

ENVIRON

DRAFT TECHNICAL MEMORANDUM

To: Tom Moore, Lee Gribovicz, WRAP
From: John Grant, Chris Lindhjem, Rajashi Parikh, and Alison Pollack
Date: March 3, 2009
Subject: WRAP PRP18b locomotive emission inventory

Per the request of the Western Regional Air Partnership (WRAP), ENVIRON has compiled an updated WRAP region locomotive emission inventory for 2018 for use in regional air quality modeling to be conducted by the WRAP. The WRAP locomotive emissions herein exclude California emissions as these were estimated separately for the state of California as described in another technical memorandum.

EPA RULEMAKING

EPA announced final emission standards that include an analysis of the expected benefit of normal fleet turnover and the additional benefit of this more recent rule¹. The emission standards include a retrofit of existing equipment as well as new locomotive emission standards called Tier 3 and Tier 4. Existing Tier 0, 1, and 2 locomotives will be subject to retrofit at the time of rebuild; so the locomotives will be rebuilt gradually throughout their remaining useful life.

The emissions standards, shown in Tables 1 and 2, depend upon the duty cycle chosen to certify the locomotives – either line-haul or switching locomotive duty cycles. The duty cycle for line-haul locomotives typically leads to lower emissions on a gram per horsepower-hour (hp-hr) basis because the switching locomotive duty cycle has considerable idling time (no hp-hr generated). In some cases the uncontrolled emissions are much lower than the emissions standards, so no emissions reduction would be expected from those standards, especially for HC and CO.

Table 1. EPA locomotive emissions standards (g/hp-hr) for line-haul (duty cycle) locomotives.

Emission Standard	Applicable Year	HC (g/hp-hr)	CO (g/hp-hr)	NOx (g/hp-hr)	PM (g/hp-hr)
Uncontrolled Emissions	Pre-1973	0.48	1.28	13.0	0.32
Tier 0 – original	1973 – 2001	1.00	5.0	9.5	0.60
Tier 0 – final ¹	2008 / 2010	1.00	5.0	8.0	0.22
Tier 1 – original	2002 – 2004	0.55	2.2	7.4	0.45
Tier 1 – final ¹	2008 / 2010	0.55	5.0	7.4	0.22
Tier 2 – original	2005	0.30	1.5	5.5	0.20
Tier 2 – final ¹	2013	0.30	1.5	5.5	0.10
Tier 3	2012 – 2014	0.30	1.5	5.5	0.10
Tier 4 ²	2015	0.14	1.5	1.3	0.03

¹ These are retrofit standards at the time of rebuild and phased in as retrofit kit availability.

¹ EPA, 2008. “Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters Per Cylinder,” Assessment and Standards Division Office of Transportation and Air Quality U.S. Environmental Protection Agency, EPA420-R-08-001, March.

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2 The Tier 4 NOx standard can be a 1.4 NOx + HC standard.

Table 2. Locomotive emissions standards for switching (duty cycle) locomotives.

Emission Standard	Applicable Year	HC (g/hp-hr)	CO (g/hp-hr)	NOx (g/hp-hr)	PM (g/hp-hr)
Uncontrolled Emissions	Pre-1973	1.01	1.83	17.4	0.44
Tier 0 – original	1973 – 2001	2.10	8.0	14.00	0.72
Tier 0 – final ¹	2008 / 2010	2.10	8.0	11.80	0.26
Tier 1 – original	2002 – 2004	1.20	2.5	11.00	0.54
Tier 1 – final ¹	2008 / 2010	1.20	2.5	11.00	0.26
Tier 2 – original	2005	0.60	2.4	8.10	0.24
Tier 2 – final ¹	2008 / 2013	0.60	2.4	8.10	0.13
Tier 3	2011 - 2015	0.60	2.4	5.00	0.10
Tier 4 ²	2015	0.14	2.4	1.30	0.03

¹ These are retrofit standards at the time of rebuild and phased in as retrofit kit availability allows.

² The Tier 4 NOx standard can be a 1.3 NOx + HC standard.

EPA provided assessment of the impact of its rulemakings for the original rule² and the more recent rule that encompass the final standards for Tier 0, 1, 2, 3, and 4 locomotives shown in Tables 1 and 2. In their most recent analysis, EPA provided the emission reductions due only to the more recent rulemaking, as they had already incorporated the 1998 rulemaking benefits in the baseline emissions estimates.

