Estimating Particulate Matter Emissions for eGRID

DRAFT White Paper

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Table of Contents

Table of Figures

Table of Tables

Introduction

EPA's Emissions & Generation Resource Integrated Database (eGRID) is a comprehensive source of data on air pollution emissions and electricity generation for nearly all electric generating units in the United States. Currently, eGRID includes emissions data on carbon dioxide (CO_2), nitrogen oxides (NO_X), sulfur dioxide (SO_2), methane (CH_4), nitrous oxide (N_2O), and mercury (Hg), but does not include information on particulate matter (PM). PM pollution ─ principally fine particulate matter 2.5 microns in diameter or smaller ($PM_{2.5}$) ─ can lead to negative health impacts, including asthma exacerbations, heart attacks, and premature mortality. For example, Lelieveld et al. (2015) estimated that in 2010, 55,000 premature deaths in the United States were attributable to two types of air pollution ─ $PM_{2.5}$ and ozone.[1] Levels of $PM_{2.5}$ pollution are of concern for human health impacts. EPA's retrospective analysis of the Clean Air Act found that approximately 85 percent of the public health benefits of air quality regulations are due to $PM_{2.5}$ reductions, rather than ozone (EPA 2011a).[2] $PM_{2.5}$ can also lead to reduced visibility, also known as haze, which has negatively affected much of the country, including many national parks.

eGRID uses CAMD's Power Sector Emissions Data reported to EPA's Clean Air Markets Division (CAMD)[3] to determine the CO_2, NO_X, SO_2, and Hg emissions at many electric generating units. For electric generating units that do not report to CAMD, eGRID estimates emissions based on fuel use, as reported to the Energy Information Administration (EIA).[4] Neither CAMD nor EIA collect data specifically about $PM_{2.5}$ emissions.[5] For this reason, it is not possible to use PM data from either CAMD or EIA data to estimate the $PM_{2.5}$ emissions and $PM_{2.5}$ emission rates from power plants.

EPA's National Emissions Inventory (NEI) is a source of $PM_{2.5}$ emissions data. The annual emissions of air pollutants, including $PM_{2.5}$, from most electric generating units are reported to the NEI.[6] While EPA has not previously used the NEI data for eGRID, EPA is proposing to use NEI data to determine $PM_{2.5}$ emissions at electric generating units. The most recent data year for both eGRID and NEI data is 2016.

This paper discusses the methods EPA proposes to use to determine $PM_{2.5}$ emission rates for each power plant, including steps to estimate emissions for units that may not report to the NEI. The 2016 $PM_{2.5}$- emission rates were calculated first, with those emission rates then applied to the eGRID2018 data to estimate 2018 $PM_{2.5}$ emissions. The accompanying Excel data file, "eGRID DRAFT PM Emissions.xlsx", lists the unit- and plant-level heat input, plant-level generation, and unit-, plant-, and eGRID subregion-level $PM_{2.5}$ emissions and emission rates for 2016 and 2018.

Note that $PM_{2.5}$ can be emitted in two forms ─ as particles (filterable $PM_{2.5}$) or as a gas that later condenses into particles when it enters the atmosphere (condensable $PM_{2.5}$). The eGRID methodology is

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[1] Lelieveld, J., J.S. Evans, M. Fnais, D. Giannadaki, and A. Pozzer. 2015. The contribution of outdoor air pollution sources to premature mortality on a global scale. *Nature* 525: 367–371.

[2] EPA. 2011a. *The Benefits and Costs of the Clean Air Act from 1990 to 2020.* U.S. Environmental Protection Agency Office of Air and Radiation. Final Report – Rev. A. April. Available: https://www.epa.gov/sites/production/files/2015-07/documents/fullreport_rev_a.pdf. U.S. Environmental Protection Agency.

[3] These data are reported to EPA under chapter 40 of the Code of Federal Regulations part 75 (40 CFR part 75) for several Clean Air Act programs, including the Acid Rain Program and Cross-state Air Pollution Rule.

