

# 2012-2016 CO<sub>2</sub>, SO<sub>2</sub> and NO<sub>x</sub> Emission Rates

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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 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 change 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 submitted by market participants

As a point of reference, for 2015, 97.2 percent of all PJM generation either was a non-emitting resource or was assigned a unit-specific emission rate calculated using EPA CEMS data. Another 2.6 percent 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.

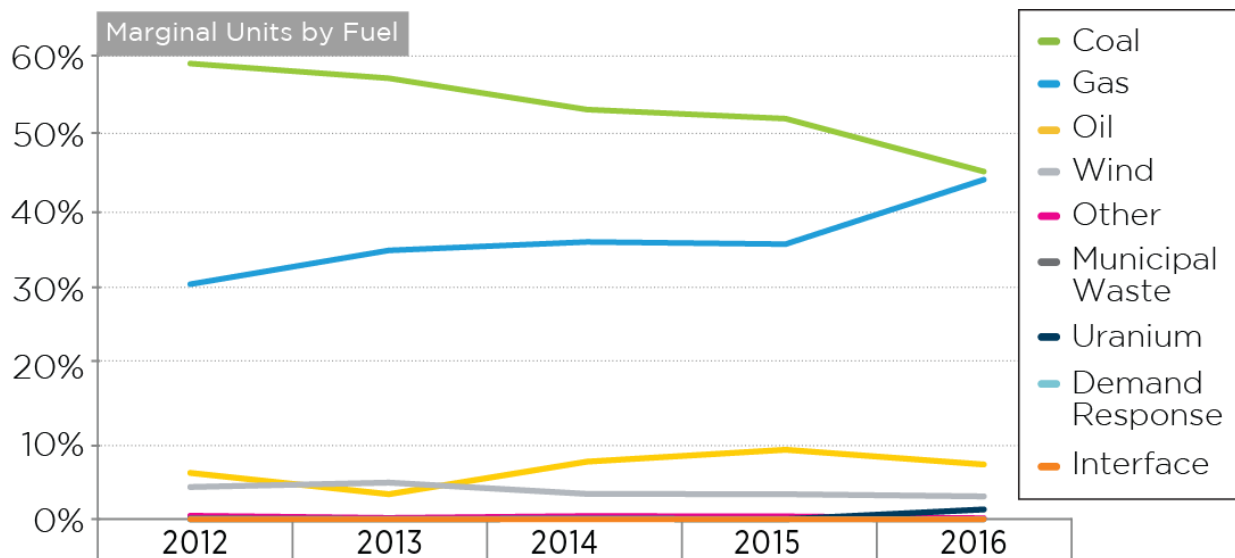
The PJM system average emissions rate is calculated monthly and is available publicly on the [PJM EIS website](http://www.pjm-eis.com) (www.pjm-eis.com). Generation (in megawatt-hours) for each PJM generator is received monthly from the PJM Market Settlement Reporting System. The energy output of each 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. <sup>1</sup>Marginal Units by Fuel Table

Fuel Type	2012	2013	2014	2015	2016
Coal	58.84%	56.94%	52.90%	51.74%	44.90%
Gas	30.35%	34.72%	35.80%	35.52%	43.86%
Oil	6.00%	3.27%	7.45%	8.99%	7.08%
Wind	4.19%	4.76%	3.29%	3.27%	2.98%
Other	0.47%	0.20%	0.43%	0.39%	0.14%
Municipal Waste	0.13%	0.07%	0.05%	0.06%	0.01%
Uranium	0.02%	0.02%	0.04%	0.03%	1.03%
Demand Response	0.00%	0.02%	0.04%	0.00%	0.00%
Interface	0.00%	0.00%	0.00%	0.00%	0.00%

Figure 2. Marginal Units by Fuel Graph



<sup>1</sup> The percentages by fuel type provided in Figure 1 and 2 are from the annual PJM State of the Market report.