Emission Rates Relative to the EPA (1998) Rulemaking

EPA in their analysis of the rulemaking provided the expected emission reductions due to the latest rulemaking (2008) beyond that realized with the original locomotive emissions standards developed in 1988. Table 3 provides the 2018 emission reductions of the 2008 rule relative to the expected emissions in that absence of the 2008 rule but include the benefits of the 1998 rulemaking. The factors in Table 3 are only applicable if one has already included the benefits of the 1998 locomotive rulemaking in emissions inventories as ENVIRON did in the previous WRAP emission inventory³.

Table 3. Locomotive emissions reductions compared with the emissions that already include the 1998 EPA rulemaking (Table 3-91 of EPA, 2008).

Year	VOC	CO	NOx	PM
2018	34.2%	0.0%	18.3%	25.4%

Fleet Average Locomotive Emissions Rates Relative to Uncontrolled Emission Factors

An alternative is to determine the effect of locomotive rulemakings including the benefits of both 1998 and 2008 rules together in order to determine relative emission reductions compared to uncontrolled emission rates. EPA provided the baseline (uncontrolled) locomotive emission factors as shown in Table 4 (1997)⁴.

² EPA, 1998. "Locomotive Emission Standards," Regulatory Support Document, United States Environmental Protection Agency, Office of Mobile Sources, April.

³ Pollack, A.K., L. Chan, P. Chandraker, J. Grant, C. Lindhjem, S. Rao, J. Russell, C. Tran. 2006. "WRAP MOBILE Source Emission Inventories Update." Prepared for Western Governors' Association, Denver, CO. May.

⁴ EPA, 1997. "Emission Factors for Locomotives," EPA420-F-97-051, December.

Table 4. Locomotive emission factors for calendar years 1999 and earlier (EPA, 1997).⁴

Locomotive Type	HC (g/hp-hr)	CO (g/hp-hr)	NOx (g/hp-hr)	PM (g/hp-hr)	Fuel Consumption (hp-hr/gallon)
Line-Haul*	0.48	1.28	13.0	0.32	20.8
Switch**	1.01	1.83	17.4	0.44	20.8

* Line-haul locomotives over the line-haul duty-cycle

** Switch locomotives over the switch duty-cycle

By combining the assessment of emissions impacts found in EPA (1998) and EPA (2008, shown in Table 3), the relative emissions factors can be determined compared with the uncontrolled emission factors in Table 4. The EPA (1998) analysis provided the relative emission reduction rates for 1999 through 2006, while the EPA (2008) analysis provided the emission reduction rates from 2006 to all forecast years. Table 5 provides the results of combining the two EPA (1998 and 2008) estimates for 2018. The emission reductions shown in Table 5 do not include activity growth and used fleet-average emission values that combine line-haul and switching locomotive emissions.

Table 5. Average locomotive emissions factors relative to uncontrolled emission factors.

Year	HC	CO	NOx	PM
2018	0.756	0.997	0.416	0.411

ESTIMATION OF WRAP LOCOMOTIVE EMISSIONS

The previous 2018 forecasted WRAP region locomotive emissions had included the 1998 rulemaking prior to the EPA (2008) rule. To correct the 2018 emissions to incorporate the EPA (2008) rule, the HC, CO, NOx, PM, and SOx emissions would be reduced by 34.2%, 0.0%, 18.3%, 25.4%, and 99.7% following Table 3. Because the original WRAP inventory was prepared prior to the 2008 final rulemaking, the 1998 rule benefits had been incorporated but not those benefits from the 2008 rule. The WRAP inventory was thus updated to include both the 1998 and 2008 rulemakings' benefits.

GENERATION OF SMOKE AND NIF FILES

Emissions files were generated in the format needed for SMOKE emissions processing as described in Pollack et.al. The pollutants included in the SMOKE files are volatile organic compounds (VOC), NO_x, carbon monoxide (CO), ammonia (NH₃), sulfur dioxide (SO₂), particulate matter less than ten microns (PM₁₀), EC₁₀, OC₁₀, SO₄(10), particulate matter less than 2.5 microns (PM_{2.5}), EC_{2.5}, OC_{2.5}, SO₄(2.5), coarse PM (PMC), NO, and NO₂. Separate 2018 emissions files were prepared by season. The SMOKE files include emissions by county and SCC, which indicates equipment type and fuel type.

