Methodology for Estimating Emission Reductions and Cost Savings from Missoula Railyard Idle Reduction Policy and Auxiliary Power Unit Installation

United States Environmental Protection Agency

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Air Program
U.S. EPA Region 8

and

Transportation and Climate Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

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Table of Contents

Project Overview

An overview of information in this document was published on [EPAs Ports Initiative website](). The Ports Initiative website includes information on other promising practices for ports, railyards, and surrounding communities.

The railyard project focuses on reducing air pollution and saving money from reduced fuel consumption by switcher locomotives at the Montana Rail Link (MRL) Railyard in Missoula, Montana during colder months. Fuel savings were realized by installing auxiliary power units (APUs) on eight switcher locomotives, and changing the mandatory idling policy to better fit daily temperature conditions.

The city of Missoula, Montana is located along the Clark Fork River in western Montana and is the second largest metropolitan area in the state. Missoula has average low temperatures below 40 degrees Fahrenheit for eight months out of the year.

The APU installation portion of this project was partially funded by a 2009 Diesel Emissions Reduction Act (DERA) grant (DE – 97897201) awarded to the Missoula Metropolitan Planning Organization that exercises jurisdictional authority over local air quality issues. The grant help fund installation of APUs in eight resident switcher locomotives at a mid-sized railyard, located adjacent to downtown Missoula, Montana operated by MRL, a Class II regional railroad.

Grantee Reported Switcher Locomotive Emissions

Switcher locomotive roster and engine characteristics were provided by the grantee. The grantee reports 8 of the 16 switcher locomotives presented in Table 1 as being assigned to the Missoula, MT switchyard.

Table 1

Switcher Engine Grant Roster and Engine Characteristics							
Engine No.	Make	Model	Engine Year	HP	Tier	Idle Fuel Use (gal/hr)	Prolonged Idling (hr/yr)
1	EMD SW	12 Cyl-567C	1957	1200	*Un*	*3.5*	*2618*
2	EMD SW	12 Cyl-567C	1957	1200	*Un*	*3.5*	*2618*
3	EMD SW	12 Cyl-645E	1968	1500	*Un*	*3.5*	*2618*
4	EMD SW	12 Cyl-645E	1968	1500	*Un*	*3.5*	*2618*
5	EMD GP9	16 Cyl-567C	1957	1700	*Un*	*3.5*	*2618*
6	EMD GP9	16 Cyl-567C	1951	1750	*Un*	*3.5*	*2618*
7	EMD GP9	16 Cyl-567C	1957	1750	*Un*	*3.5*	*2618*
8	EMD GP9	16 Cyl-567C	1956	1750	*Un*	*3.5*	*2618*
9	EMD GP9	16 Cyl-567C	1957	1500	*Un*	*3.5*	*2618*
10	EMD GP9	16 Cyl-567C	1957	1750	*Un*	*3.5*	*2618*
11	EMD GP35	16 Cyl-567D3A	1964	2500	*Un*	*5*	*2618*
12	EMD GP35	16 Cyl-567D3A	1964	2500	*Un*	*5*	*2618*
13	EMD GP35	16 Cyl-567D3A	1965	2500	*Un*	*5*	*2618*
14	EMD GP35	16 Cyl-567D3A	1965	2500	*Un*	*5*	*2618*
15	EMD GP35	16 Cyl-567D3A	1965	2500	*Un*	*5*	*2618*
16	EMD GP35	16 Cyl-567D3A	1979	2500	*0+*	*5*	*2618*

Emissions were calculated using EPA-approved switcher locomotive emissions factors in grams per brake horsepower hour (g/bhp-hr) with an EPA-provided switcher fuel consumption conversion factor of 15.2 brake horsepower hour per gallon (bhp-hr/gal)[1] (Tables 2 and 3; Eq. 1).

