

2014-2018 CO₂, SO₂ and NO_x Emission Rates

April 5, 2019



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Introduction

To support the efforts of regulators, stakeholders, and other interested parties as they work towards achieving environmental goals, PJM Interconnection provides this annual emissions report with data on both marginal and average emissions rates from electric generators in the PJM footprint.

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 system-wide 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 rate accordingly.

Methodology

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

PJM-EIS, Inc. is a wholly owned subsidiary of PJM Technologies, Inc. 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. Emissions 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 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, approximately 97 percent of all PJM generation either was a non-emitting resource or was assigned a unit-specific emission rate calculated using EPA CEMS 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 emissions 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.

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 emissions rates for all marginal units in each five-minute interval forms a marginal emissions rate for that interval. These five-minute rates are averaged to form the marginal emissions rates provided in this report.

Figure 1. ¹Marginal Units by Fuel Type & Technology Table

Fuel Type	Technology	2014	2015	2016	2017	2018
Gas	CC	25.40%	29.58%	31.22%	44.63%	53.45%
Coal	Steam	52.90%	51.73%	43.39%	32.28%	27.26%
Gas	CT	8.35%	4.16%	6.57%	4.70%	7.80%
Oil	CT	6.55%	5.03%	5.98%	5.18%	4.58%
Wind	Wind	3.29%	3.27%	2.98%	7.28%	2.56%
Gas	Steam	1.81%	3.77%	4.66%	3.53%	1.73%
Uranium	Steam	0.04%	0.03%	1.06%	1.23%	1.04%
Oil	RICE	0.42%	1.23%	0.75%	0.26%	0.42%
Gas	RICE	0.01%	0.05%	0.12%	0.39%	0.36%
Oil	Steam	0.25%	0.13%	0.04%	0.05%	0.29%
Other	Steam	0.43%	0.37%	0.12%	0.19%	0.15%
Oil	CC	0.21%	0.48%	0.02%	0.01%	0.13%
Other	Solar	0.00%	0.01%	0.02%	0.18%	0.12%
Landfill Gas	RICE	0.13%	0.01%	0.04%	0.01%	0.04%
Landfill Gas	Steam	0.07%	0.01%	0.02%	0.05%	0.03%
Landfill Gas	CT	0.04%	0.00%	0.00%	0.01%	0.02%
Municipal Waste	Steam	0.05%	0.06%	0.01%	0.01%	0.01%
Gas	Fuel Cell	0.00%	0.03%	0.00%	0.00%	0.00%
Emergency DR		0.04%	0.00%	0.00%	0.00%	0.00%

¹ The percentages by fuel type and technology provided in Figure 1 are from the annual PJM State of the Market report.

Carbon Dioxide

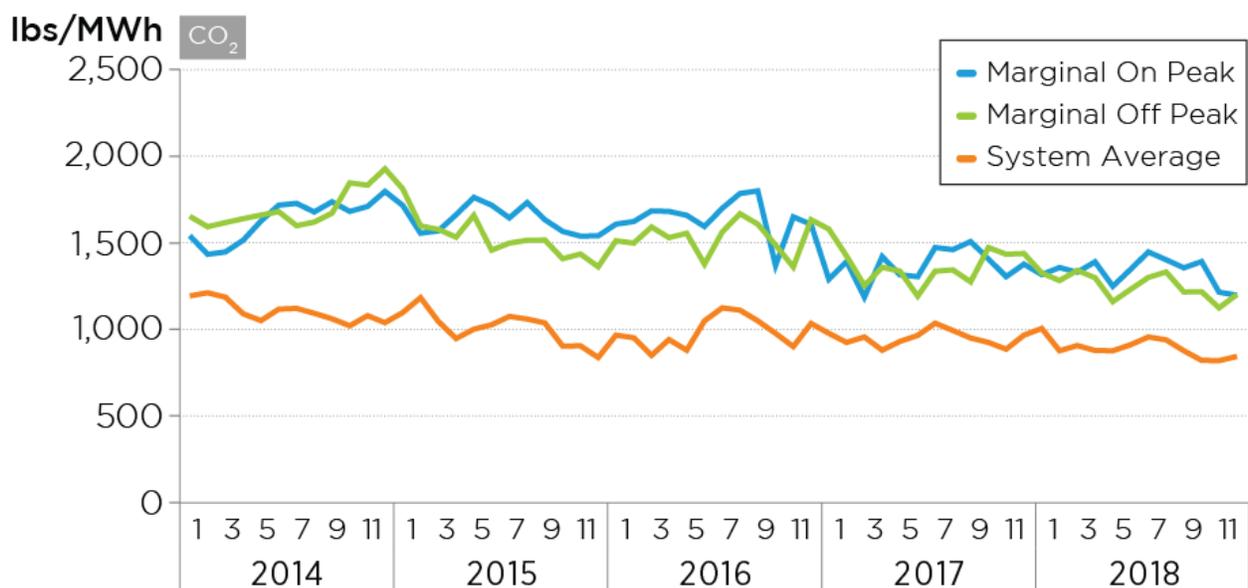
The table and graph below show the emission rates, measured in pounds per megawatt-hour, from marginal units in the PJM footprint as well as the monthly average CO₂ emissions.

