2018–2022 CO_2, SO_2 and NO_X Emission Rates

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Contents

Introduction

To support the efforts of regulators, stakeholders and other interested parties as they work toward achieving environmental goals, PJM Interconnection provides this annual emission report with data on both marginal and average emission rates from electric generators in the PJM footprint. In addition to this annual report, PJM posts 5-minute marginal emission rates for individual load nodes on Data Miner.

PJM expects to release this yearly report in the spring following the end of each calendar year.

Marginal Units

To balance electricity supply and demand, strategically located electric generating units are scheduled to operate to ensure the efficient and reliable delivery of power. A marginal unit is the generation resource that sets the real-time energy price (locational marginal price or LMP) in each five-minute interval. The price at which the final resource committed to maintain system reliability and match energy supply and demand is the marginal price of electricity. The marginal price, in comparison to the average price, most accurately represents the cost of producing the last megawatt of energy used or saved. Any variations in dispatch patterns to ensure systemwide reliability may change the set of marginal units for that dispatch interval. Therefore, a significant change in dispatch could shift the marginal generating unit, and thus, the marginal emission rates accordingly.

Methodology

PJM Environmental Information Services Inc. (PJM EIS) developed the average emission rates for electric generators in the PJM footprint for use in the Generation Attribute Tracking System (GATS).

PJM EIS is a wholly owned subsidiary of PJM Connext LLC, which is a subsidiary of PJM Interconnection. It provides consulting services on energy and the environment and owns and operates the GATS.

The GATS is an all-generation data tracking system administered by PJM EIS to enable compliance with states' mandates for fuel mix, emission disclosures and renewable energy. Emission data tracked in GATS include carbon dioxide, sulfur dioxide and nitrogen oxides. PJM EIS calculates emission factors for all generators in the PJM region on an annual basis, using PJM generation data and emission data from a number of publicly available sources:

- U.S. Environmental Protection Agency (EPA) unit-level annual emissions from Continuous Emission Monitoring Systems (CEMS) for generators required to report air emissions
- EPA Emissions & Generation Resource Integrated Database (eGRID) emission rates
- Fuel-type default factors

As a point of reference, the vast majority of all PJM generation either was from a non-emitting resource or was assigned a unit-specific emission rate calculated using EPA Clean Air Markets Division (CAMD) data. A small percentage of generation was assigned an emission factor based on EPA eGRID data. Only a tiny percentage of PJM generation was assigned a fuel-type default emission factor. As a general matter, PJM has visibility only into generation resources that participate in the wholesale electricity market. Other generation sources, including small diesel and behind-the-meter generation, are not accounted for in this emission report.

Generation (in megawatt-hours) for each PJM generator is received monthly from the PJM Market Settlement Reporting System. The energy output of each generator is multiplied by an emission factor, and a weighted-average emission rate is calculated for all PJM generation for the month. The PJM System Average Annual Value is a weighted average accounting for higher loads during the summer and winter months.

In a given five-minute interval, there is one marginal unit on the system, plus an additional marginal unit for each transmission constraint that is being experienced. The mathematical average of the emission rates for all marginal units in each five-minute interval forms a marginal emission rate for that interval. These five-minute rates are averaged to form the monthly marginal emission rates provided in this report.

Table 1. Marginal Units by Fuel Type & Technology[1]