[4] These data are reported to EIA through form EIA-923.

[5] EIA collects some data on PM emission rates, but it does not specify whether the rates are for $PM_{2.5}$ or PM_{10} (particulate matter 10 microns in diameter or smaller).

[6] Electric generating units and other point sources of air pollution emissions do not report emissions directly to the NEI. Rather they report to state, local, or tribal agencies, which then report the data to the NEI.

designed to include both of these types, which are also known as primary $PM_{2.5}$.[7]

Methodology

The most recent year in which both eGRID and NEI data were both available was 2016. To estimate $PM_{2.5}$ emissions and emission rates for 2018, unit-level $PM_{2.5}$ emission rates, expressed in pounds per million British thermal units (lb/MMBtu), were developed using the 2016 NEI $PM_{2.5}$ mass emissions data and the 2016 EIA heat input data. The unit-level $PM_{2.5}$ emission rates developed for 2016 were then multiplied by the 2018 unit-level heat input to estimate 2018 unit-level $PM_{2.5}$ emissions. The 2018 unit-level $PM_{2.5}$ emissions were summed to the plant-level and eGRID subregion-level to estimate 2018 plant-level $PM_{2.5}$ emissions and eGRID subregion $PM_{2.5}$ output emission rates.

The following methodology discusses how the 2016 unit-, plant-, and eGRID subregion-level $PM_{2.5}$ emissions and emission rates were calculated.

The 2016 eGRID unit file contains data on 25,031 electric generating units, 15,538 of which combust some fuel to generate electricity (as opposed to, for example, geothermal, nuclear, solar, water, or wind generation). There were 11,525 combustion units with positive heat input that were operational during at least some part of 2016.

The NEI contains annual $PM_{2.5}$ emissions data for electric generating units, but the first step in integrating NEI data is to match the electric generating units to the eGRID data. The NEI uses Emissions Inventory System (EIS) codes to identify facilities and units, while eGRID uses Office of Regulatory Information Systems Plant (ORISPL) codes to identify facilities and units. EPA's Office of Air Quality Planning and Standards (OAQPS), which compiles the NEI, has matched electric generating units between EIS identifiers used in the NEI and the ORISPL identifiers used in eGRID.[8] The EIS and ORISPL systems do not always have a one-to-one relationship; in some cases, multiple EIS IDs are used to refer to a single unit in eGRID (or vice versa). In order to use the NEI data in eGRID, the NEI data are mapped to the appropriate ORISPL plant and unit ID. Multiple units in the NEI that are reported as matching to one eGRID unit are grouped and summed to determine the total emissions for each eGRID unit. For units that cannot be matched directly to the NEI, EPA estimated the $PM_{2.5}$ emissions using a series of emission factors. In general, the process of determining the $PM_{2.5}$ emissions for each unit follows a four-step process:

1. **Direct match.** First, out of the 11,451 operational combustion units with positive heat input, the EPA matched 3,859 units directly between the 2016 NEI and 2016 eGRID. This leaves 7,592 operational combustion units that could not be matched to a specific unit in the NEI. These units either do not report to the NEI as point sources or an adequate match between NEI and eGRID could not be determined.

2. **Average emission factors by fuel type, unit firing type, and prime mover.** EPA developed average emission factors by grouping the 3,859 units from the NEI that can be matched to eGRID by fuel type (e.g., bituminous coal), unit firing type (e.g., wall-fired), and prime mover (e.g., steam turbine). The $PM_{2.5}$ emissions and heat input, expressed as million British thermal units (MMBtu), for all units in each group were summed. The emission factor was calculated by

[7] In addition to primary $PM_{2.5}$ emitted by electric generating units, secondary $PM_{2.5}$ can form in the atmosphere based on reactions of gases, such as NO_X, SO_2, and ammonia. This proposed method only addresses primary $PM_{2.5}$.

