



2016–2020 CO₂, SO₂ and NO_x Emission Rates

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Introduction

To support the efforts of regulators, stakeholders and other interested parties as they work toward achieving environmental goals, PJM Interconnection provides this annual emissions report with data on both marginal and average emission 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 emission 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 Connex L.L.C, 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 includes 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, approximately 98 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. 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 & Technology¹**

Fuel Type	Technology	2016	2017	2018	2019	2020
Gas	CC	31.22%	44.63%	53.45%	62.13%	64.33%
Coal	Steam	46.39%	32.28%	27.26%	24.37%	17.53%
Wind	Wind	2.98%	7.28%	2.56%	3.81%	6.75%
Gas	CT	6.57%	4.70%	7.80%	5.97%	5.89%
Gas	Steam	4.66%	3.52%	1.68%	1.29%	2.12%
Uranium	Steam	1.06%	1.23%	1.04%	1.31%	1.35%
Oil	CT	5.98%	5.18%	4.58%	0.49%	1.25%
Other	Solar	0.02%	0.18%	0.12%	0.07%	0.33%
Oil	Steam	0.04%	0.05%	0.29%	0.03%	0.06%
Other	Steam	0.12%	0.19%	0.15%	0.06%	0.03%
Municipal Waste	Steam	0.01%	0.01%	0.04%	0.02%	0.02%
Landfill Gas	CT	0.00%	0.00%	0.02%	0.01%	0.01%
Oil	RICE	0.75%	0.26%	0.42%	0.00%	0.00%
Oil	CC	0.02%	0.01%	0.13%	0.01%	0.00%
Municipal Waste	RICE	0.00%	0.00%	0.00%	0.00%	0.00%
Gas	Fuel Cell	0.00%	0.00%	0.00%	0.00%	0.00%
Municipal Waste	CT	0.00%	0.00%	0.00%	0.00%	0.00%
Landfill Gas	Steam	0.02%	0.04%	0.00%	0.00%	0.00%
Gas	RICE	0.12%	0.40%	0.41%	0.00%	0.00%
Landfill Gas	RICE	0.04%	0.01%	0.04%	0.00%	0.00%

¹ The percentages by fuel type and technology provided in Table 1 are from the annual 2020 PJM State of the Market Report, Table 3-60.

Carbon Dioxide (CO₂)

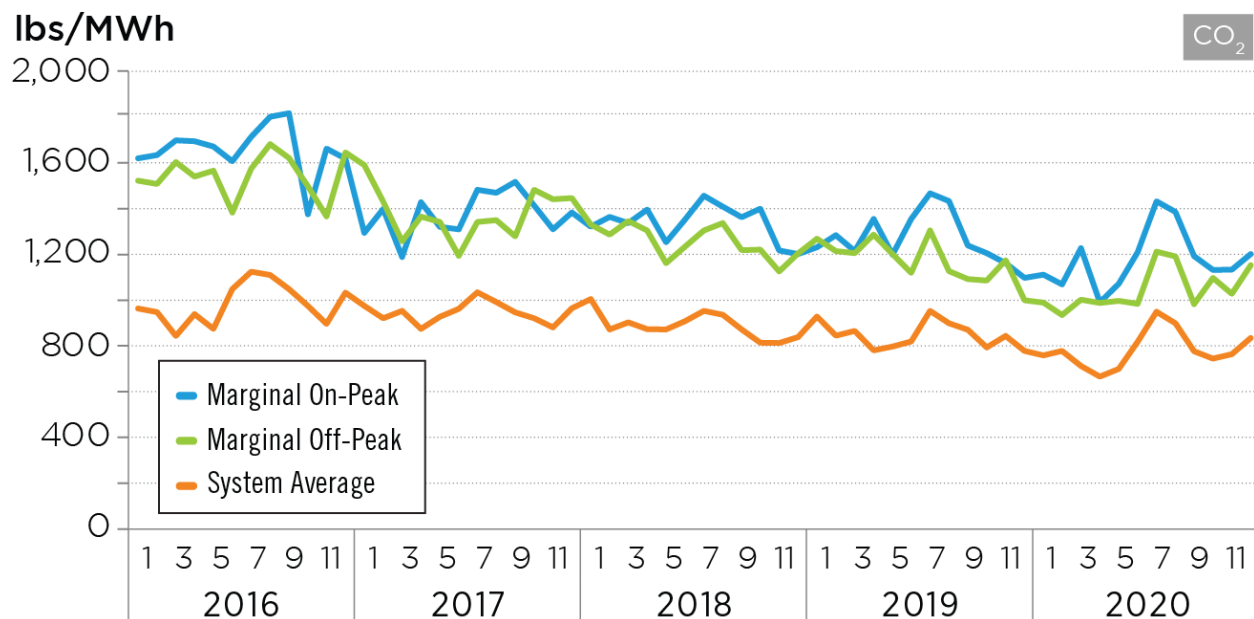
The table and graph below show the emission rates, measured in pounds per megawatt-hour, from marginal units in the PJM footprint, as well as the monthly average CO₂ emissions. The PJM System Average Annual Value is a weighted average accounting for higher loads during the summer and winter months.