Fuel Type	Technology	2018	2019	2020	2021	2022
Gas	CC	53.45%	62.13%	64.33%	59.75%	61.66%
Coal	Steam	27.26%	24.37%	17.53%	14.15%	10.02%
Wind	Wind	2.56%	3.81%	6.75%	11.04%	11.12%
Gas	CT	7.80%	5.97%	5.89%	10.06%	11.26%
Gas	Steam	1.68%	1.29%	2.12%	1.17%	1.42%
Oil	CT	4.58%	0.49%	1.25%	1.13%	2.25%
Uranium	Steam	1.04%	1.31%	1.35%	1.00%	0.39%
Other	Solar	0.12%	0.07%	0.33%	0.76%	0.74%
Gas	RICE	0.41%	0.00%	0.29%	0.67%	0.86%
Other	Steam	0.15%	0.06%	0.03%	0.08%	0.05%
Oil	Steam	0.29%	0.03%	0.06%	0.06%	0.03%
Oil	RICE	0.42%	0.00%	0.04%	0.06%	0.11%
Oil	CC	0.13%	0.01%	0.00%	0.02%	0.06%
Municipal Waste	Steam	0.04%	0.02%	0.02%	0.02%	0.04%
Landfill Gas	CT	0.00%	0.01%	0.01%	0.01%	0.00%
Municipal Waste	RICE	0.04%	0.00%	0.00%	0.00%	0.00%
Municipal Waste	CT	0.02%	0.00%	0.00%	0.00%	0.00%
Landfill Gas	Steam	0.00%	0.00%	0.00%	0.00%	0.00%
Gas	Fuel Cell	0.00%	0.00%	0.00%	0.00%	0.00%
Landfill Gas	RICE	0.04%	0.00%	0.00%	0.00%	0.00%

[1] The percentages by fuel type and technology provided in Table 1 are from the annual 2022 PJM State of the Market Report, Table 3-67 Type of fuel used and technology (By real-time marginal units): 2018 through 2022.

Carbon Dioxide (CO_2)

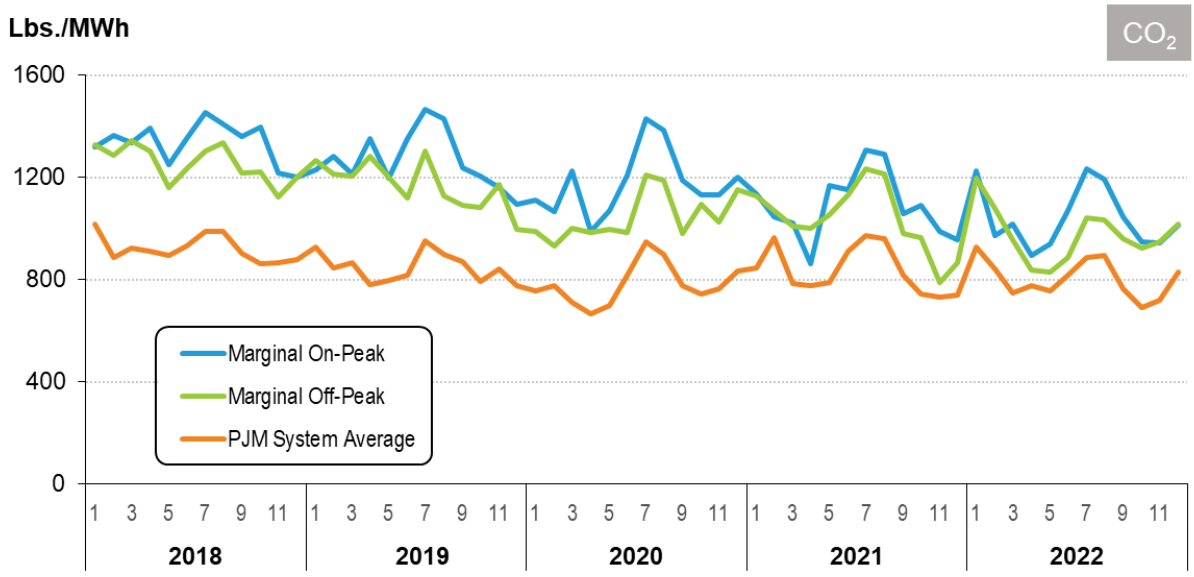
The table and graph below show the emission rates, measured in pounds per megawatt-hour, from marginal units in the PJM footprint, as well as the monthly average CO_2 emissions. The PJM System Average Annual Value is a weighted average accounting for higher loads during the summer and winter months.

Peak periods are all non-holiday weekdays from 7 a.m. to 11 p.m., and off-peak periods are all other hours.