[8] This analysis uses the data from the 2016v1 air emissions modeling platform (available at https://www.epa.gov/air-emissions-modeling/2016v1-platform) to identify $PM_{2.5}$ emissions from power plants.

dividing the total emissions in each group by the total heat input in each group. This emission factor is multiplied by the heat input reported by EIA for all units that could not be matched to a unit in the NEI, but which have the same fuel type, firing type, and prime mover. This accounts for 641 units, leaving an additional 6,951 units that could not be either matched to a unit in the NEI or to a fuel, firing type, and prime mover-specific emission factor.

3. **Average emission factors by fuel type and prime mover.** EPA next developed more general average emission factors by grouping the units from the NEI by fuel and prime mover, using the same process described in step 2. To capture more units, firing type was not included in this step because not all units have firing type data. These emission factors were multiplied by the reported heat input for all units that could not be matched to a unit in the NEI or to an emission factor created under step 2. This accounts for 1,407 units with positive heat input in eGRID.

4. **Emission factors from AP-42.** For the remaining 5,544 units, EPA estimated the $PM_{2.5}$ emissions using an emission factor reported in EPA's AP-42.[9] The emission factors from AP-42 are specific to the unit's fuel, firing type, and prime mover. For 336 of these units, EPA was able to match the units to a PM control efficiency reported in EIA's form 923. Therefore, for these units, the $PM_{2.5}$ emissions estimated using the emission factor were adjusted to account for the control efficiency. Since the NEI emissions included in step 1 and the average emission factors developed in steps 2 and 3 are based on reported emissions to the NEI, the control efficiency is already accounted for in these emission factors. The emissions in steps 1 through 3 therefore did not need to be further adjusted for any control efficiencies.

There are some fuel types for which there are no emission factors in AP-42 or another source. For these factors, EPA applied an emission factor from a similar fuel type. For example, there is no emission factor for other gas (OG), so EPA used the emission factor for natural gas (NG).

For some fuel types, including lignite coal, petroleum coke, and waste oil, the $PM_{2.5}$ emission factors depend on the ash content of the fuel. For the 9 units combusting these fuels that could not be directly matched to the NEI, EPA first estimated an ash content of the fuel. EIA-923 reports ash content at the unit-level for each month. EPA calculated a weighted average ash content for each unit that uses lignite, petroleum coke, or waste oil, weighted by the amount of heat input for each unit in each month, which were used with equations from AP-42 to determine unit-specific emission factors for those three fuel types.

As is done in eGRID, an adjustment is applied to the emissions and heat input for all combined heat and power (CHP) plants to allocate emissions for CHP plants between electricity and thermal output. For more information, please see the eGRID Technical Support Document.[10]

Unit-level $PM_{2.5}$ emission rates were developed with the 2016 data and applied to eGRID2018 unit-level heat input to determine the 2018 $PM_{2.5}$ plant- and eGRID subregion-level emissions and emission rates. For any new plants in 2018, steps 2-4 (listed above) were repeated to develop emission factors to estimate $PM_{2.5}$ emissions. Unit-, plant-, and eGRID subregion level $PM_{2.5}$ emission rates were then calculated for

[9] United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Compilation of Air Pollutant Emission Factors, AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources.

[10] United States Environmental Protection Agency. The Emissions & Generation Resource Integrated Database: Technical Support Document for eGRID with Year 2018 Data. Available at https://www.epa.gov/energy/egrid-technical-support-document

2018. There were 1,038 new units that could not be updated using an emission rate calculated from 2016 $PM_{2.5}$ emissions.

Results

Figure 1 displays the 22 contiguous eGRID subregions. The 2018 subregion-level annual net generation, $PM_{2.5}$ emissions, and $PM_{2.5}$ output emission rates are shown in Figure 2 and in Table 1. The 2016 and 2018 unit-, plant-, and subregion-level annual net generation, $PM_{2.5}$ emissions, and $PM_{2.5}$ output emission rates are included in the Excel data file "eGRID DRAFT PM Emissions.xlsx."