Table 2

Switcher Emission Factors (g/bhp-hr)						
	PM_{10}	HC	NO_x	CO	VOCs	PM2.5
Uncontrolled	0.44	1.01	17.40	1.83	1.06	0.43
Tier 0	0.44	1.01	12.60	1.83	1.06	0.43
Tier 0+	0.23	0.57	10.60	1.83	0.60	0.22
Tier 1	0.43	1.01	9.90	1.83	1.06	0.42
Tier 1+	0.23	0.57	9.90	1.83	0.60	0.22
Tier 2	0.19	0.51	7.30	1.83	0.54	0.18
Tier 2+	0.11	0.26	7.30	1.83	0.27	0.11
Tier 3	0.08	0.26	4.50	1.83	0.27	0.08
Tier 4	0.015	0.08	1.00	1.83	0.08	0.01
"+" Indicates these are revised standards in 40 CFR 1033						

All but one of the switcher engines in the grant were originally manufactured before 1973, the start date for Tier 0 requirements. Therefore, although the grantee reported Tier 0 engines, emissions reductions for 15 engines have been calculated based on the factors for "uncontrolled engines (un)".

A locomotive operator trade association reported fuel consumption of **5** gallons per hour (gph) for EMD GP35 locomotives and **3.5** gph for all other EMD switcher locomotives on the fleet roster.[2] The total grant reported idling hours is 2618.

Eq 1:

$$\left(\frac{15.2\ bhp\ hr}{gal}\right) * \left(\frac{0.44\ g_{PM_{10},uncontrolled}}{bhp\ hr}\right) * \left(\frac{3.5\ gal}{engine{-}hr}\right) * \left(\frac{2618\ hr\ idling}{yr}\right) * \left(\frac{1.10231\times10^{-6}\ ton}{1g}\right)$$

$$= 0.068\ tons_{PM_{10}}\ engine^{-1}\ yr^{-1}$$

Table 3 provides a summary of the emissions as a result of idling from the 16 switchers in the roster calculated using Equation 1 and the emission factors for each pollutant.

[1] Office of Transportation and Air Quality, U.S. Environmental Protection Agency, "Emission Factors for Locomotives," *Technical Highlights*, EPA-420-F-09-025, April 2009.

[2] *Source*: International Association of Railway Operating Officers

Table 3

Switcher Roster Emissions From Idling						
	Annual Emissions (tons/engine-yr)					
Engine No.	PM_{10}	HC	NO_x	CO	VOCs	PM2.5
1	*0.068*	*0.155*	*2.671*	*0.281*	*0.163*	*0.066*
2	*0.068*	*0.155*	*2.671*	*0.281*	*0.163*	*0.066*
3	*0.068*	*0.155*	*2.671*	*0.281*	*0.163*	*0.066*
4	*0.068*	*0.155*	*2.671*	*0.281*	*0.163*	*0.066*
5	*0.068*	*0.155*	*2.671*	*0.281*	*0.163*	*0.066*
6	*0.068*	*0.155*	*2.671*	*0.281*	*0.163*	*0.066*
7	*0.068*	*0.155*	*2.671*	*0.281*	*0.163*	*0.066*
8	*0.068*	*0.155*	*2.671*	*0.281*	*0.163*	*0.066*
9	*0.068*	*0.155*	*2.671*	*0.281*	*0.163*	*0.066*
10	*0.068*	*0.155*	*2.671*	*0.281*	*0.163*	*0.066*
11	*0.097*	*0.222*	*3.816*	*0.401*	*0.233*	*0.094*
12	*0.097*	*0.222*	*3.816*	*0.401*	*0.233*	*0.094*
13	*0.097*	*0.222*	*3.816*	*0.401*	*0.233*	*0.094*
14	*0.097*	*0.222*	*3.816*	*0.401*	*0.233*	*0.094*
15	*0.097*	*0.222*	*3.816*	*0.401*	*0.233*	*0.094*
16	*0.050*	*0.125*	*2.325*	*0.401*	*0.132*	*0.049*

Total preventable switcher idling emissions were calculated for the 16 switcher locomotives included in the grantee's reporting (Table 4).

Table 4

Total Switcher Preventable Engine Emissions						
	PM_{10}	HC	NO_x	CO	VOCs	PM2.5
TOTAL (tons/yr)	*1.208*	*2.783*	*48.120*	*5.218*	*2.931*	*1.172*

Idle Hour Estimates Adjusted for Yard Idling Policy

The updated railyard policy calls for long-term idling of switcher engines or APU usage only during temperatures below 40 degrees Fahrenheit. This policy facilitates quick engine start-up and prevents engine damage during near-freezing conditions.