Table 2. Marginal CO_2 Emission Rates Table

	CO_2 (Lbs./MWh)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2018	MARGINAL	On-Peak	1,319	1,362	1,334	1,394	1,251	1,350	1,454	1,407	1,360	1,397	1,215	1,199	**1,374**
		Off-Peak	1,328	1,285	1,344	1,302	1,160	1,232	1,302	1,335	1,216	1,219	1,124	1,202	**1,374**
	PJM System Average		1,003	870	901	872	870	906	952	935	870	813	812	837	**888**
2019	MARGINAL	On-Peak	1,229	1,282	1,212	1,353	1,197	1,353	1,464	1,431	1,237	1,204	1,160	1,095	**1,337**
		Off-Peak	1,266	1,213	1,204	1,284	1,200	1,117	1,302	1,125	1,091	1,084	1,173	998	**1,254**
	PJM System Average		927	843	864	780	796	818	951	897	869	792	842	777	**851**
2020	MARGINAL	On-Peak	1,110	1,067	1,225	989	1,070	1,207	1,430	1,383	1,190	1,130	1,131	1,199	**1,268**
		Off-Peak	987	933	1,001	986	995	983	1,210	1,189	981	1,096	1,026	1,151	**1,171**
	PJM System Average		757	777	711	665	698	816	948	898	776	743	763	833	**791**
2021	MARGINAL	On-Peak	1,135	1,044	1,022	862	1,169	1,151	1,308	1,292	1,056	1,091	987	956	**1,180**
		Off-Peak	1,125	1,070	1,008	1,001	1,053	1,131	1,232	1,213	979	964	787	867	**1,046**
	PJM System Average		844	963	783	755	786	909	972	961	818	745	730	740	**843**
2022	MARGINAL	On-Peak	1,124	973	1,017	893	938	1,071	1,232	1,192	1,044	946	944	1,012	**1,041**
		Off-Peak	1,196	1,078	954	839	830	888	1,041	1,033	958	924	947	1,017	**976**
	PJM System Average		929	842	747	778	754	816	885	893	765	691	718	828	**811**

Figure 1. Marginal CO_2 Emission Rates Graph



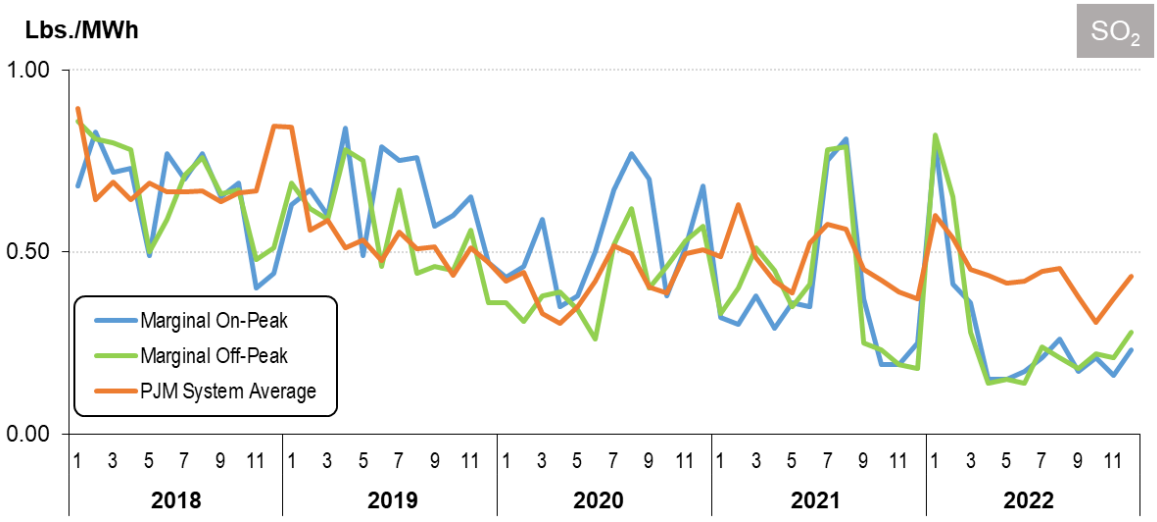
Sulfur Dioxide (SO_2)

The table and graph below show the SO_2 emission rates, measured in pounds per megawatt-hour, from marginal units in the PJM footprint, as well as the monthly average SO_2 emissions. The PJM System Average Annual Value is a weighted average accounting for higher loads during the summer and winter months.