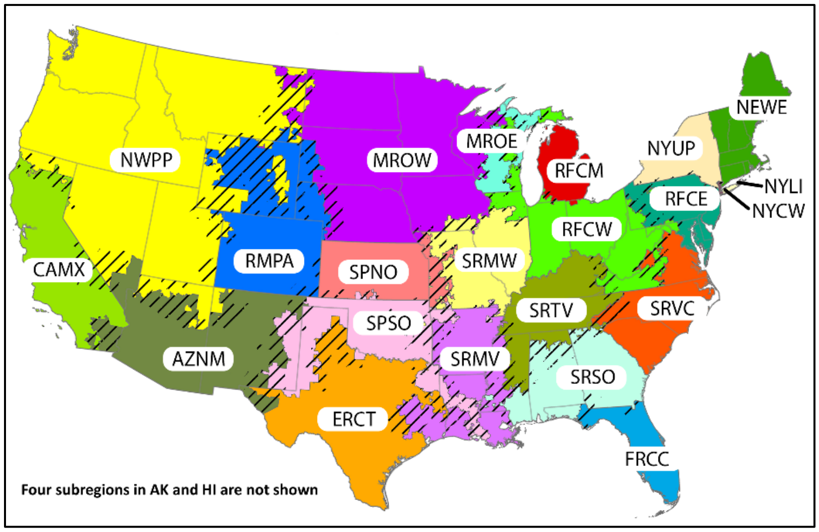

Figure 1. eGRID subregion map

The 2018 subregion-level $PM_{2.5}$ output emission rates range from 0.0165 lbs/MWh in the NYUP subregion to 0.9257 lbs/MWh in the HIMS subregion. The highest output emission rates are in the subregions in Alaska and Hawaii, which generally have a higher percentage of generation from oil and a lower percentage of generation of natural gas compared to the subregions in the contiguous United States. Because oil has a relatively high $PM_{2.5}$ output emission rate and natural gas has a lower rate, this could explain why the Alaska and Hawaii subregions have higher $PM_{2.5}$ output emission rates.