## Carbon Dioxide

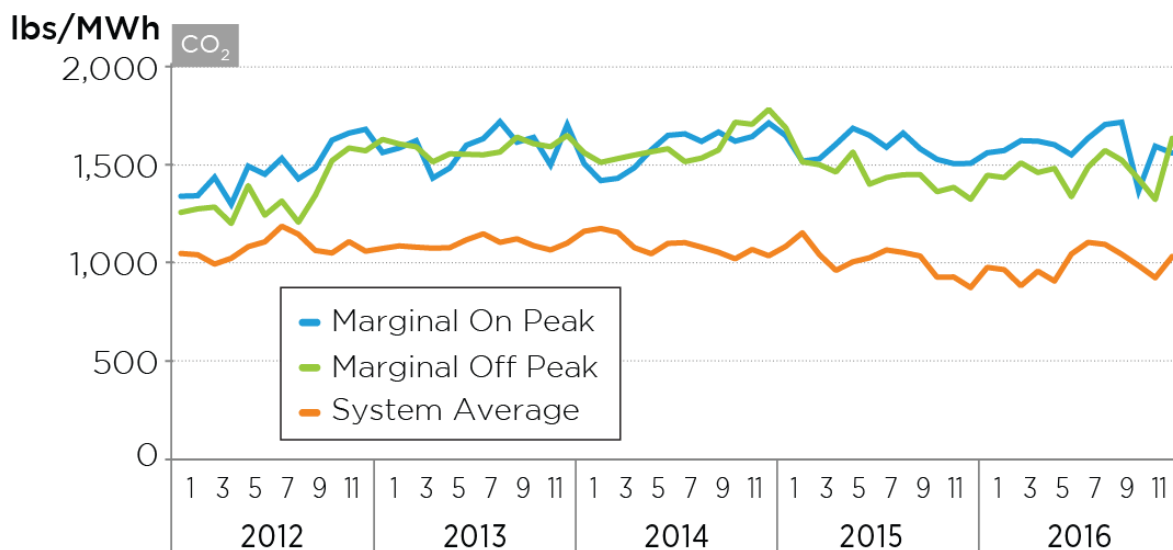
The table and graph below show the emission rates, measured in pounds per megawatt-hour, from marginal units in the PJM footprint as well as the monthly average CO<sub>2</sub> emissions.

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

Figure 3. Marginal CO<sub>2</sub> Emission Rates Table

CO <sub>2</sub> (lbs/MWh)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2012	Marginal On-Peak	1,338	1,341	1,460	1,286	1,531	1,479	1,581	1,449	1,520	1,698	1,745	1,769	1,516
	Marginal Off-Peak	1,281	1,303	1,315	1,208	1,453	1,262	1,353	1,217	1,391	1,614	1,695	1,678	1,400
	PJM System Average	1,051	1,042	983	1,020	1,094	1,125	1,227	1,175	1,070	1,054	1,127	1,066	1,092
2013	Marginal On-Peak	1,619	1,648	1,696	1,455	1,520	1,666	1,708	1,817	1,686	1,716	1,539	1,798	1,656
	Marginal Off-Peak	1,752	1,722	1,704	1,606	1,658	1,655	1,652	1,670	1,766	1,723	1,703	1,777	1,699
	PJM System Average	1,083	1,100	1,092	1,085	1,089	1,139	1,177	1,123	1,145	1,101	1,073	1,117	1,112
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

