APPENDIX B

Emission Reduction Analysis
For Proposed Amendments to Rule 4702

July 20, 2021

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I. SUMMARY

The purpose of this rule project is to obtain as much reductions of nitrogen oxides (NOx) and Volatile Organic Compounds (VOC) emission from the source category as expeditiously practical, technologically feasible, and economically reasonable. The District committed to amending Rule 4702 as part of the *2018 PM2.5 Plan*. This appendix details the calculations and assumptions used to estimate the NOx and VOC emission reductions associated with the proposed amendments to Rule 4702.

Emission reductions were estimated using permit conditions of each individual affected engine and the proposed rule's emission limits. **Table 1** shows the percent emission reductions estimated to be achieved from the baseline emissions for spark-ignited engines, and the number of engines that would be affected in each rule category.

Table 1 – Summary of NOx and VOC Percent Reductions from Spark-Ignited Engines

Affected Engine Category	Total Engines	Affected Engines	Total Rated Power (bhp)	NOx Reduction	VOC Reduction	Year
Rich-Burn	223	78	148,539	8%	39%	2024
Lean-Burn	69	42	137,281	48%	83%	2024
AO Lean-Burn	150	115	45,141	56%	81%	2030
AO Rich-Burn	364	359	80,290	87%	62%	2024
Total	806	594	411,255	48%	76%	2030

II. BACKGROUND

There are two types of spark-ignited engines that would be affected by the proposed rule changes: rich-burn and lean-burn engines. District staff estimates that there are 223 rich-burn engines and 69 lean-burn non-emergency-standby engines that are currently under permit with the District and are subject to Rule 4702. There are an additional estimated 364 rich-burn and 150 lean-burn engines that are used at agricultural operations within the District.

As further detailed earlier in this staff report, effective NOx emission control equipment for rich-burn engines includes non-selective catalytic reduction systems (NSCR). For lean-burn engines, the most common NOx emission control equipment is selective catalytic reduction (SCR). Both control systems require catalysts to convert NOx to nitrogen gas. NSCR tends to be less expensive to install and operate than a SCR system, but requires high temperature at the engine's outlet in order to be effective. NSCR is usually installed on rich-burn engines, and SCR is a control that is only able to be utilized for lean-burn engines.

Currently, the District does not take State Implementation Plan (SIP) credit for emissions reductions achieved through fee payment programs and related monetary incentive programs. However, as the fee payment program within this rule is proposed to sunset in 2023, the District will be proposing to take SIP credit for the emission reductions estimated to be achieved through this rule amendment.

III. EMISSION REDUCTION ANALYSIS

It is the District's experience that, when an emission limit is reduced, a small percentage of operators will choose to replace their internal combustion (IC) engines with electric motors, rather than retrofit with an emission control system. It would be speculative, at best, to determine which engines may be electrified as a result of this rule amendment, therefore the following emission reduction analysis does not include any estimate of NOx reductions for electrification. District staff will be quantifying the emissions achieved through the existing District Ag Pump Replacement incentive program in a separate reporting effort.

A. Affected Engines

District staff queried the Permit Services Permits Database for spark-ignited engines. The returned records were then sorted into one of three groups: emergency standby/dormant engines; rich-burn engines; and lean-burn engines. The emergency standby engines and dormant engines were removed from the analysis. The information about the remaining engines' facility and the permit information were scrutinized to estimate which engines would fit into one of six categories: limited-use, cyclic-loaded field gas fueled, waste gas fueled, two-stroke gaseous fueled greater than 50 brake horsepower (bhp) and less than 100 bhp, gas compression, or not listed above engine definitions. The number of affected engines and estimated emissions reductions from the potential to emit baseline for each rule category are shown in the table below.