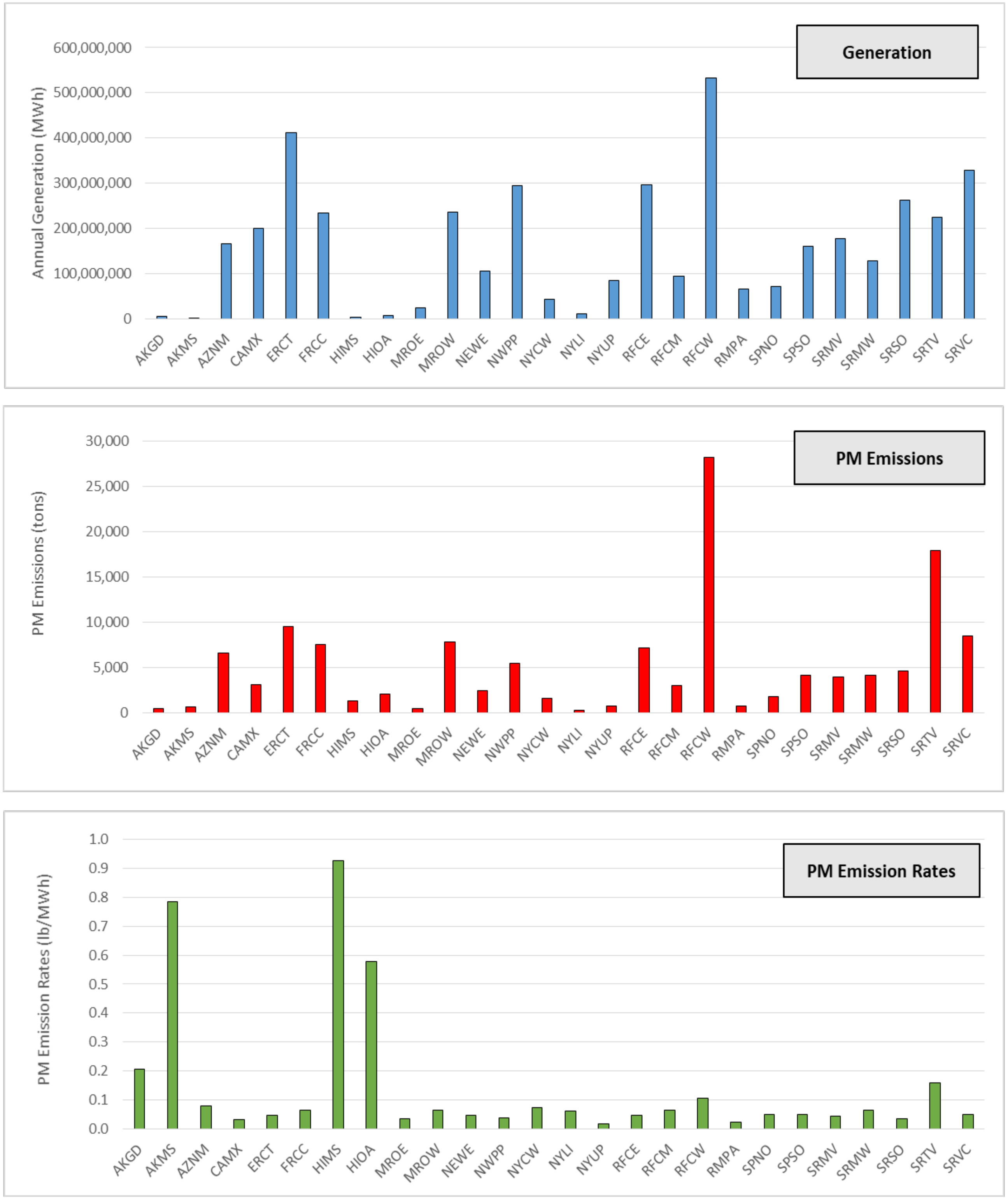

Figure 2. eGRID Subregion-level 2018 generation, $PM_{2.5}$ emissions, and $PM_{2.5}$ emission rates

Table 1. eGRID Subregion-level 2018 generation, $PM_{2.5}$ emissions, and $PM_{2.5}$ output emission rates

Subregion	Annual Generation (MWh)	Annual $PM_{2.5}$ Emissions (short tons)	Annual $PM_{2.5}$ Output emission rate (lbs/MWh)
AKGD	4,641,060	478	0.2059
AKMS	1,603,241	628	0.7832
AZNM	165,353,383	6,613	0.0800
CAMX	200,103,502	3,143	0.0314
ERCT	411,784,692	9,557	0.0464
FRCC	233,469,406	7,555	0.0647
HIMS	2,743,591	1,270	0.9257
HIOA	7,053,182	2,034	0.5766
MROE	24,091,646	441	0.0366
MROW	236,704,124	7,774	0.0657
NEWE	105,482,006	2,421	0.0459
NWPP	294,782,039	5,496	0.0373
NYCW	43,455,637	1,588	0.0731
NYLI	10,573,426	325	0.0615
NYUP	84,997,204	703	0.0165
RFCE	297,325,701	7,154	0.0481
RFCM	94,438,353	3,021	0.0640
RFCW	532,056,236	28,141	0.1058
RMPA	65,413,620	790	0.0242
SPNO	70,807,115	1,779	0.0502
SPSO	160,677,686	4,112	0.0512
SRMV	177,877,883	3,941	0.0443
SRMW	128,388,555	4,163	0.0648
SRSO	262,135,271	4,609	0.0352
SRTV	224,259,819	17,884	0.1595
SRVC	328,151,742	8,446	0.0515
U.S.	**4,168,370,118**	**134,064**	**0.0643**

Quality Assurance

EPA conducted quality assurance (QA) on the 2016 $PM_{2.5}$ emissions and emission rates data prior to the development of the 2018 $PM_{2.5}$ emissions and emission rates. The QA discussed here is therefore for the 2016 $PM_{2.5}$ emissions and emission rates data.