Figure 4. Marginal CO<sub>2</sub> Emission Rates Graph



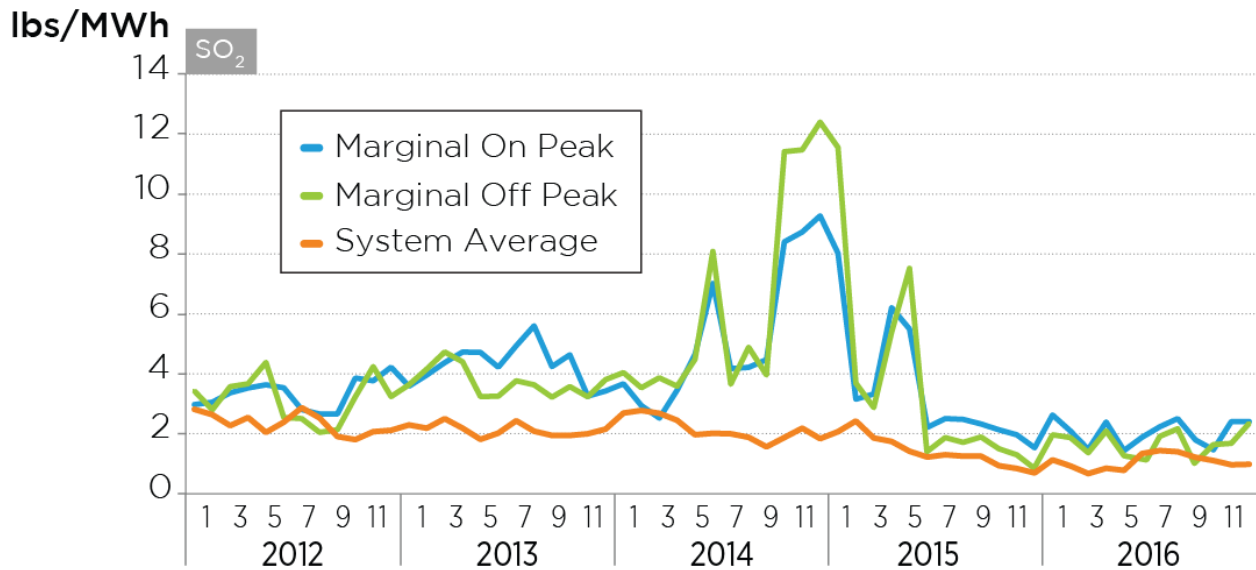
## Sulfur Dioxide

The table and graph below show the SO<sub>2</sub> emission rates, measured in pounds per megawatt-hour, from marginal units in the PJM footprint, as well as the monthly average SO<sub>2</sub> emissions.

Figure 5. Marginal SO<sub>2</sub> Emission Rates Table

SO <sub>2</sub> (lbs/MWh)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2012	Marginal On-Peak	2.88	2.96	3.27	3.43	3.54	3.44	2.72	2.57	2.57	3.76	3.67	4.12	3.24
	Marginal Off-Peak	3.33	2.71	3.48	3.57	4.28	2.45	2.42	1.96	2.05	3.14	4.14	3.15	3.06
	PJM System Average	2.78	2.63	2.36	2.55	2.13	2.42	2.83	2.54	2.01	1.92	2.15	2.19	2.38
2013	Marginal On-Peak	3.49	3.86	4.29	4.63	4.61	4.12	4.83	5.49	4.14	4.53	3.16	3.33	4.21
	Marginal Off-Peak	3.54	4.06	4.62	4.30	3.15	3.16	3.67	3.54	3.13	3.48	3.14	3.71	3.63
	PJM System Average	2.34	2.25	2.52	2.25	1.93	2.11	2.46	2.16	2.04	2.04	2.09	2.22	2.20
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