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 CO₂ Emission Rates Table**

	CO ₂ (lbs/MWh)	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
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	1,657
	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	1,540
	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	1,374
	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	1,374
	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	1,337
	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
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	1,268
	Marginal 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	1,171
	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	1,180
	Marginal Off-Peak	987	933	1,001	986	995	983	1,210	1,189	981	1,096	1,026	1,151	1,046
	PJM System Average	757	777	711	665	698	816	948	898	776	743	763	833	791

Figure 1. **Marginal CO₂ Emission Rates Graph**



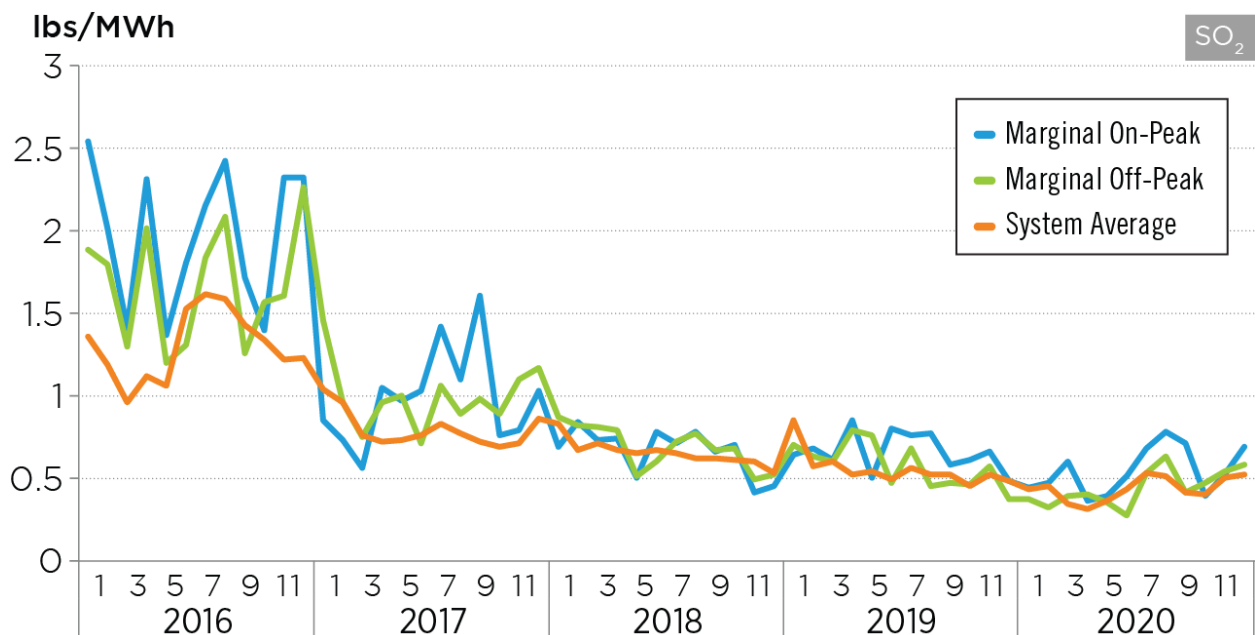
Sulfur Dioxide (SO₂)

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. The PJM System Average Annual Value is a weighted average accounting for higher loads during the summer and winter months.