For the 2016 data, the units that EPA is able to directly match to a unit in the NEI represent approximately 34 percent of the units in eGRID with positive $PM_{2.5}$ emissions. However, these units tend to be the larger units, and as a result, the matched units account for 86 percent of the heat input and 83 percent of the estimated emissions (Figure 3). In other words, even though a relatively small number of units could be matched directly to the NEI, these units make up the majority of $PM_{2.5}$ emissions.

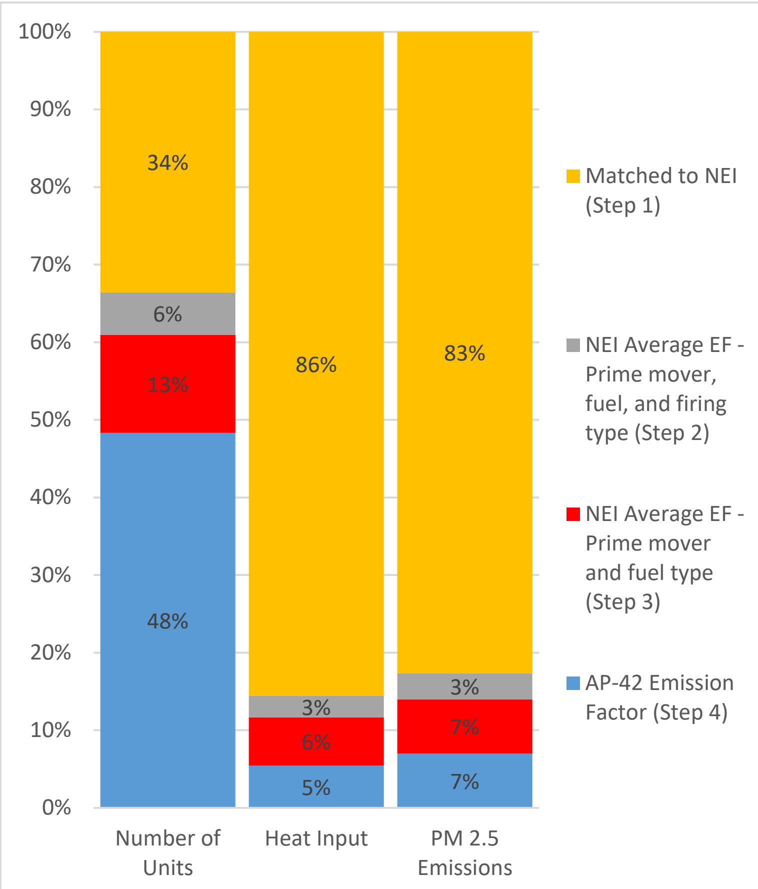

Figure 3. Proportions of units, heat input, and PM emissions by method of determination for 2016

In order to perform quality assurance on the $PM_{2.5}$ emissions calculated by an emission factor, EPA grouped the emissions by fuel type and compared the average emission rates across the different methods used to determine the $PM_{2.5}$ emissions (Table 2). In general, the fuel types that make up a majority of the $PM_{2.5}$ emissions in eGRID are either taken directly from the NEI or are calculated using an average emission factor from the NEI. For example, coal units, including bituminous, subbituminous, lignite, refined coal, and waste coal units, account for 63 percent of the $PM_{2.5}$, and none of the emissions for these units is estimated using an emission factor from AP-42.

The $PM_{2.5}$ emission rates from the units matched to the NEI compare well to the emission rates from the units using an NEI-derived emission factor. This is to be expected, given that these emission factors are based on average emission rates from the NEI.