Missoula's northern continental climate requires 24-hour engine activity for much of the year. National Oceanic and Atmospheric Administration (NOAA) data[3] can be used to determine the average number of hours which fall

[3] National Oceanic and Atmospheric Administration, "Local Climatological Data for Missoula International Airport, MT US," accessed May 1, 2018, https://www.ncdc.noaa.gov/cdo-web/datasets/LCD/stations/WBAN:24153/detail.

below the 40-degree threshold per year. For the years 2010 – 2017, the annual average of hours below 40-degress was **3,557** (Table 5).

Table 5

Annual "Must Idle" Condition (<40 degrees Fahrenheit) Hours								
Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
"Must Idle" Hours Count	*3623*	*3746*	*3511*	*3752*	*3527*	*3376*	*3214*	*3709*
Average Annual "Must Idle" Hours	*3557*							

To clarify, not all 3557 hours are idling hours, as most of them could fall within normal winter usage hours. To estimate the number of “must-idle” hours, or time when locomotives are expected to idle solely due to the ambient temperature and engine maintenance, the reported annual activity hours per engine (**5,736**) is converted to represent the average daily activity hours- equaling **15.7**. This is rounded to the nearest whole number (16) and assumed to represent a typical work day. Without detailed yard logs, it’s assumed that the 16 hours represents two shifts from early morning to late afternoon (04:00 – 20:00). This would leave an eight-hour window overnight in which locomotives, due to yard inactivity, would be required to idle continuously during sub 40-degree Fahrenheit conditions. Using the hourly Missoula meteorological data from NOAA for the eight-year period (filtered for only the hours 20:00 – 04:00) an average annual “off-shift must-idle” hours number is calculated at **1,355**. This number represents the bulk of the idling hours reduced by APU usage after APU install (Table 6).

Table 6

Annual Overnight (20:00--4:00) "Must Idle" Condition (<40 degrees Fahrenheit) Hours								
Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Overnight "Must Idle" Hours Count	*1417*	*1404*	*1318*	*1420*	*1323*	*1281*	*1262*	*1412*
Avg. Annual Overnight "Must Idle" Hours	*1355*							

A smaller annual idling-hours number will be added to this bulk-hours total. This smaller number comes from a calculation derived from the reported annual use-hours, annual idling-hours and “summer hours,” which together is assumed to represent a complete picture of daily use throughout the year. This smaller number of idling hours accounts for the grantee’s estimates of locomotive movements during work shifts, annual idling hours and summer non-idle hours derived from a strictly defined 275/90-day winter/summer year. Using these reported hours, a daily average prolonged idling period of **1.15** hours per day (**418** hours annually from Equation 2) is assumed during normal usage hours.

Eq 2: $$\left(2618\,\frac{hr_{idling}}{yr}\right) - \left(275\,\frac{day_{winter}}{yr} * 8\,\frac{hr_{off-shift}}{day}\right) = 418\,\frac{hr_{idling,on-shift}}{yr}$$

<u>Average annual total hours predicted after yard policy change and APU install</u>: **1,773** (1,355 + 418)

<u>Average annual total idling hours replaced by APU usage and ambient temperature yard policy</u>: **2618** (grant reported)

Based on the above, engine activity would be reduced by 845 hours annually due to the yard policy change (2618 hours minus 1773 hours = 845 hours)

Aggregate APU emissions for the 8 Missoula railyard HotStart DDHSJR-110 APUs with Yanmar 2TNV70-ASA 2008 EPA Tier 4 engines were based on the APU engine characteristics (Table 7) and EPA emission factors for non-road compression ignition engines[4] (Table 8). Aggregate APU emissions were for temperature-defined "must-idle" hours tabulated as Local Climatological Data (LCD) hours below 40 degrees Fahrenheit as measured at Missoula International Airport, WBAN station ID: 24153. Accessed from NOAA, National Centers for Environmental Information's (NCEI) LCD clearinghouse (www.ncdc.noaa.gov/cdo-web/datatools/lcd). APU usage hours were restricted to those hours reported as prolonged idling hours by the grantee (Table 9).