Table 2 – Summary of NOx and VOC Emissions Reductions

Affected Engine Category	Number Affected Engines	Total Rated Power (bhp)	Estimated NOx Reductions (tpy)	Estimated VOC Reductions (tpy)
Rich-Burn	78	43,112	13.4	194.2
Lean-Burn	42	85,211	500.3	2118.5
AO Lean-Burn	115	31,407	86.8	115.3
AO Rich-Burn	359	79,217	133.5	82.9
Total	594	238,947	734.0	2510.9

B. Emission Reduction Calculation Methodology

An emissions factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., pounds of NOx emitted per hour). Such factors facilitate estimation of emissions from various sources of air pollution. In most cases, these factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category (i.e., a population average).

The general equation for emissions estimation is[1]:

$$E = A \times EF \times (1 - \frac{ER}{100}) \tag{1}$$

Where:

E = emissions;
A = activity rate;
EF = emissions factor; and
ER = overall emission reduction efficiency, %.

In order to use Equation 1 to estimate the emissions for the proposed revisions to Rule 4702, District staff prepared emissions factors for permitted engines in pounds of pollutant per hour of operation for both NOx and VOC. Rule and permit limits for engines are expressed in parts per million by volume (ppmv) and required conversion. To start, District staff applied EPA Method 19[2] to convert from ppmv to lb/MMBtu, as follows:

$$E_h = C_d F_d \frac{20.9}{20.9 - \%O_{2d}} \tag{2}$$

Where:

E_h = Emissions per heat content of fuel, in lb/MMBtu
C_d = Pollutant concentration, dry basis in lb/scf;
F_d = Volume of combustion components per unit of heat content in scf/MMBtu;
$\%O_{2d}$ = Concentration of oxygen on a dry basis, in percent.

Default values for F_d are provided by EPA Method 19, for natural gas, propane, or butane the value is 8,710 scf/MMBtu determined at standard conditions including a temperature of 68ºF. However, the District uses standard temperature of 60ºF, so that value must be converted resulting in 8,578 scf/MMBtu. Rule 4702 uses a standard

[1] https://www.epa.gov/air-emissions-factors-and-quantification/basic-information-air-emissions-factors-and-quantification
[2] https://www.epa.gov/sites/production/files/2017-08/documents/method_19.pdf

oxygen concentration (%O_{2d}) value of 15%. Pollutant concentration (C_d) is converted from ppmv as measured to lb/scf for this calculation. To accomplish this conversion, staff used the following equation:

$$C_d = \frac{ppmv}{10^6} \times \frac{PMM}{StdVol} \tag{3}$$

Where:

Cd = Pollutant concentration, per Equation 2;
ppmv = The permitted concentration limit of pollutant corrected to 15% O_2;
PMM = The pollutant molecular mass, in lb/lb-mol;
StdVol = The standard volume of a lb-mol of gas in scf/lb-mol.

Concentration limits were obtained from engine permits. Pollutant molecular mass for NOx was taken as 46 lb/lb-mol as NO_2, and for VOC is 16 lb/lb-mol as CH_4. Standard volume of a lb-mol of gas at District standard temperature is 379.5 scf/lb-mol.

The output of Equation 2 is in lb/MMBtu of fuel. To prepare a value that can be scaled to engine size and hours of operation staff converted to pounds per break horsepower hour (lb/bhp-hr) requiring an engine efficiency and unit conversion constants, as follows:

$$E_w = \frac{E_h}{Eff} \times \left(\frac{1\ MMBtu}{10^6\ Btu}\right) \times \left(\frac{2{,}545\ Btu}{1\ bhp-hr}\right) \tag{4}$$

Where:

E_w = Emissions per unit work, in lb/bhp-hr;
E_h = Emissions per heat content of fuel, in lb/MMBtu from Equation 2;
Eff = Engine efficiency, a unitless number.

A typical internal combustion engine efficiency, used for these calculations is 0.3 or 30%.

To determine the emissions factor to use in Equation 1, individual engine ratings in hp are used with a load factor based on the application, as follows:

$$EF = E_w \times P \times LF \tag{5}$$

Where:

EF = Emissions factor, in lb/hr;
E_w = Emissions per unit work, in lb/bhp-hr from Equation 4;
P = Engine rated power, in bhp;
LF = Load factor, a unitless number.

The load factor for 0.8 or 80% for agricultural engines, and 1.0 or 100% for all other engines.

