2017–2021 CO₂, SO₂ and NOₓ
Emission Rates
April 18, 2022
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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 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, approximately 98% of all PJM generation either was 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

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Technology</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
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<tbody>
<tr>
<td>Gas</td>
<td>CC</td>
<td>44.63%</td>
<td>53.45%</td>
<td>62.13%</td>
<td>64.33%</td>
<td>59.75%</td>
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<tr>
<td>Coal</td>
<td>Steam</td>
<td>32.28%</td>
<td>27.26%</td>
<td>24.37%</td>
<td>17.53%</td>
<td>14.15%</td>
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<tr>
<td>Wind</td>
<td>Wind</td>
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<td>2.56%</td>
<td>3.81%</td>
<td>6.75%</td>
<td>11.04%</td>
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<td>Gas</td>
<td>CT</td>
<td>4.70%</td>
<td>7.80%</td>
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<td>5.89%</td>
<td>10.06%</td>
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<tr>
<td>Gas</td>
<td>Steam</td>
<td>3.52%</td>
<td>1.68%</td>
<td>1.29%</td>
<td>2.12%</td>
<td>1.17%</td>
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<tr>
<td>Oil</td>
<td>CT</td>
<td>5.18%</td>
<td>4.58%</td>
<td>0.49%</td>
<td>1.25%</td>
<td>1.13%</td>
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<tr>
<td>Uranium</td>
<td>Steam</td>
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<td>1.04%</td>
<td>1.31%</td>
<td>1.35%</td>
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<td>Other</td>
<td>Solar</td>
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<td>0.07%</td>
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<td>Oil</td>
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<td>CC</td>
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<td>0.01%</td>
<td>0.00%</td>
<td>0.02%</td>
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<td>0.01%</td>
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<tr>
<td>Municipal Waste</td>
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<td>0.04%</td>
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<td>CT</td>
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<tr>
<td>Landfill Gas</td>
<td>Steam</td>
<td>0.04%</td>
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<tr>
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<td>0.00%</td>
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<tr>
<td>Landfill Gas</td>
<td>RICE</td>
<td>0.02%</td>
<td>0.04%</td>
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<td>0.00%</td>
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1 The percentages by fuel type and technology provided in Table 1 are from the annual 2021 PJM State of the Market Report, Table 3-64 Type of fuel used and technology (By real-time marginal units): 2017 through 2021.
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

<table>
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<tr>
<th>CO₂ (Lbs./MWh)</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
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<tr>
<td>On-Peak</td>
<td>1,292</td>
<td>1,396</td>
<td>1,187</td>
<td>1,426</td>
<td>1,318</td>
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<td>1,480</td>
<td>1,467</td>
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<td>1,412</td>
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<td>1,340</td>
<td>1,347</td>
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<td>961</td>
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<td>880</td>
<td>963</td>
<td>946</td>
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<tr>
<td>On-Peak</td>
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<tr>
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<td>1,344</td>
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<td>1,160</td>
<td>1,232</td>
<td>1,302</td>
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<tr>
<td>On-Peak</td>
<td>1,229</td>
<td>1,282</td>
<td>1,212</td>
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<tr>
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<td>1,213</td>
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<td>1,284</td>
<td>1,200</td>
<td>1,117</td>
<td>1,302</td>
<td>1,125</td>
<td>1,091</td>
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<td>796</td>
<td>818</td>
<td>951</td>
<td>897</td>
<td>869</td>
<td>792</td>
<td>842</td>
<td>777</td>
<td>851</td>
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<td>1,430</td>
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<td>1,001</td>
<td>986</td>
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<td>816</td>
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<tr>
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<td>909</td>
<td>972</td>
<td>961</td>
<td>818</td>
<td>745</td>
<td>730</td>
<td>740</td>
<td>843</td>
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</table>

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**

<table>
<thead>
<tr>
<th>SO₂ (Lbs./MWh)</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
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<th>Dec</th>
<th>Annual</th>
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</tr>
<tr>
<td>On-Peak</td>
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<td>1.41</td>
<td>1.09</td>
<td>1.60</td>
<td>0.75</td>
<td>0.78</td>
<td>1.02</td>
<td>0.98</td>
</tr>
<tr>
<td>Off-Peak</td>
<td>1.45</td>
<td>0.95</td>
<td>0.74</td>
<td>0.95</td>
<td>0.99</td>
<td>0.70</td>
<td>1.05</td>
<td>0.88</td>
<td>0.97</td>
<td>0.88</td>
<td>1.09</td>
<td>1.16</td>
<td>0.98</td>
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<tr>
<td><strong>PJM System Average</strong></td>
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<td>0.72</td>
<td>0.75</td>
<td>0.82</td>
<td>0.76</td>
<td>0.71</td>
<td>0.68</td>
<td>0.70</td>
<td>0.85</td>
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</tr>
<tr>
<td>On-Peak</td>
<td>0.68</td>
<td>0.83</td>
<td>0.72</td>
<td>0.73</td>
<td>0.49</td>
<td>0.77</td>
<td>0.70</td>
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<td>0.69</td>
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<td>0.71</td>
<td>0.76</td>
<td>0.66</td>
<td>0.48</td>
<td>0.51</td>
<td>0.68</td>
<td>0.51</td>
<td>0.68</td>
</tr>
<tr>
<td><strong>PJM System Average</strong></td>
<td>0.82</td>
<td>0.66</td>
<td>0.70</td>
<td>0.66</td>
<td>0.64</td>
<td>0.66</td>
<td>0.64</td>
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</table>

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

**Lbs./MWh**

1.00  | 1.50  | 2.00  | 0.00  | 0.50  | 1.00  | 1.50  | 2.00  | 0.00  | 0.50  | 1.00  | 1.50  | 2.00  |


Marginal On-Peak | Marginal Off-Peak | System Average
Nitrogen Oxides (NO\textsubscript{x})

The table and graph below show the NO\textsubscript{x} emission rates, measured in pounds per megawatt-hour, from marginal units in the PJM footprint, as well as the monthly average NO\textsubscript{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\textsubscript{x} Emission Rates Table

<table>
<thead>
<tr>
<th>Year</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
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<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
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### Figure 3. Marginal NO\textsubscript{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. CO₂ Emission Rates Standard Deviation

<table>
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<th>CO₂ Std (Lbs./MWh)</th>
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<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual</th>
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<td><strong>2017</strong> On-Peak</td>
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<td>273</td>
<td>289</td>
<td>361</td>
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<td><strong>2020</strong> On-Peak</td>
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## Table 6. SO₂ Emission Rates Standard Deviation

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<th>Oct</th>
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## Table 7. NOₓ Emission Rates Standard Deviation

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<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
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