily NOx emissions for Minnesota Electricity Generating Units by fuel category

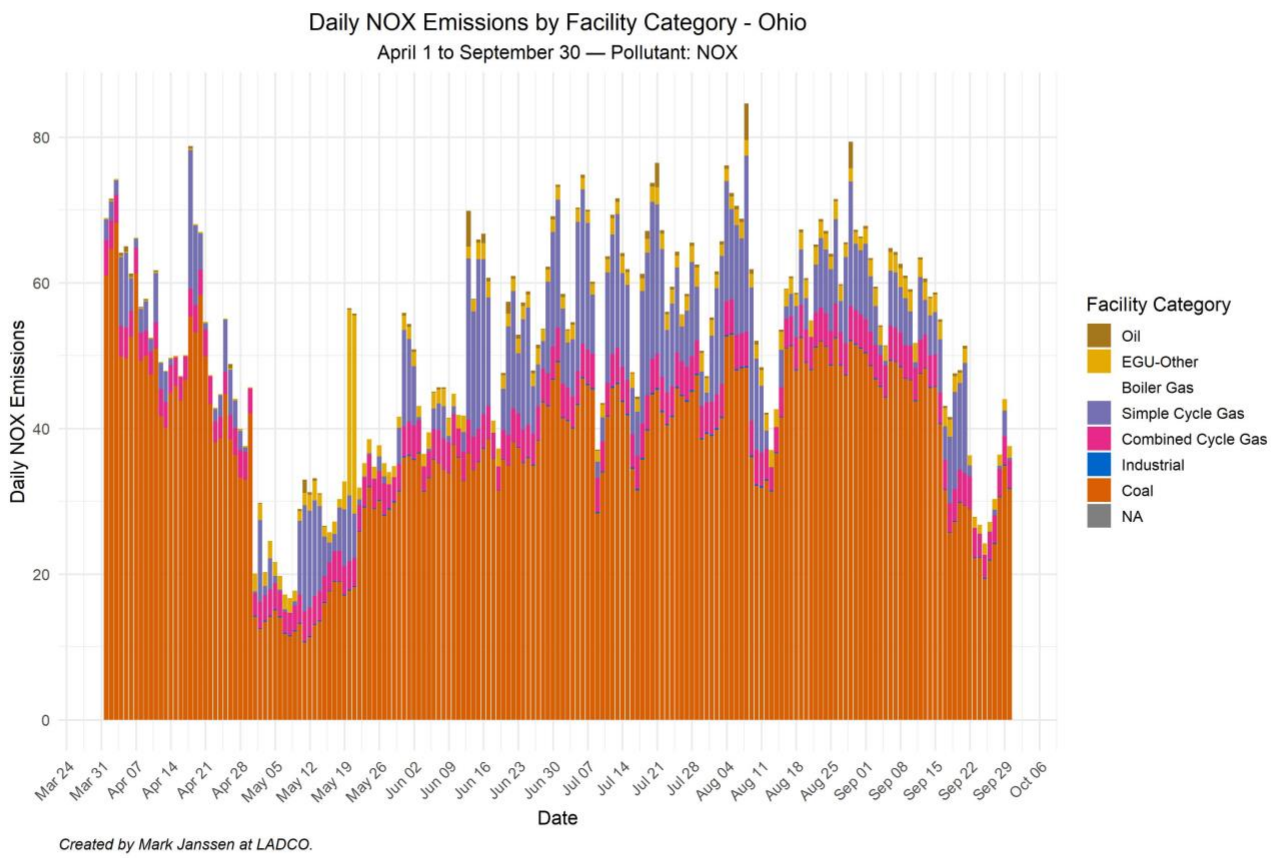

Figure S5-5. Daily NOx emissions for Ohio Electricity Generating Units by fuel category

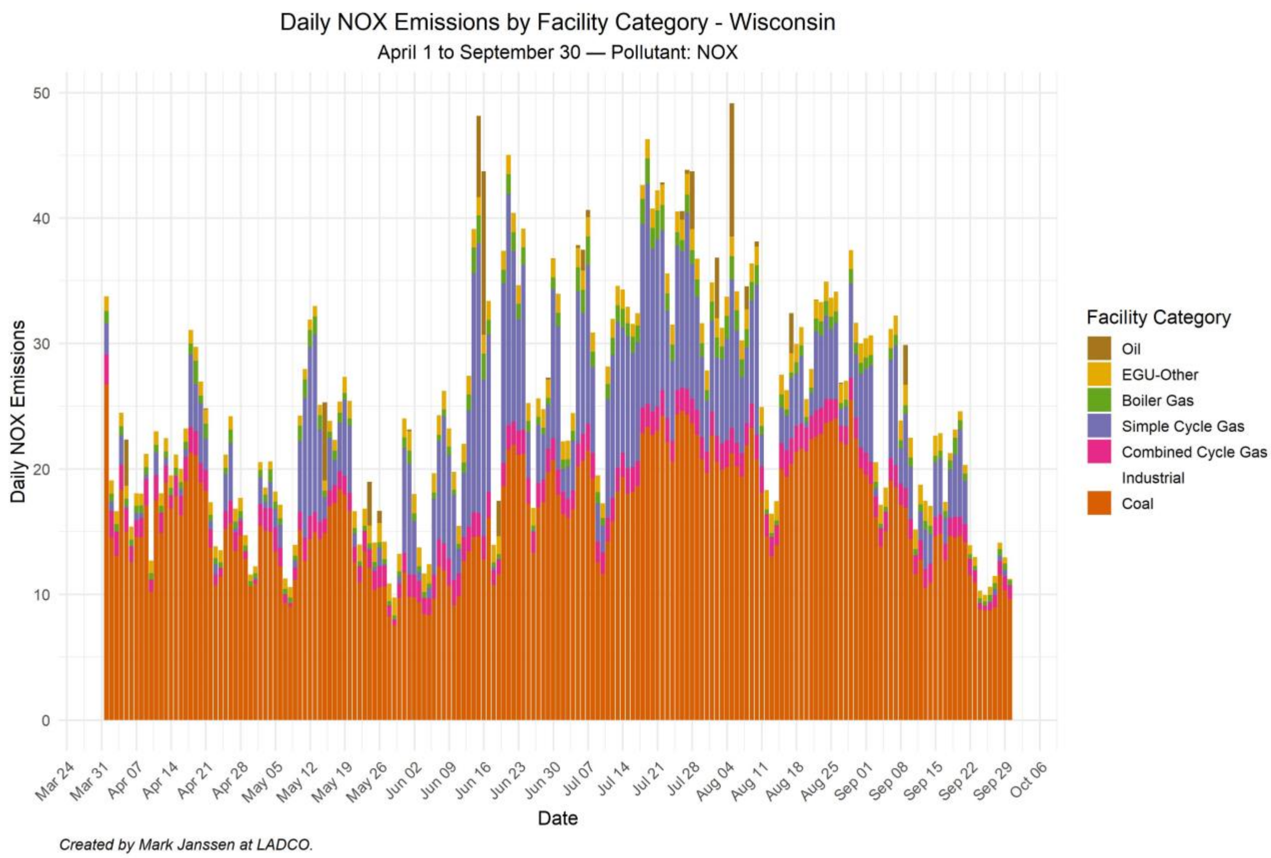

Figure S5-6. Daily NOx emissions for Illinois Electricity Generating Units by fuel category