Table 3. Marginal SO_2 Emission Rates Table

	SO_2 (Lbs./MWh)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2018	MARGINAL	On-Peak	0.68	0.83	0.72	0.73	0.49	0.77	0.70	0.77	0.65	0.69	0.40	0.44	**0.98**
		Off-Peak	0.86	0.81	0.80	0.78	0.50	0.59	0.71	0.76	0.66	0.67	0.48	0.51	**0.98**
	PJM System Average		0.82	0.66	0.70	0.66	0.64	0.66	0.64	0.61	0.61	0.60	0.59	0.52	**0.64**
2019	MARGINAL	On-Peak	0.63	0.67	0.60	0.84	0.49	0.79	0.75	0.76	0.57	0.60	0.65	0.47	**0.66**
		Off-Peak	0.69	0.62	0.59	0.78	0.75	0.46	0.67	0.44	0.46	0.45	0.56	0.36	**0.68**
	PJM System Average		0.84	0.56	0.59	0.51	0.53	0.48	0.55	0.51	0.51	0.44	0.51	0.47	**0.55**
2020	MARGINAL	On-Peak	0.43	0.46	0.59	0.35	0.38	0.50	0.67	0.77	0.70	0.38	0.51	0.68	**0.65**
		Off-Peak	0.36	0.31	0.38	0.39	0.34	0.26	0.52	0.62	0.40	0.46	0.53	0.57	**0.57**
	PJM System Average		0.42	0.44	0.33	0.30	0.35	0.42	0.52	0.50	0.40	0.39	0.49	0.51	**0.43**
2021	MARGINAL	On-Peak	0.32	0.30	0.38	0.29	0.36	0.35	0.75	0.81	0.37	0.19	0.19	0.25	**0.54**
		Off-Peak	0.33	0.40	0.51	0.45	0.35	0.41	0.78	0.79	0.25	0.23	0.19	0.18	**0.43**
	PJM System Average		0.49	0.63	0.48	0.42	0.39	0.53	0.58	0.56	0.45	0.42	0.39	0.37	**0.48**
2022	MARGINAL	On-Peak	0.80	0.41	0.36	0.15	0.15	0.17	0.21	0.26	0.17	0.21	0.16	0.23	**0.27**
		Off-Peak	0.82	0.65	0.28	0.14	0.15	0.14	0.24	0.21	0.18	0.22	0.21	0.28	**0.29**
	PJM System Average		0.60	0.54	0.45	0.44	0.42	0.42	0.45	0.45	0.38	0.31	0.37	0.43	**0.44**

Figure 2. Marginal SO_2 Emission Rates Graph



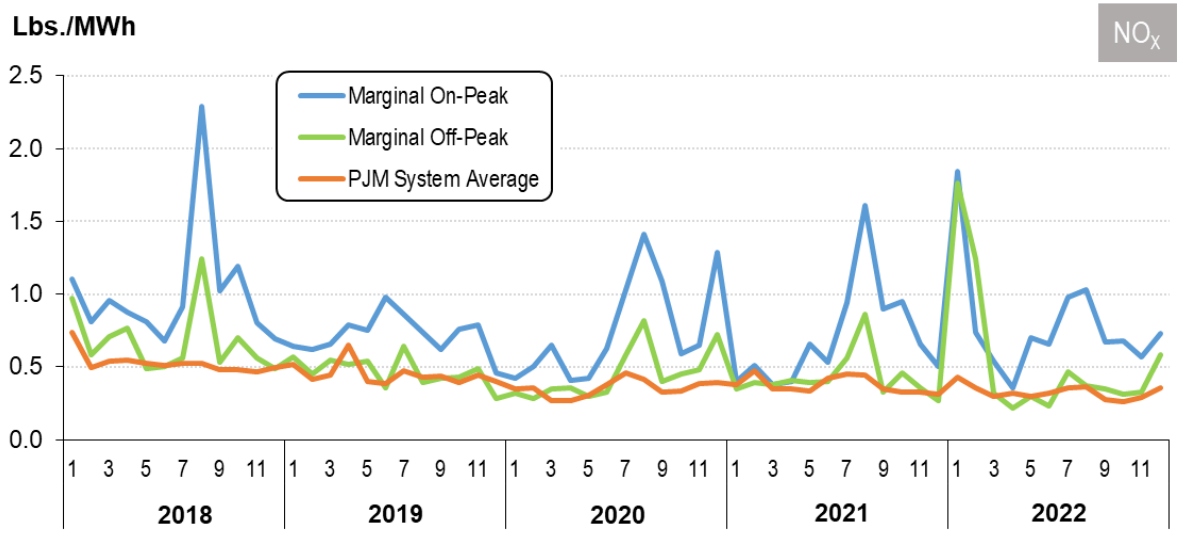
Nitrogen Oxides (NO_X)