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

Figure 2. Marginal CO₂ Emission Rates Table

CO ₂ (lbs/MWh)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2014	Marginal On-Peak	1,548	1,439	1,453	1,522	1,636	1,729	1,740	1,690	1,750	1,692	1,721	1,810	1,646
	Marginal Off-Peak	1,664	1,602	1,627	1,650	1,671	1,691	1,608	1,630	1,682	1,861	1,848	1,944	1,707
	PJM System Average	1,194	1,212	1,187	1,088	1,049	1,116	1,121	1,092	1,059	1,017	1,077	1,036	1,108
2015	Marginal On-Peak	1,728	1,564	1,578	1,673	1,775	1,729	1,654	1,745	1,643	1,575	1,547	1,549	1,647
	Marginal Off-Peak	1,826	1,606	1,587	1,540	1,670	1,463	1,505	1,522	1,524	1,414	1,441	1,366	1,541
	PJM System Average	1,096	1,184	1,044	942	997	1,023	1,073	1,057	1,034	898	899	831	1,014
2016	Marginal On-Peak	1,617	1,632	1,696	1,692	1,669	1,604	1,711	1,799	1,814	1,373	1,660	1,616	1,617
	Marginal Off-Peak	1,520	1,505	1,600	1,537	1,563	1,381	1,572	1,679	1,618	1,495	1,364	1,643	1,471
	PJM System Average	962	947	842	937	873	1,047	1,123	1,109	1,047	973	895	1,031	992
2017	Marginal On-Peak	1,292	1,396	1,187	1,426	1,318	1,308	1,480	1,467	1,514	1,412	1,308	1,381	1,372
	Marginal Off-Peak	1,588	1,428	1,255	1,363	1,340	1,192	1,340	1,347	1,277	1,480	1,439	1,444	1,376
	PJM System Average	973	920	952	873	926	961	1,032	990	945	919	880	963	948
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	1,338
	Marginal 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	1,254
	PJM System Average	1,003	870	901	872	870	906	952	935	870	813	812	837	888