Annual emissions files in EPA's NIF format were also prepared for submission to the WRAP Emissions Data Management System (EDMS), the on-line repository of all WRAP emissions data (http://www.wrappedms.org/default_login.asp). These NIF files contain a smaller set of pollutants; the additional pollutants needed for air quality modeling are not included.

EMISSIONS SUMMARIES

Annual 2018 locomotive emissions by year for the previous and current updated emission inventory are presented in Table 6. Results show considerable decreases in NO_x, PM₁₀, PM_{2.5}, and VOC emissions from previous 2018 emissions inventory as a result of integrating the effects of the latest locomotive standards into the 2018 revised inventory; these changes are the same as shown in Table 3.

Table 9. 2018 WRAP region by state, previous and revised locomotive emissions.

State	VOC	CO	NOx	PM10	PM2.5	SO2	NH3
Revised 2018 Emissions (tons per day)							
Alaska	0.14	0.66	3.15	0.09	0.09	0.00	0.00
Arizona	2.63	13.13	55.96	1.82	1.77	0.05	0.06
Colorado	1.69	8.20	35.32	1.12	1.09	0.03	0.03
Idaho	0.50	2.82	10.55	0.29	0.28	0.01	0.00
Montana	2.57	12.50	53.81	1.71	1.66	0.04	0.05
Nevada	1.22	5.93	25.36	0.81	0.79	0.02	0.03
New Mexico	2.75	13.36	57.53	1.83	1.78	0.05	0.06
North Dakota	1.62	7.90	34.02	1.08	1.05	0.03	0.03
Oregon	1.31	6.38	27.47	0.87	0.85	0.02	0.03
South Dakota	0.35	1.70	7.33	0.23	0.23	0.01	0.01
Utah	1.34	6.52	28.08	0.89	0.87	0.02	0.03
Washington	1.94	9.44	40.65	1.29	1.25	0.03	0.04
Wyoming	5.54	27.93	118.66	3.88	3.77	0.10	0.12
Revised 2018 Totals	23.59	116.47	497.90	15.94	15.46	0.41	0.49
Previous 2018 Emissions (tons per day)							
Alaska	0.21	0.66	3.86	0.12	0.12	0.00	0.00
Arizona	4.00	13.13	68.50	2.44	2.37	0.05	0.06
Colorado	2.56	8.20	43.23	1.51	1.46	0.03	0.03
Idaho	0.76	2.82	12.91	0.39	0.38	0.01	-
Montana	3.90	12.50	65.87	2.29	2.23	0.04	0.05
Nevada	1.85	5.93	31.04	1.09	1.06	0.02	0.03
New Mexico	4.17	13.36	70.42	2.45	2.38	0.05	0.06
North Dakota	2.47	7.90	41.64	1.45	1.41	0.03	0.03
Oregon	1.99	6.38	33.63	1.17	1.14	0.02	0.03
South Dakota	0.53	1.70	8.97	0.31	0.30	0.01	0.01
Utah	2.04	6.52	34.37	1.20	1.16	0.02	0.03
Washington	2.95	9.44	49.76	1.73	1.68	0.03	0.04
Wyoming	8.42	27.93	145.24	5.20	5.05	0.10	0.12
Previous 2018 Totals	35.85	116.47	609.42	21.37	20.73	0.41	0.49
2018 percent change from previous to revised emissions							
Alaska	-34%	0%	-18%	-25%	-25%	0%	0%
Arizona	-34%	0%	-18%	-25%	-25%	0%	0%
Colorado	-34%	0%	-18%	-25%	-25%	0%	0%
Idaho	-34%	0%	-18%	-25%	-25%	0%	0%
Montana	-34%	0%	-18%	-25%	-25%	0%	0%
Nevada	-34%	0%	-18%	-25%	-25%	0%	0%
New Mexico	-34%	0%	-18%	-25%	-25%	0%	0%
North Dakota	-34%	0%	-18%	-25%	-25%	0%	0%
Oregon	-34%	0%	-18%	-25%	-25%	0%	0%
South Dakota	-34%	0%	-18%	-25%	-25%	0%	0%
Utah	-34%	0%	-18%	-25%	-25%	0%	0%
Washington	-34%	0%	-18%	-25%	-25%	0%	0%
Wyoming	-34%	0%	-18%	-25%	-25%	0%	0%
Totals	-34%	0%	-18%	-25%	-25%	0%	0%