Finally, the overall emission reduction efficiency (ER in Equation 1) is based on the percent reduction from the permit limit to the proposed rule limit. Calculated as follows:

$$ER = \frac{PL-RL}{PL} \tag{6}$$

Where:

ER = overall emission reduction efficiency, %.
PL = Permit limit, in ppmv @ 15% O2
RL = Proposed Rule 4702 Limit, in ppmv @ 15% O2

Activity for permitted engines was taken to be 4,000 hr/yr for non-agricultural limited use engines, 8,760 hr/yr for other non-agricultural engines, and 1,800 hr/yr for agricultural engines.

Example NOx Calculation

Bhp rating = 191 bhp
Permit Limit for NOx = 25 ppmv @ 15% O2
Proposed Limit for NOx = 11 ppmv @ 15% O2
Annual Hours of Operation: 4,000 hour/yr

Starting with Equation 3:

$$C_d = \frac{25}{10^6} \times \frac{46\ {}^{lb}/_{lb-mol}}{379.5\ {}^{scf}/_{lb-mol}} = 3.03 \times 10^{-6}\ {}^{lb}/_{scf} \tag{7}$$

Then applying Equation 2:

$$E_h = 3.03 \times 10^{-6}\ {}^{lb}/_{scf} \times 8{,}578\ {}^{scf}/_{MMBtu} \times \frac{20.9}{20.9-15} = 0.0921\ {}^{lb}/_{MMBtu} \tag{8}$$

Then applying Equation 4:

$$E_w = \frac{0.0921\ {}^{lb}/_{MMBtu}}{0.3} \times \left(\frac{1\ MMBtu}{10^6\ Btu}\right) \times \left(\frac{2{,}545\ Btu}{1\ bhp-hr}\right) = 0.000781\ {}^{lb}/_{bhp-hr} \tag{9}$$

Then applying Equation 5:

$$EF = 0.000781\ {}^{lb}/_{bhp-hr} \times 191\ bhp \times 1 = 0.149\ {}^{lb}/_{hr} \tag{10}$$

Determining the emission reduction efficiency using Equation 6:

$$ER = \frac{25\ ppmv - 11\ ppmv}{25\ ppmv} = 0.56 = 56\% \tag{11}$$

Finally, applying Equation 1:

$$E = 4{,}000\ hr\ \times\ 0.149\ {}^{lb}/_{hr}\ \times \left(1 - \frac{56}{100}\right) = 262.59\ {}^{lb}/_{yr} \qquad (12)$$

Thus, the estimated annual emissions for this example engine after complying with proposed new limits of the proposed amendments to Rule 4702 would be 262.59 lb/yr NOx, or 0.131 tpy NOx. Subtracting this from the same calculation with no reductions from Equation 6 would provide the emissions reduction estimate for this engine.

These calculations were performed for every permitted engine expected to be affected by the proposed Rule 4702. Detailed results of these calculations can be found **Table 8** at the end of this Appendix.

C. SIP Credit from Proposed Rule

The emissions reductions calculated above are based on the potential to emit for permitted engines in the Valley, and were used in cost-effectiveness calculations in Appendix C. However, in order to determine the emissions reductions that may be applied to commitments in the SIP, the reductions must be normalized to the planning inventory used in the analysis for the *2018 PM2.5 Plan*. The *2018 PM2.5 Plan* inventory for Engines from CEPAM v. 1.05 is shown in **Table 3**.

Table 3 – Annual Average Emissions Inventory from Engines (tpd)

Pollutant	2020	2022	2023	2024	2025	2026	2028	2029	2030
NOx	6.18	5.72	5.52	5.34	5.16	5.00	4.67	4.51	4.36
VOC	0.80	0.75	0.73	0.71	0.69	0.67	0.64	0.63	0.61

The emissions reduction calculations performed in this analysis focus on spark ignited engines subject to more stringent emissions requirements in the proposed amendment. As a result, normalizing the emissions reductions should be based only on the portion of the inventory specific to spark ignited engines. The emissions inventory is divided into categories based on source type, fuel, and other factors with each category represented by an emissions inventory code (EIC). Overall, Rule 4702 affects 28 EICs and of those only 15 are spark ignited engines. **Table 4** lists the EICs that represent spark ignited internal combustion engines.