Figure 3. Marginal CO₂ Emission Rates Graph



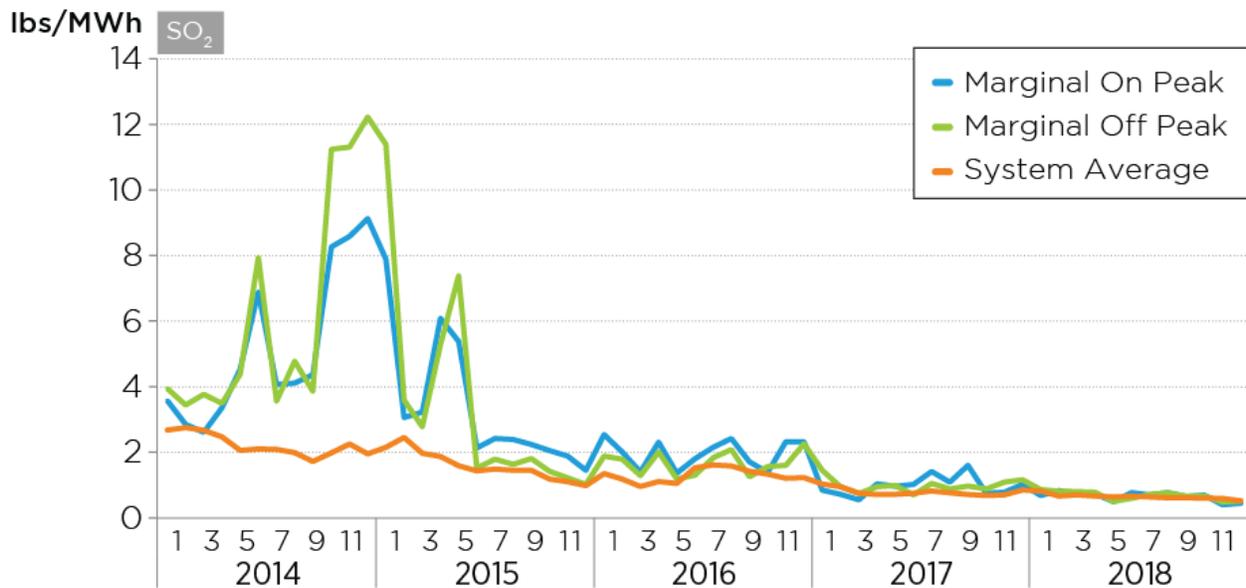
Sulfur Dioxide

The table and graph below show the SO₂ emission rates, measured in pounds per megawatt-hour, from marginal units in the PJM footprint, as well as the monthly average SO₂ emissions.

Figure 4. Marginal SO₂ Emission Rates Table

SO ₂ (lbs/MWh)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2014	Marginal On-Peak	3.57	2.85	2.61	3.36	4.54	6.89	4.07	4.11	4.37	8.27	8.59	9.13	5.20
	Marginal Off-Peak	3.94	3.44	3.77	3.49	4.38	7.95	3.56	4.78	3.86	11.25	11.31	12.23	6.16
	PJM System Average	2.68	2.75	2.67	2.47	2.06	2.10	2.09	1.99	1.72	1.98	2.25	1.92	2.22
2015	Marginal On-Peak	7.89	3.06	3.23	6.09	5.38	2.13	2.42	2.39	2.24	2.05	1.88	1.45	3.34
	Marginal Off-Peak	11.39	3.59	2.78	5.28	7.39	1.52	1.79	1.63	1.81	1.42	1.22	1.02	3.46
	PJM System Average	2.15	2.45	1.97	1.87	1.59	1.43	1.49	1.45	1.45	1.18	1.10	0.98	1.61
2016	Marginal On-Peak	2.54	2.01	1.40	2.31	1.36	1.80	2.15	2.42	1.71	1.39	2.32	2.32	1.73
	Marginal Off-Peak	1.88	1.79	1.29	2.01	1.19	1.30	1.83	2.08	1.25	1.56	1.60	2.26	1.45
	PJM System Average	1.35	1.18	0.95	1.11	1.05	1.52	1.61	1.58	1.42	1.33	1.21	1.22	1.32
2017	Marginal On-Peak	0.84	0.72	0.55	1.04	0.96	1.02	1.41	1.09	1.60	0.75	0.78	1.02	0.97
	Marginal Off-Peak	1.45	0.95	0.74	0.95	0.99	0.70	1.05	0.88	0.97	0.88	1.09	1.16	0.99
	PJM System Average	1.03	0.95	0.75	0.71	0.72	0.75	0.82	0.76	0.71	0.68	0.70	0.85	0.79
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	0.66
	Marginal 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	0.68
	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