Table 3. **Marginal SO₂ Emission Rates Table**

SO ₂ (lbs/MWh)		Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
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	1.98
	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	1.67
	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	0.98
	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	0.98
	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
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	0.65
	Marginal 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	0.57
	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	0.54
	Marginal 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	0.43
	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

Figure 2. **Marginal SO₂ Emission Rates Graph**



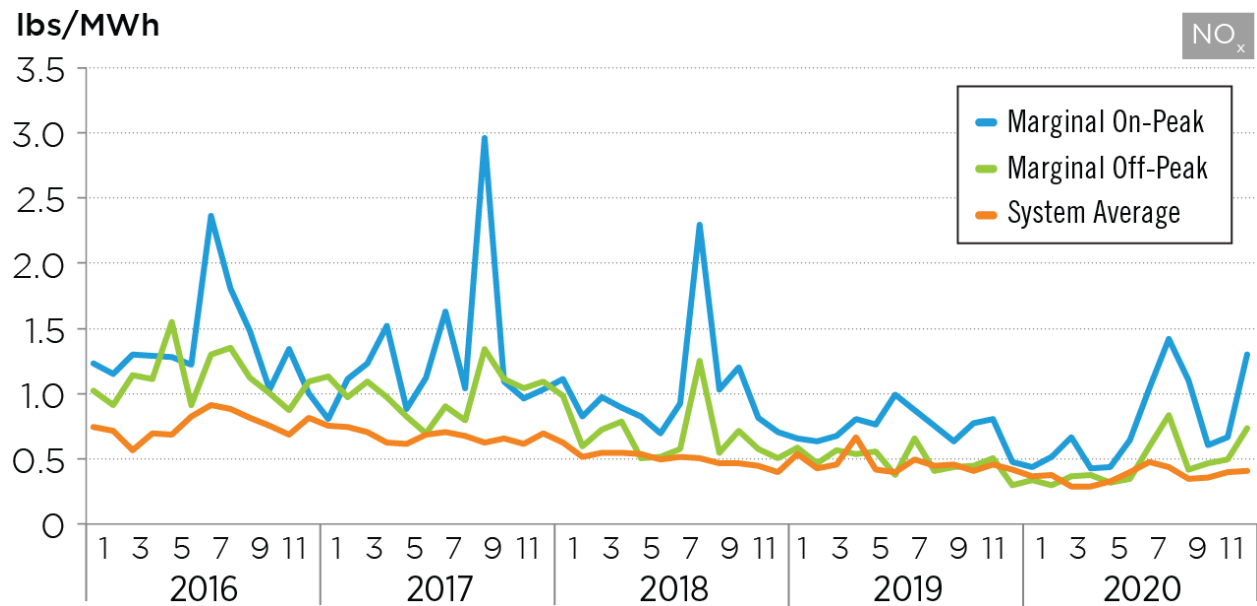
Nitrogen Oxides (NO_x)

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
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	1.37
	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	1.10
	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	1.27
	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	1.01
	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	0.68
	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	0.72
	Marginal 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	0.47
	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	0.76
	Marginal 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	0.45
	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

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.

Figure 1. **CO₂ Emission Rates Standard Deviation**

CO ₂ STD (lbs/MWh)		Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
2016	Marginal On-Peak	265	247	314	280	229	275	268	209	320	261	319	367	280
	Marginal Off-Peak	362	369	413	359	428	401	411	342	423	378	392	370	387
2017	Marginal On-Peak	392	273	289	361	315	354	290	257	521	272	252	240	318
	Marginal Off-Peak	352	312	311	378	376	367	369	281	443	301	284	282	338
2018	Marginal On-Peak	240	286	224	214	194	216	219	234	252	239	232	221	231
	Marginal Off-Peak	232	334	232	254	241	297	304	279	273	283	257	248	270
2019	Marginal On-Peak	234	236	211	245	212	263	234	267	188	190	266	242	232
	Marginal Off-Peak	289	232	265	266	303	299	342	312	233	216	259	199	268
2020	Marginal On-Peak	188	247	332	272	210	279	247	294	295	184	299	316	294
	Marginal Off-Peak	205	249	363	334	201	285	309	321	306	237	341	293	304

Figure 2. **SO₂ Emission Rates Standard Deviation**

SO ₂ STD (lbs/MWh)		Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
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	1.3
	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	0.7
	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	0.4
	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
2019	Marginal 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
	Marginal 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	Marginal 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
	Marginal 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

Figure 3. **NO_x Emission Rates Standard Deviation**

NO _x STD (lbs/MWh)		Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
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	0.7
	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	0.7
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	1.3
	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	1.0
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
	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	0.8
2019	Marginal 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
	Marginal 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	Marginal 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
	Marginal 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