The table and graph below show the NO_x emission rates, measured in pounds per megawatt-hour, from marginal units in the PJM footprint, as well as the monthly average NO_x emissions. The PJM System Average Annual Value is a weighted average accounting for higher loads during the summer and winter months.

Table 4. NO_X Emission Rates Table

	NO_X (Lbs./MWh)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2018	MARGINAL	On-Peak	1.10	0.81	0.96	0.88	0.81	0.68	0.91	2.29	1.02	1.19	0.80	0.69	**1.27**
		Off-Peak	0.97	0.58	0.71	0.77	0.49	0.50	0.56	1.24	0.53	0.70	0.56	0.49	**0.99**
	PJM System Average		0.61	0.50	0.53	0.53	0.52	0.48	0.50	0.49	0.45	0.45	0.43	0.38	**0.49**
2019	MARGINAL	On-Peak	0.64	0.62	0.66	0.79	0.75	0.98	0.86	0.74	0.62	0.76	0.79	0.46	**1.01**
		Off-Peak	0.57	0.45	0.55	0.52	0.54	0.36	0.64	0.39	0.42	0.43	0.49	0.28	**0.68**
	PJM System Average		0.52	0.41	0.44	0.65	0.40	0.38	0.48	0.43	0.44	0.39	0.44	0.40	**0.45**
2020	MARGINAL	On-Peak	0.42	0.50	0.65	0.41	0.42	0.63	1.03	1.41	1.09	0.59	0.65	1.29	**0.72**
		Off-Peak	0.32	0.28	0.35	0.36	0.30	0.33	0.58	0.82	0.40	0.45	0.48	0.72	**0.47**
	PJM System Average		0.35	0.36	0.27	0.27	0.31	0.38	0.46	0.42	0.33	0.34	0.38	0.39	**0.36**
2021	MARGINAL	On-Peak	0.40	0.51	0.38	0.40	0.66	0.53	0.94	1.61	0.90	0.95	0.66	0.50	**0.76**
		Off-Peak	0.35	0.39	0.38	0.41	0.39	0.40	0.56	0.86	0.33	0.46	0.36	0.27	**0.45**
	PJM System Average		0.38	0.47	0.35	0.35	0.34	0.42	0.45	0.45	0.35	0.33	0.33	0.31	**0.38**
2022	MARGINAL	On-Peak	1.84	0.74	0.54	0.36	0.70	0.66	0.98	1.03	0.67	0.68	0.57	0.73	**0.79**
		Off-Peak	1.76	1.24	0.32	0.22	0.30	0.23	0.47	0.37	0.35	0.31	0.33	0.58	**0.54**
	PJM System Average		0.43	0.35	0.30	0.32	0.30	0.32	0.36	0.36	0.28	0.26	0.29	0.35	**0.33**

Figure 3. Marginal NO_X Emission Rates Graph



Appendix – Statistical Information

The following tables list standard deviations for the emission rates; they are provided to show the level of variance in the averages presented above.