Figure 6. Marginal SO<sub>2</sub> Emission Rates Graph



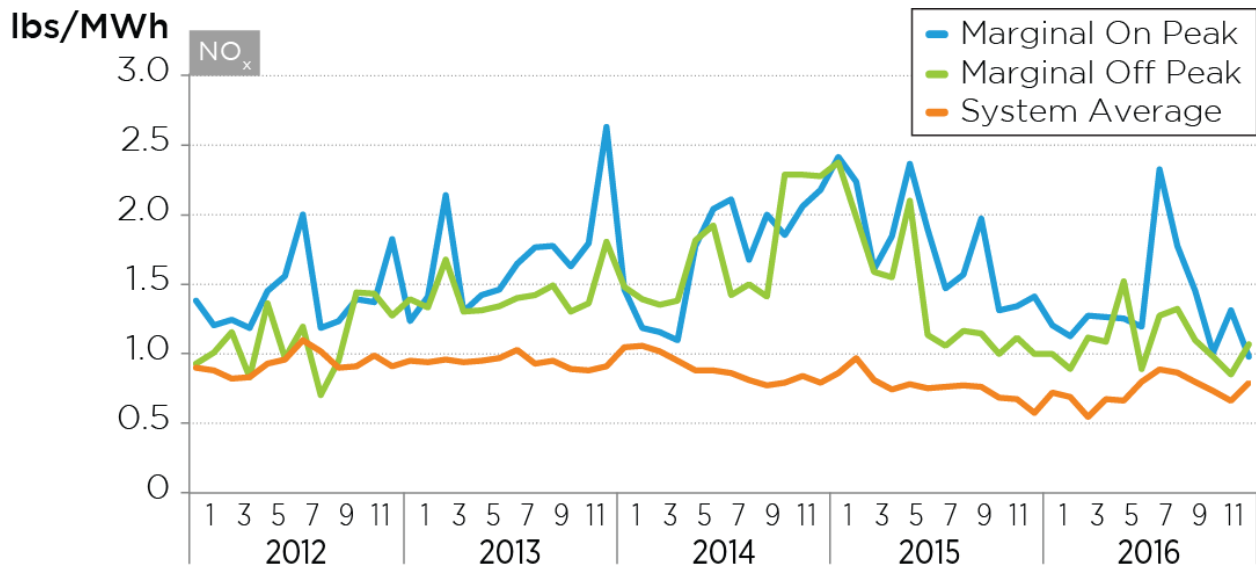
## Nitrogen Oxides

The table and graph below show the NO<sub>x</sub> emission rates, measured in pounds per megawatt-hour, from marginal units in the PJM footprint, as well as the monthly average NO<sub>x</sub> emissions.

Figure 7. NO<sub>x</sub> Emission Rates Table

NO <sub>x</sub> (lbs/MWh)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2012	Marginal On-Peak	1.40	1.22	1.26	1.20	1.47	1.58	2.03	1.20	1.25	1.41	1.39	1.85	1.44
	Marginal Off-Peak	0.94	1.02	1.17	0.84	1.38	0.98	1.21	0.71	0.96	1.46	1.45	1.29	1.12
	PJM System Average	0.92	0.89	0.83	0.84	0.94	0.97	1.11	1.03	0.91	0.92	1.00	0.92	0.94
2013	Marginal On-Peak	1.25	1.43	2.17	1.32	1.44	1.48	1.67	1.79	1.80	1.65	1.82	2.67	1.71
	Marginal Off-Peak	1.41	1.35	1.70	1.32	1.33	1.36	1.42	1.44	1.51	1.32	1.38	1.83	1.45
	PJM System Average	0.96	0.95	0.97	0.95	0.96	0.98	1.04	0.94	0.96	0.90	0.89	0.92	0.95
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

Figure 8. Marginal NO<sub>x</sub> 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 9. CO<sub>2</sub> Emission Rates Standard Deviation**

CO <sub>2</sub> STD (lbs/MWh)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2012	Marginal On-Peak	421	473	389	355	326	390	416	388	358	239	302	365	369
	Marginal Off-Peak	384	379	408	352	428	434	451	426	377	331	334	335	387
2013	Marginal On-Peak	325	340	341	332	326	288	247	295	248	274	407	300	310
	Marginal Off-Peak	321	340	326	370	310	336	337	460	289	289	369	278	335
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

**Figure 10. SO<sub>2</sub> Emission Rates Standard Deviation**

SO <sub>2</sub> STD (lbs/MWh)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2012	Marginal On-Peak	3.6	2.4	2.8	2.5	2.8	3.6	2.1	2.2	2.0	2.4	3.0	3.3	2.7
	Marginal Off-Peak	3.6	2.4	3.2	3.2	4.2	2.7	2.1	2.2	1.6	2.1	3.2	2.5	2.8
2013	Marginal On-Peak	3.0	2.6	3.6	4.1	4.0	3.2	3.8	4.4	2.9	2.9	2.7	2.2	3.3
	Marginal Off-Peak	2.9	3.2	3.8	4.2	2.7	2.9	3.3	3.2	2.2	2.5	2.4	2.6	3.0
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

**Figure 11. NO<sub>x</sub> Emission Rates Standard Deviation**

NO <sub>x</sub> STD (lbs/MWh)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2012	Marginal On-Peak	1.8	1.1	1.0	1.1	0.9	1.5	2.0	0.9	0.9	0.5	0.5	1.4	1.1
	Marginal Off-Peak	0.8	0.7	0.9	0.6	1.0	1.1	1.3	0.5	0.6	1.0	0.6	0.6	0.8
2013	Marginal On-Peak	0.6	1.0	2.4	0.7	0.7	0.6	0.6	1.0	1.1	0.9	2.5	3.2	1.3
	Marginal Off-Peak	0.6	0.7	1.4	0.9	0.6	0.6	0.6	0.7	0.7	0.5	1.3	1.7	0.9
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