Table 4 – List of EICs for Spark Ignited Engines

EIC	EIC Summary
010- 040- 0110- 0000	Reciprocating Engines Fueled By Natural Gas
020- 040- 0110- 0000	Reciprocating Engines Fueled By Natural Gas
030- 040- 0110- 0000	Reciprocating Engines Fueled By Natural Gas
030- 040- 0124- 0000	Reciprocating Engines Fueled By Propane

EIC	EIC Summary
040- 040- 0110- 0000	Reciprocating Engines Fueled By Natural Gas
050- 040- 0012- 0000	Reciprocating Engines with Unspecified Fuel
050- 040- 0110- 0000	Reciprocating Engines Fueled By Natural Gas
050- 040- 0124- 0000	Reciprocating Engines Fueled By Propane
052- 040- 0110- 0000	Reciprocating Engines Fueled By Natural Gas
052- 042- 0110- 0000	AG. Irrigation I. C. Engines Fueled By Natural Gas
060- 040- 0110- 0000	Reciprocating Engines Fueled By Natural Gas
060- 040- 0124- 0000	Reciprocating Engines Fueled By Propane
060- 040- 0142- 0000	Reciprocating Engines Fueled By Landfill Gas
060- 040- 0146- 0000	Reciprocating Engines Fueled By Digester Gas
060- 040- 1100- 0000	Reciprocating Engines Fueled By Unspecified Gasoline

The total emissions from the EICs are provided in **Table 5**.

Table 5 – Annual Average Emissions Inventory from Spark Ignited Engines (tpd)

Pollutant	2020	2022	2023	2024	2025	2026	2028	2029	2030
NOx	1.51	1.48	1.47	1.45	1.43	1.41	1.39	1.38	1.37
VOC	0.46	0.44	0.44	0.43	0.42	0.42	0.41	0.40	0.40

To normalize the calculated emissions reductions to the *2018 PM2.5 Plan* inventory, the total potential emissions without reductions was calculated to determine the emissions reductions from affected engines as a percentage of the category. These percentages are shown in **Table 6**.

Table 6 – Percent Emissions Reductions by Year

Pollutant	2024—2029	2030 and Later
NOx	44%	50%
VOC	72%	75%

To determine the emissions reductions achieved for SIP purposes, District staff multiplied the percent reductions by the spark ignited inventory included in CEPAM version 1.05 (the inventory used for the *2018 PM2.5 Plan*). Emission reductions from spark ignited engines for the proposed amendments are shown in **Table 7**.

Table 7 – Emissions Reductions from Proposed Amendment in Implementation Years (tpd)

Pollutant	2024	2030
NOx	0.62	0.70
VOC	0.31	0.32

Table 8- Estimated NOx and VOC Reductions from Proposed Amendments

Engine Category	Current NOx Permit Limit (ppmv)	Current VOC Permit Limit (ppmv)	Number of Units	Sum of Engine Power (bhp)	Proposed NOx Limit (ppmv)	Proposed VOC Limit (ppmv)	Sum of NOx Reductions (tpy)	Sum of VOC Reductions (tpy)
RB Cyclic Loaded, Field Gas Fueled	50	250	7	1101	11	90	5.88	8.39
RB Limited Use	25	250	18	7887	11	90	6.9	7.3
RB Not Listed Above	5	30	55	68064	11	90	0	0
	5.8	14	1	460	11	90	0	0
	6	25	1	539	11	90	0	0
	9	350	32	8179	11	90	0	9.13
	10.4	125	4	3360	11	90	0	1.4
	11	350	99	56698	11	90	0	167.95
	25	30	1	330	11	90	0.63	0
LB Gas Compression	11.9	34.1	4	17780	40	90	0	0
	64	212	3	978	40	90	3.21	5.68
	65	750	8	9755	40	90	33.38	195.87
	75	355	2	2000	40	90	9.58	25.23
	83	710	6	30000	40	90	176.55	885.41
	86	355	1	1000	40	90	6.3	12.61
	88	710	3	6000	40	90	39.41	177.08
	90	750	1	1000	40	90	6.84	31.42
	95	710	3	15000	40	90	112.91	442.7
	101	710	3	6000	40	90	50.09	177.08