Table 5. CO_2 Emission Rates Standard Deviation

CO_2 STD (Lbs./MWh)			Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
2018	MARGINAL	On-Peak	240	286	224	214	194	216	219	234	252	239	232	221	**231**
		Off-Peak	232	334	232	254	241	297	304	279	273	283	257	248	**270**
2019		On-Peak	234	236	211	245	212	263	234	267	188	190	266	242	**232**
		Off-Peak	289	232	265	266	303	299	342	312	233	216	259	199	**268**
2020		On-Peak	188	247	332	272	210	279	247	294	295	184	299	316	**294**
		Off-Peak	205	249	363	334	201	285	309	321	306	237	341	293	**304**
2021		On-Peak	245	230	276	247	276	191	240	324	226	170	296	235	**280**
		Off-Peak	219	260	285	300	361	234	267	276	198	207	285	219	**292**
2022		On-Peak	324	278	236	195	224	196	204	194	148	224	213	260	**254**
		Off-Peak	354	375	220	200	264	176	218	214	187	233	206	264	**269**

Table 6. SO_2 Emission Rates Standard Deviation

SO_2 STD (Lbs./MWh)			Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
2018	MARGINAL	On-Peak	0.5	0.5	0.4	0.4	0.3	0.4	0.5	0.5	0.4	0.6	0.3	0.4	**0.4**
		Off-Peak	0.6	0.5	0.4	0.4	0.4	0.5	0.5	0.6	0.4	0.5	0.4	0.4	**0.5**
2019		On-Peak	0.4	0.4	0.4	0.5	0.4	0.5	0.5	0.5	0.4	0.4	0.4	0.3	**0.4**
		Off-Peak	0.5	0.4	0.5	0.5	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.3	**0.5**
2020		On-Peak	0.3	0.4	0.5	0.3	0.3	0.4	0.5	0.8	0.8	0.3	0.4	0.9	**0.5**
		Off-Peak	0.3	0.3	0.4	0.5	0.4	0.4	0.5	0.7	0.6	0.4	0.5	0.6	**0.5**
2021		On-Peak	0.3	0.3	0.3	0.3	0.3	0.3	0.9	1.1	0.6	0.2	0.2	0.3	**0.5**
		Off-Peak	0.3	0.4	0.7	0.4	0.4	0.4	0.9	0.9	0.3	0.3	0.2	0.2	**0.5**
2022		On-Peak	0.6	0.5	0.3	0.2	0.2	0.2	0.2	0.3	0.2	0.6	0.2	0.3	**0.4**
		Off-Peak	0.8	0.7	0.3	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.2	0.3	**0.4**

Table 7. NO_X Emission Rates Standard Deviation

NO_x STD (Lbs./MWh)			Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
2018	MARGINAL	On-Peak	0.9	0.9	0.9	0.5	1.1	0.5	0.5	4.3	1.0	1.3	1.0	0.7	**1.1**
		Off-Peak	0.9	0.4	0.4	0.6	0.5	0.3	0.3	3.3	0.4	0.9	0.8	0.4	**0.8**
2019		On-Peak	0.7	0.5	0.7	0.6	0.8	2.3	0.5	0.4	0.4	0.8	0.9	9.5	**1.5**
		Off-Peak	0.7	0.3	0.6	0.3	0.7	0.3	0.6	0.4	0.3	0.4	0.4	0.2	**0.4**
2020		On-Peak	0.3	0.7	0.5	0.5	0.3	0.4	0.7	1.7	1.8	0.5	0.5	1.8	**1.0**
		Off-Peak	0.4	0.3	0.3	0.4	0.2	0.4	0.5	1.4	0.8	0.4	0.4	0.9	**0.7**
2021		On-Peak	0.3	0.9	0.4	0.3	0.9	0.4	0.9	2.1	1.4	1.1	0.7	0.6	**1.0**
		Off-Peak	0.3	0.5	0.4	0.4	0.5	0.4	0.5	1.3	0.4	0.9	0.4	0.4	**0.6**
2022		On-Peak	1.9	1.2	0.7	0.4	1.0	0.6	0.9	1.1	0.8	1.0	0.9	1.0	**1.1**
		Off-Peak	2.1	1.9	0.4	0.2	0.6	0.3	0.9	0.6	0.6	0.5	0.5	0.9	**1.1**