

2012-2016 CO₂, SO₂ and NO_x Emission Rates

March 17, 2017



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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.

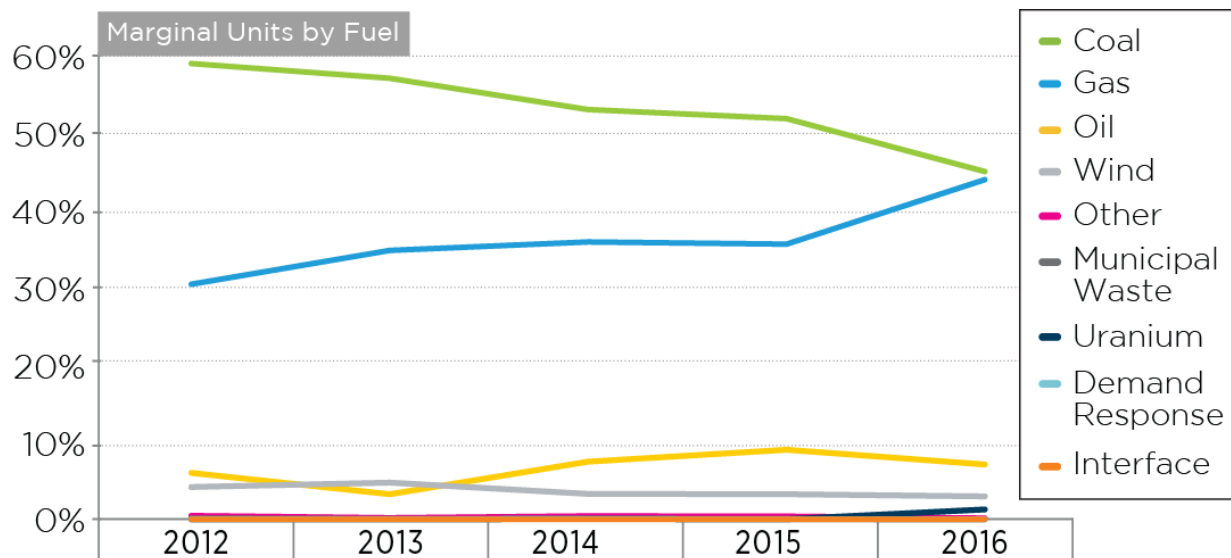
The PJM system average emissions rate is calculated monthly and is available publicly on the [PJM EIS website](http://www.pjm-eis.com) (www.pjm-eis.com). Generation (in megawatt-hours) for each PJM generator is received monthly from the PJM Market Settlement Reporting System. The energy output of each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



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

Carbon Dioxide

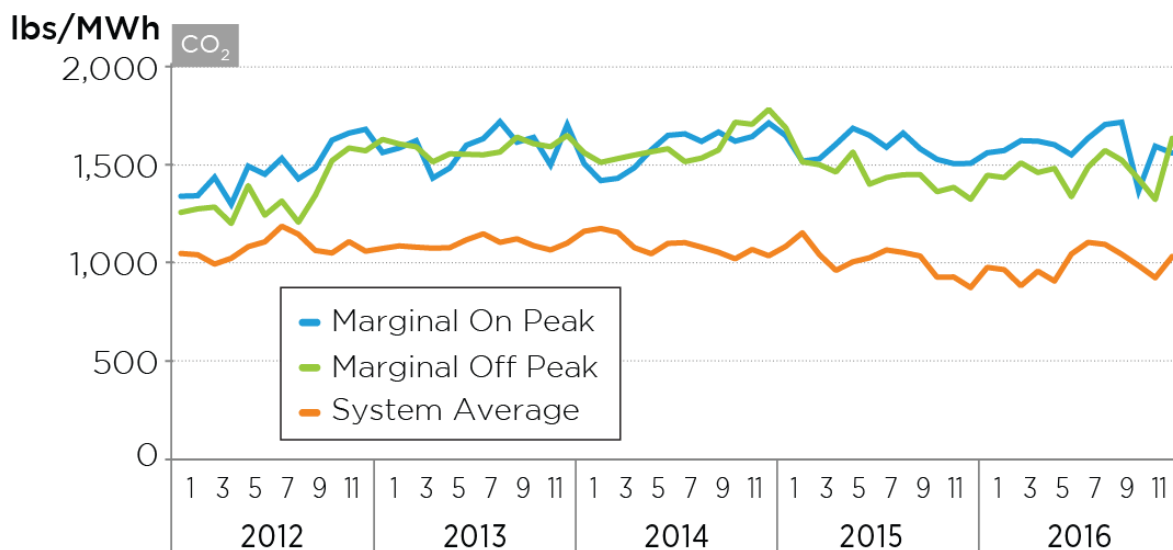
The table and graph below show the emission rates, measured in pounds per megawatt-hour, from marginal units in the PJM footprint as well as the monthly average CO₂ emissions.