Figure 5. Marginal SO₂ Emission Rates Graph



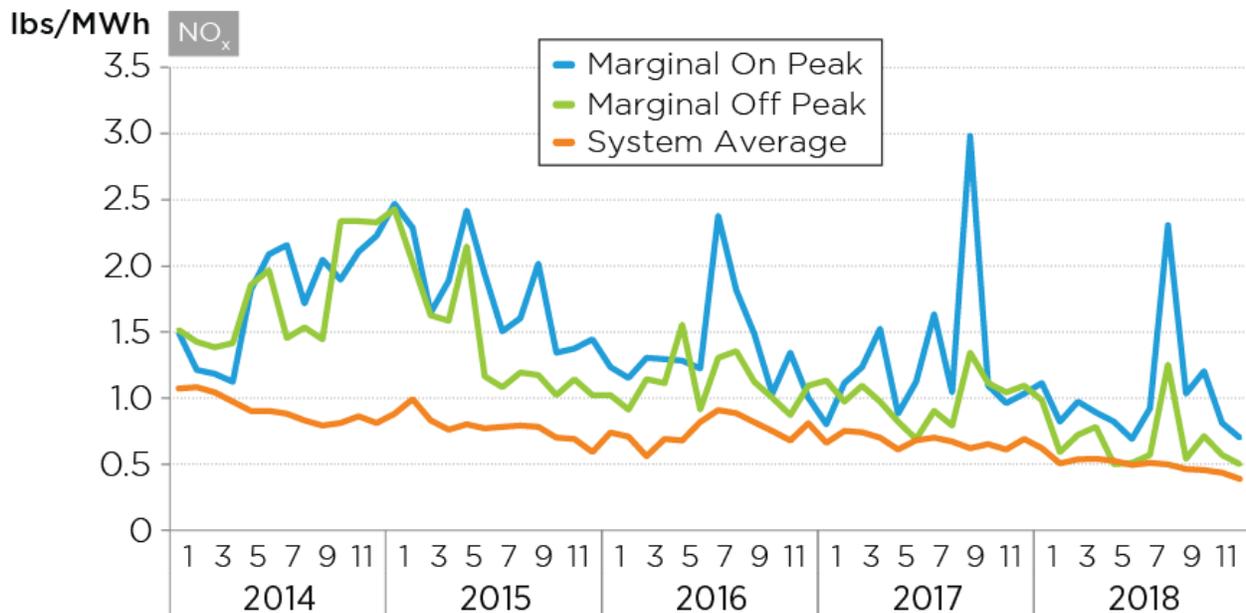
Nitrogen Oxides

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.

Figure 6. NO_x Emission Rates Table

NO _x (lbs/MWh)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2014	Marginal On-Peak	1.48	1.20	1.17	1.11	1.80	2.07	2.14	1.70	2.03	1.88	2.09	2.21	1.74
	Marginal Off-Peak	1.50	1.41	1.37	1.40	1.84	1.95	1.44	1.52	1.43	2.32	2.32	2.31	1.73
	PJM System Average	1.06	1.07	1.03	0.96	0.89	0.89	0.87	0.82	0.78	0.80	0.85	0.80	0.90
2015	Marginal On-Peak	2.45	2.27	1.63	1.87	2.40	1.92	1.49	1.59	2.00	1.33	1.36	1.43	1.80
	Marginal Off-Peak	2.41	2.01	1.61	1.57	2.13	1.15	1.07	1.18	1.16	1.01	1.13	1.01	1.46
	PJM System Average	0.87	0.98	0.82	0.75	0.79	0.76	0.77	0.78	0.77	0.69	0.68	0.58	0.78
2016	Marginal On-Peak	1.22	1.14	1.29	1.28	1.27	1.21	2.36	1.80	1.47	1.02	1.33	0.99	1.48
	Marginal Off-Peak	1.01	0.90	1.13	1.10	1.54	0.90	1.29	1.34	1.11	0.99	0.86	1.08	1.14
	PJM System Average	0.73	0.70	0.55	0.68	0.67	0.81	0.90	0.87	0.80	0.74	0.67	0.80	0.75
2017	Marginal On-Peak	0.79	1.10	1.22	1.51	0.87	1.11	1.62	1.03	2.96	1.08	0.95	1.02	1.26
	Marginal Off-Peak	1.12	0.96	1.08	0.96	0.81	0.68	0.89	0.78	1.33	1.10	1.03	1.08	0.99
	PJM System Average	0.74	0.73	0.69	0.61	0.60	0.67	0.69	0.66	0.61	0.64	0.60	0.68	0.66
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	1.03
	Marginal 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	0.67
	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