Table 7

APU Engine Characteristics				
Engine Make	**Model**	**Power kW**	**Tier**	**Number**
Yanmar	*2TNV70-ASA*	*10.2*	*4*	*16*

Table 8

Tier 4 Emission Standards 8≤kW<19 (g/kW-hr)				
			Assumed	
NMHC + NO_x	**PM**	**CO**	**NMHC**	**NO_x**
7.5	*0.4*	*6.6*	*0.375*	*7.125*

Table 9

APU Aggregate Emissions						
		NMHC + NO_x	**PM**	**CO**	**NMHC**	**NO_x**
Total Operation (hr):	1773					
Number Engines:	8					
	TOTAL (tons/yr):	*1.196*	*0.064*	*1.053*	*0.060*	*1.136*

Annual, 8-year, and 10-year APU lifecycle net emissions reductions were based on a switcher fleet average emissions rate applied to the eight switchers assigned to the Missoula railyard. The 16 locomotive roster switchers were assumed to periodically be assigned to different yards. The eight switchers represented here are composites of the fleet-wide average locomotive (Table 10).

Table 10

	Emissions Locomotive (tons)			APU Emissions (tons)			Net Reduction (tons)		
	NO_x	PM	CO	NO_x	PM	CO	NO_x	PM	CO
Annual	*24.060*	*0.604*	*2.609*	*1.136*	*0.064*	*1.053*	*22.924*	*0.540*	*1.556*
8-Year	*192.479*	*4.834*	*20.871*	*9.090*	*0.510*	*8.420*	*183.389*	*4.324*	*12.450*
10 year	240.59888	6.0423877	26.08864	11.36286645	0.63791531	10.52560261	229.236018	5.404472354	15.56304

[4] Office of Transportation and Air Quality, U.S. Environmental Protection Agency, *Nonroad Compression-Ignition Engines: Exhaust Emission Standards*, EPA-420-B-16-022, March 2016.

Estimated APU Project Costs and Emission Benefits

APU technology and install costs for the 16 switchers were reported by the grantee (Table 11).

Table 11

APU Install Costs (USD)		
Locomotive No.	**Tech Unit Cost**	**Install Cost**
1	27366.93	2566.16
2	27151.17	3591.69
3	27755.24	3623.84
4	27596.37	4119.79
5	27566.70	3903.97
6	27994.90	3293.22
7	27413.28	2995.13
8	27794.54	3143.81
9	27808.78	3584.41
10	27926.00	3429.45
11	27036.88	2139.07
12	27037.20	2087.74
13	27563.35	3018.58
14	27157.77	2635.90
15	27464.82	2200.77
16	27556.94	1461.00
TOTAL (USD)	440190.87	47794.53

Total cost of APU installs on 16 locomotives was $487,985. The average cost per locomotive retrofit was applied to the eight Missoula yard switchers and used to find cost over a 10-year APU lifecycle per unit reduction of pollutant for oxides of nitrogen, particulate matter and carbon monoxide (Table 12).

Table 12

Lifecycle Cost per Unit Reduction			
	NO_x	PM	CO
10-year cost (USD/ton)	1064.37	45146.41	15677.69
10-year cost (USD/lb)	0.53	22.57	7.84

Estimated APU Project Fuel Cost Savings

Reduced fuel consumption cost savings were tabulated monthly and summed to find approximate year end cost savings. First, temperature dependent APU operation hours were further broken into monthly counts over the 8-year study period (Table 13).