It is more difficult to compare the $PM_{2.5}$ emission rates between the units matched to the NEI and the units using an AP-42 emission factor, because for most of the fuel types, all units either a) match to the NEI or an NEI-derived emission factor, or b) are calculated using an AP-42 emission factor. For example, an AP-42 emission factor was not used to estimate $PM_{2.5}$ emissions for any of the coal units. However, for other fuel types, such as municipal solid waste, EPA was not able to match any of the units to the NEI or to an NEI-derived emission factor, and therefore all emissions from these units are estimated using an emission factor from AP-42.

Of the fuel types that EPA can compare $PM_{2.5}$ emission rates between units that match to the NEI and units that use an AP-42 emission factor — such as natural gas, wood solids, residual fuel oil, and distillate fuel oil — the emission rates do not always compare well. For example, the average emission rate from units using an AP-42 emission factor for natural gas is an order of magnitude lower than the average emission rate from units matched to the NEI. For wood and oil units, the opposite is true; the average emission rate from units using an AP-42 emission factor is at least an order of magnitude higher than the average emission rate from units matched to the NEI.

However, there is a relatively small proportion of heat input from units with these fuel types where the $PM_{2.5}$ emissions are estimated using an AP-42 emission factor. For example, natural gas units using an AP-42 emission factor account for less than 1 percent of the total heat input for natural gas units in eGRID. Therefore, any potential overall bias from the AP-42 emission factors is likely low.

Table 2. 2016 $PM_{2.5}$ emission rates (lbs/MMBtu) by fuel type and method for determining emissions.

Fuel	Fuel Code	Proportion of $PM_{2.5}$ Emissions	$PM_{2.5}$ Emissions Matched to NEI (lb/MMBtu)	$PM_{2.5}$ Emissions NEI avg. EF [prime mover, fuel, and firing type] (lb/MMBtu)	$PM_{2.5}$ Emissions NEI avg. EF [prime mover and fuel type] (lb/MMBtu)	$PM_{2.5}$ Emissions AP-42 emission factor (lb/MMBtu)
Bituminous coal	BIT	29.63%	0.0183	0.0179	0.0183	
Natural gas	NG	23.00%	0.0065	0.0070	0.0083	0.0004
Subbituminous coal	SUB	20.74%	0.0131	0.0135	0.0131	
Refined coal	RC	7.94%	0.0109		0.0109	
Wood solids	WDS	4.25%	0.0244	0.0309	0.0244	0.1770
Lignite coal	LIG	3.54%	0.0171		0.0171	
Process gas	PRG	1.76%	0.0321	0.0806	0.0925	0.0004
Municipal solid waste	MSW	1.59%				0.0171
Residual fuel oil	RFO	1.45%	0.0082	0.0093	0.0082	0.3100
Agricultural biomass	AB	1.25%				0.1013
Distillate fuel oil	DFO	1.19%	0.0167	0.0190	0.0051	0.2872
Waste oil	WO	0.79%				0.3100
Waste coal	WC	0.66%	0.0170	0.0170		
Landfill gas	LFG	0.65%	0.0046		0.0046	0.0164
Black Liquor	BLQ	0.58%				0.0024
Other gas	OG	0.42%	0.0056	0.0110	0.0113	0.0004
Petroleum coke	PC	0.37%	0.0110	0.0110	0.0110	
Other biomass gas	OBG	0.07%				0.0153
Sludge waste	SLW	0.05%				1.0020
Other biomass liquid	OBL	0.03%				0.1770
Synthetic gas from coal	SGC	0.02%	0.0023			
Other biomass solid	OBS	0.01%				0.0047
Kerosene	KER	0.005%	0.0495		0.0495	
Blast furnace gas	BFG	0.003%				0.0004
Wood liquids	WDL	0.002%				0.0006
Other	OTH	0.001%				0.0004
Coke oven gas	COG	0.001%				0.0004
Jet fuel	JF	0.0003%	0.0092	0.0092	0.0092	
Propane gas	PG	0.000001%				0.0004
Tire derived fuel	TDF	0.00%				