Engine Category	Current NOx Permit Limit (ppmv)	Current VOC Permit Limit (ppmv)	Number of Units	Sum of Engine Power (bhp)	Proposed NOx Limit (ppmv)	Proposed VOC Limit (ppmv)	Sum of NOx Reductions (tpy)	Sum of VOC Reductions (tpy)
	104	750	3	4000	40	90	35.04	79.83
LB Waste Gas	10	20	4	12048	40	90	0	0
	43	51	1	1175	40	90	0.48	0
	50	57	1	892	40	90	1.22	0
	64	122	1	577	40	90	1.9	0.88
	65	750	6	6834	40	90	23.38	84.73
LB Not Listed Above	5	25	1	1737	11	90	0	0
	9	48	4	7667	11	90	0	0
	10	24	3	3736	11	90	0	0
	11	21	8	8002	11	90	0	0
AO Rich-Burn	2.8	6	1	398	11	90	0	0
	14.1	2	5	1010	11	90	0.07	0
	14.8	2	1	202	11	90	0.02	0
	19.8	4	4	500	11	90	0.1	0
	20	30	1	380	11	90	0.08	0
	20.1	3	1	200	11	90	0.04	0
	30	25	8	1770	11	90	0.76	0
	31	4	1	159	11	90	0.07	0
	36	5	1	173	11	90	0.1	0
	38	79	1	250	11	90	0.15	0
	40.9	6	1	174	11	90	0.12	0
	42	7	1	129	11	90	0.09	0
	70	138	1	151	11	90	0.2	0.06

Engine Category	Current NOx Permit Limit (ppmv)	Current VOC Permit Limit (ppmv)	Number of Units	Sum of Engine Power (bhp)	Proposed NOx Limit (ppmv)	Proposed VOC Limit (ppmv)	Sum of NOx Reductions (tpy)	Sum of VOC Reductions (tpy)
	90	750	333	74119	11	90	131.73	82.83
AO Lean-Burn	33	21	2	644	11	90	0	0
	38	2	2	644	11	90	0	0
	39	17	1	322	11	90	0	0
	40	7	1	322	11	90	0	0
	42.3	6	14	4503	11	90	0	0
	43	6	10	3220	11	90	0	0
	50	16	1	240	11	90	0.21	0
	50.2	6	1	241	11	90	0.21	0
	74	70	1	449	11	90	0.64	0
	79	50	1	322	11	90	0.49	0
	83.6	50	9	4497	11	90	7.34	0
	90	750	7	1563	11	90	2.77	3.33
	150	750	88	22085	11	90	69.06	108.68
AO Lean-Burn Digester Engine	10	24	1	1215	43	90	0	0
	11	21	1	1057	43	90	0	0
	150	87	2	400	43	90	5.86	0
AO Lean-Burn Permit Mod	49.4	750	2	644	43	90	0.09	3.33
	50	7	3	966	43	90	0.15	0
Dormant AO Lean-Burn	0	0	3	1811	0	90	0	0

Engine Category	Current NOx Permit Limit (ppmv)	Current VOC Permit Limit (ppmv)	Number of Units	Sum of Engine Power (bhp)	Proposed NOx Limit (ppmv)	Proposed VOC Limit (ppmv)	Sum of NOx Reductions (tpy)	Sum of VOC Reductions (tpy)
Digester Engine								
Dormant AO Rich-Burn	0	0	4	675	0	90	0	0
Dormant LB Not Listed Above	0	0	3	1100	0	90	0	0
Dormant RB Not Listed Above	0	0	5	1921	0	90	0	0
Grand Total							734.05	2510.92

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