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

Figure 3. Marginal CO₂ Emission Rates Table

| CO ₂ (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 CO₂ Emission Rates Graph



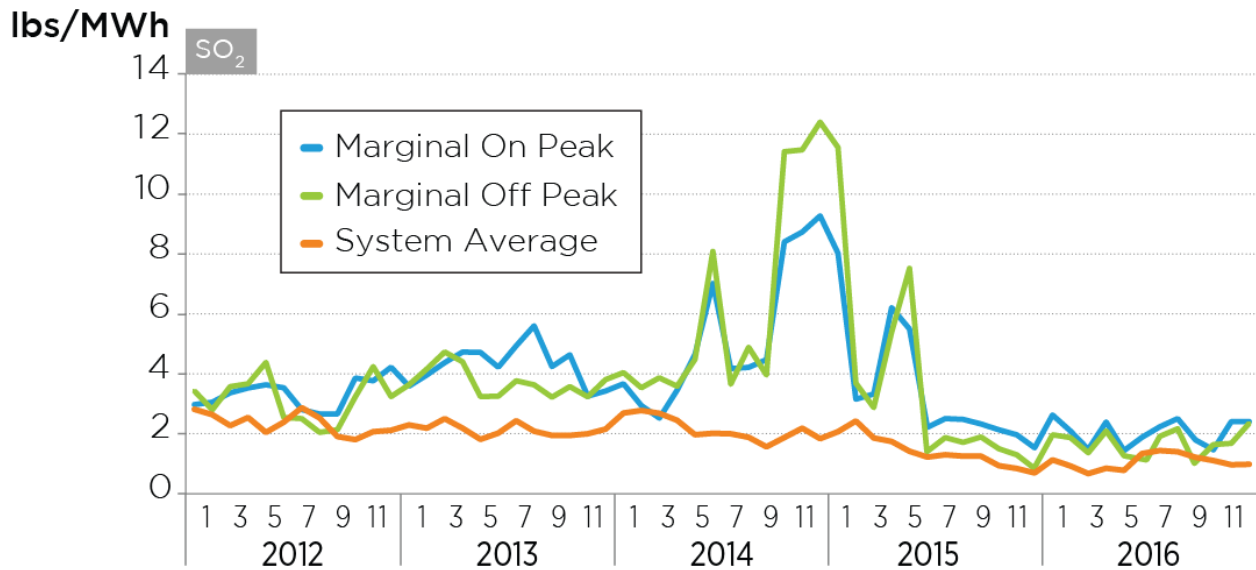
Sulfur Dioxide

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 5. Marginal SO₂ Emission Rates Table

| SO ₂ (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 SO₂ Emission Rates Graph



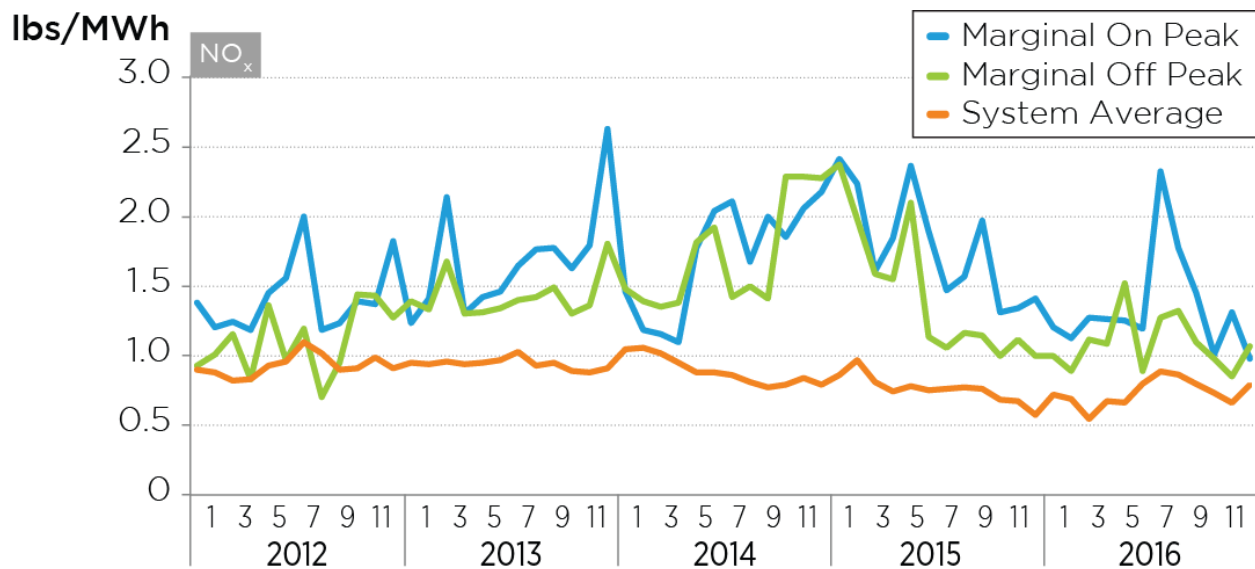
Nitrogen Oxides

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 7. NO_x Emission Rates Table

| NO _x (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_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 9. CO₂ Emission Rates Standard Deviation

| CO ₂ 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. SO₂ Emission Rates Standard Deviation

| SO ₂ 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_x Emission Rates Standard Deviation

| NO _x 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 |