Figure 7. Marginal NO_x Emission Rates Graph



Appendix – Statistical Information

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

Figure 8. CO₂ Emission Rates Standard Deviation

CO ₂ STD (lbs/MWh)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2014	Marginal On-Peak	288	272	280	266	194	274	207	242	233	177	209	245	241
	Marginal Off-Peak	268	296	307	330	254	305	408	304	301	231	176	310	291
2015	Marginal On-Peak	248	254	273	211	250	203	233	208	295	214	241	257	254
	Marginal Off-Peak	250	274	299	339	328	381	359	379	383	334	346	415	364
2016	Marginal On-Peak	265	247	314	280	229	275	268	209	320	261	319	367	302
	Marginal Off-Peak	362	369	413	359	428	401	411	342	423	378	392	370	398
2017	Marginal On-Peak	392	273	289	361	315	354	290	257	521	272	252	240	338
	Marginal Off-Peak	352	312	311	378	376	367	369	281	443	301	284	282	357
2018	Marginal On-Peak	240	286	224	214	194	216	219	234	252	239	232	221	243
	Marginal Off-Peak	232	334	232	254	241	297	304	279	273	283	257	248	279

Figure 9. SO₂ Emission Rates Standard Deviation

SO ₂ STD (lbs/MWh)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2014	Marginal On-Peak	3.2	2.2	2.1	2.8	2.8	4.7	2.7	3.9	3.5	3.5	4.3	4.1	3.3
	Marginal Off-Peak	2.4	3.0	2.9	3.0	3.2	5.5	3.3	5.0	3.9	3.7	3.4	3.8	3.6
2015	Marginal On-Peak	5.5	2.1	2.3	4.6	4.2	1.5	2.0	1.9	2.0	1.5	2.0	1.2	3.5
	Marginal Off-Peak	5.9	2.2	1.6	5.5	6.0	1.2	1.6	1.5	1.6	1.2	1.3	1.3	4.5
2016	Marginal On-Peak	1.9	1.5	1.0	1.0	0.8	1.3	1.3	1.3	1.0	1.0	1.5	2.0	1.4
	Marginal Off-Peak	1.7	1.5	1.4	1.2	1.3	1.4	1.6	1.5	1.0	0.9	1.4	1.5	1.4
2017	Marginal On-Peak	0.7	0.5	0.4	0.7	0.7	0.7	1.0	0.7	1.8	0.4	0.5	0.6	0.8
	Marginal Off-Peak	0.7	0.6	0.5	0.6	0.6	0.6	0.8	0.6	1.3	0.5	0.6	0.7	0.7
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	0.5
	Marginal 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

Figure 10. NO_x Emission Rates Standard Deviation

NO _x STD (lbs/MWh)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2014	Marginal On-Peak	0.8	0.6	0.7	0.5	0.6	0.7	1.1	1.1	2.0	0.5	0.8	1.1	0.9
	Marginal Off-Peak	0.6	0.8	0.6	0.6	0.6	0.7	0.8	1.0	1.2	0.6	0.5	0.5	0.7
2015	Marginal On-Peak	1.5	1.8	1.1	0.8	1.6	1.3	0.6	0.5	1.8	0.5	0.6	1.2	1.3
	Marginal Off-Peak	0.9	1.7	1.3	1.0	1.1	0.8	0.6	0.7	0.7	0.5	0.6	0.9	1.1
2016	Marginal On-Peak	0.5	0.5	0.6	0.4	0.3	0.7	1.7	0.9	0.5	0.4	0.9	0.4	0.8
	Marginal Off-Peak	0.6	0.5	0.6	0.4	1.8	0.8	1.1	0.9	0.5	0.4	0.5	0.5	0.9
2017	Marginal On-Peak	0.7	0.7	2.4	1.5	0.6	1.0	2.1	0.5	4.3	0.5	1.0	0.7	1.8
	Marginal Off-Peak	1.4	0.5	2.3	0.8	0.4	0.5	0.7	0.5	2.9	0.5	0.6	0.7	1.3
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	1.6
	Marginal 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	1.1