Table 13

Count of "Off-Shift" Hours Below 40 Between Jan, 2010--Dec, 2017								
	2010	2011	2012	2013	2014	2015	2016	2017
Jan	242	229	236	242	243	247	247	248
Feb	214	209	231	223	223	195	210	210
Mar	211	214	188	199	213	138	199	138
Apr	142	162	79	123	133	134	66	116
May	61	38	47	23	26	25	7	45
Jun	0	2	5	3	0	0	6	4
Jul	0	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0
Sep	1	5	2	8	10	15	9	23
Oct	102	92	119	158	46	80	67	161
Nov	202	212	172	203	186	219	205	222
Dec	242	241	239	238	244	228	246	244

Yanmar engine specifications list APU fuel consumption rates as either 0.35 grams per hour (gph) (low setting) or 0.76 gph (high setting). Fuel consumption was calculated for temperature specified operation hours. The high fuel consumption rate was used to give a conservative estimate of fuel savings after APU retrofits. Fuel costs over the study period were averaged for No. 2 Ultra Low-Sulfur Diesel (ULSD). Averaged monthly fuel prices were calculated from weekly ULSD retail prices provided by the U.S. Energy Information Administration at: https://www.eia.gov/opendata/qb.php?sdid=PET.EMD_EPD2DXL0_PTE_NUS_DPG.W (Tables 14 and 15).

Table 14

Monthly APU Fuel Costs (USD) at High Consumption Rate (0.76 gph)								
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Jan	526.43	592.57	690.76	722.27	722.41	565.26	404.11	488.50
Feb	456.08	572.41	697.36	700.24	678.61	426.02	320.66	412.10
Mar	470.42	638.44	593.20	618.76	651.11	306.37	317.92	270.04
Apr	333.18	503.94	250.66	370.81	404.17	285.78	109.80	229.93
May	145.13	120.41	145.59	71.03	81.35	57.39	14.34	89.80
Jun	2.58	9.42	17.57	12.14	3.41	2.51	13.16	9.83
Jul	2.54	3.41	3.25	3.38	3.39	2.44	2.10	2.18
Aug	2.59	3.37	3.48	3.41	3.35	2.27	2.05	2.27
Sep	4.81	17.94	9.86	27.54	32.14	30.75	18.47	51.11
Oct	239.22	268.85	373.82	469.88	131.89	155.37	127.12	344.34
Nov	484.80	641.82	526.38	595.60	518.76	412.76	382.05	493.31
Dec	599.19	710.56	722.90	705.53	635.44	402.21	471.46	541.99

Table 15

Monthly APU Fuel Costs (USD) at Low Consumption Rate (0.35 gph)								
	2010	2011	2012	2013	2014	2015	2016	2017
Jan	242.44	272.90	318.12	332.62	332.69	260.32	186.10	224.97
Feb	210.04	263.61	321.15	322.48	312.52	196.19	147.67	189.78
Mar	216.64	294.02	273.18	284.96	299.85	141.09	146.41	124.36
Apr	153.44	232.08	115.44	170.77	186.13	131.61	50.57	105.89
May	66.84	55.45	67.05	32.71	37.47	26.43	6.60	41.36
Jun	1.19	4.34	8.09	5.59	1.57	1.16	6.06	4.53
Jul	1.17	1.57	1.50	1.56	1.56	1.12	0.97	1.00
Aug	1.19	1.55	1.60	1.57	1.54	1.04	0.95	1.04
Sep	2.22	8.26	4.54	12.68	14.80	14.16	8.51	23.54
Oct	110.17	123.81	172.15	216.39	60.74	71.55	58.54	158.58
Nov	223.26	295.58	242.41	274.29	238.90	190.09	175.94	227.18
Dec	275.94	327.23	332.92	324.92	292.64	185.23	217.12	249.60

Locomotive main engine monthly fuel costs due to prolonged idling were based upon the same pricing data, reported prolonged idling from the grantee and fuel consumption at idle rates from the International Association of Railway Operating Officers. Consumption rate for EMD SW1200, SW1500 and GP9 locomotives was fixed at 3.5 gph. Fuel consumption rate for EMD GP35 locomotives was set at 5 gph (Tables 16 and 17).

Table 16

Monthly Locomotive Fuel Costs (USD/engine) - GP35; 5 gph at idle								
	2010	2011	2012	2013	2014	2015	2016	2017
Jan	4040.24	4804.75	5435.58	5543.23	5521.60	4250.85	3038.96	3658.80
Feb	3573.03	4591.10	5063.15	5265.55	5102.86	3660.78	2559.69	3289.61
Mar	4137.89	5537.56	5852.41	5769.09	5673.85	4108.67	2964.14	3621.50
Apr	4203.28	5578.18	5647.84	5393.93	5440.93	3818.64	2952.93	3544.48
May	4357.71	5739.37	5642.51	5488.98	5591.81	4095.20	3282.68	3631.29
Jun	508.79	678.44	648.34	664.00	673.82	495.59	417.88	433.06
Jul	519.02	696.11	663.27	689.11	692.23	496.92	428.60	444.98
Aug	527.37	688.01	709.88	695.98	684.12	462.56	418.99	462.56
Sep	4043.73	5266.63	5654.70	5436.20	5205.07	3438.11	3286.11	3822.07
Oct	4327.79	5385.95	5806.03	5509.55	5219.87	3572.93	3480.95	3962.87
Nov	4309.65	5437.85	5490.00	5268.68	5005.85	3385.96	3346.84	3992.26
Dec	4598.68	5475.86	5617.40	5505.36	4837.08	3275.45	3559.81	4125.69

Table 17

Monthly Locomotive Fuel Costs (USD/engine) - GP9, SW; 3.5 gph at idle								
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Jan	2828.17	3363.32	3804.91	3880.26	3865.12	2975.59	2127.27	2561.16
Feb	2501.12	3213.77	3544.21	3685.89	3572.00	2562.54	1791.79	2302.73
Mar	2896.52	3876.29	4096.69	4038.36	3971.70	2876.07	2074.90	2535.05
Apr	2942.30	3904.73	3953.49	3775.75	3808.65	2673.05	2067.05	2481.14
May	3050.40	4017.56	3949.76	3842.29	3914.26	2866.64	2297.88	2541.90
Jun	356.15	474.91	453.84	464.80	471.67	346.91	292.52	303.14
Jul	363.31	487.28	464.29	482.38	484.56	347.84	300.02	311.49
Aug	369.16	481.61	496.92	487.18	478.89	323.79	293.30	323.79
Sep	2830.61	3686.64	3958.29	3805.34	3643.55	2406.68	2300.28	2675.45
Oct	3029.45	3770.16	4064.22	3856.68	3653.91	2501.05	2436.67	2774.01
Nov	3016.76	3806.49	3843.00	3688.08	3504.10	2370.17	2342.79	2794.58
Dec	3219.07	3833.10	3932.18	3853.75	3385.96	2292.81	2491.87	2887.98

Fuel cost savings for the Montana Rail Link (MRL) switcher engines were based upon the average fuel savings of the 16 retrofitted switcher engines in the Missoula Metropolitan Planning Organization (MPO) DERA grant. Year-end fuel savings were adjusted to 2010 USD to compare total savings over the APU life cycle to the initial investment cost for the APU materials and installation labor (Table 18).

Table 18

8-year Fuel Cost Savings for the 8-locomotive Missoula Switcher Fleet (2010 USD)							
2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2018**
228321	282808	292942	280438	271857	191241	159256	180843
TOTAL:	$1,887,707.92						

Note: detailed activity logs of each switcher locomotive, railyard assignment logs, activity data, and engine characteristics of the estimated 30 line-haul locomotives that pass through the Missoula yard daily would be useful in further ensuring emission benefits and cost savings estimates are accurate.

Acronyms & Abbreviations

APU – Auxiliary Power Unit

bhp-hr/gal – brake horsepower hour per gallon

CFR – Code of Federal Regulations

CO – Carbon Monoxide

DERA – Diesel Emissions Reduction Act

EPA – U.S. Environmental Protection Agency

g/bhp-hr – grams per brake horsepower hour

GPH – Gallons Per Hour

HC – Hydrocarbons

HP – Horsepower

kW - Kilowatt

NMHC – Non-methane Hydrocarbon

MPO – Metropolitan Planning Organization

MRL – Montana Rail Link

NOAA - National Oceanic and Atmospheric Administration

NO_x – Nitrogen oxides

PM_{10} – Particulate Matter smaller than 10 micrometers in diameter

$PM_{2.5}$ – Particulate Matter smaller than 2.5 micrometers in diameter

ULSD - Ultra Low-Sulfur Diesel

Un – Uncontrolled Engines

USD – United States Dollars

VOC – Volatile Organic Compounds