Impact Assessment of Renewable and Biodiesel Blends on Emissions of Respirable Pollutants from Diesels in Portland

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September 26. 2022

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Background

The City of Portland is considering modifying its renewable fuel standard (RFS) to allow renewable diesel (hydrotreated vegetable oil, or HVO) and higher blends of biodiesel (fatty acid methyl ester). The objective of this study was to quantify the effect of these fuels on particulate matter (PM), ozone precursors (VOC, NOx) and carbon monoxide (CO) emitted from the diesel fleet in Portland. To this end, an emission inventory analysis was conducted to assess the effect of switching to either 100 renewable diesel or a blend of renewable and biodiesel, on the emissions of Portland's onroad and nonroad diesel fleet in 2028.

This assessment was conducted by Rick Baker, John Koupal, and Allison DenBleyker of Eastern Research Group (ERG). ERG gratefully acknowledges the project leadership and technical input of Kyle Diesner of the City of Portland, and the contribution of Kevin Downing (Skookum Environmental Advisors) in scoping the initial study parameters. This report was prepared for the City of Portland by ERG as an independent contractor. ERG makes no statements other than those presented within the report.

The scope of the analysis is summarized in Table 1.

Table 1. Scope of Analysis

Geography	City of Portland
Emission Sectors	Onroad and Nonroad Diesel Engines
Analysis Year	2028
Base Fuel	95% ULSD / 5% Biodiesel (B5)
RFS Scenarios	99% Renewable Diesel (R99) 79% Renewable Diesel / 20% Biodiesel (R79/B20)
Output	Annual Mass Emissions (tons)
Pollutants	VOC, CO, NO_x, Direct $PM_{2.5}$

Modeling Approach

This section details three stages of the modeling analysis: synthesizing fuel study results and adapting them for use in assessing Portland's RFS scenarios; compiling an onroad diesel emissions inventory for a 2028 base case and RFS scenarios; and compiling a nonroad diesel emissions inventory for a 2028 base case and RFS scenarios. The emission inventory was developed using EPA's MOVES3 model for onroad sources, and projection of the 2017 inventory compiled for Oregon DEQ for nonroad sources.[1,2] Post-processing adjustments were made to

[1] U.S. EPA MOVES website (https://www.epa.gov/moves)

[2] ERG 2020. "Oregon Nonroad Diesel Equipment Survey and Emissions Inventory", Final Report prepared for the Oregon Department of Environmental Quality, November 23, 2020

the base inventories to simulate the “business as usual” scenario of B5 currently in use in Portland, RFS scenarios of 100 percent renewable diesel (R100), and a blend of 65 percent renewable diesel with 35 percent biodiesel meeting (R65/B35).

Fuel Effects

The City of Portland requested the analysis consider two recent studies of biodiesel and renewable diesel fuels on diesel engine emissions. The first was a meta-analysis of biodiesel effects on modern diesel engines published by the International Council on Clean Transportation (ICCT).[3] Renewable diesel emissions were based on a study published by University of California Riverside College of Engineering-Center for Environmental Research and Technology (UCR CE-CERT).[4] ERG adapted the results from these studies to the specific fuel blends analyzed for Portland, and to align with the technology distribution of diesel engines projected for 2028.

Biodiesel

The effect of biodiesel on modern engines was informed by the ICCT study, a meta-analysis of previously published biodiesel studies analyzing the effect of biodiesel blends by blend level and engine technology. Results from the study are shown in Table 2. Note the legacy engine impacts are comparable to the effects modeled by MOVES3, which were based on a similar meta-analysis of published studies conducted for EPA’s Renewable Fuel Standards rule. The consistency between the ICCT estimates and MOVES for legacy engines is due to the overlap of studies used by the two meta-analyses. ICCT also analyzed more recent studies on modern engines, while MOVES does not assign any effect for modern engines due to lack of data in their older meta-analysis.

Table 2. Emission Effects from ICCT Biodiesel Study

	ICCT 2021			MOVES3	
	Pre-2004	2004 EGR/CR	2007+ DPF/SCR	Pre-2007	2007+ DPF/SCR
NOx	↑2%	↑4%	Not reported	↑2%	No effect applied
PM	↓6%	-		↓16%	
HC	↓4%	↑7%		↓14%	
CO	-	↑10%		↓13%	

[3] ICCT 2021. O’Malley & Searle, “Air Quality Impacts of Biodiesel in the United States”, ICCT White Paper March 2021

[4] UCR 2021. Durbin et al., “Low Emission Diesel (LED) Study: Biodiesel and Renewable Diesel Emissions in Legacy and New Technology Diesel Engines”, Report for California Air Resources Board prepared by UC Riverside CE-CERT, November 2021

The ICCT reports statistical results for "modern" engines having common rail injection systems that were prevalent in the U.S. heavy duty diesel fleet by model year 2004. Though not included in the Table 2 results, the ICCT also found a statistically significant NOx increase for engines with EGR (common by model year 2004) and diesel particulate filters (DPFs, common by model year 2007). Though the ICCT study did not include enough data to isolate a NOx effect on modern trucks equipped with selective catalytic reduction (SCR) systems, the ICCT reported that the presence of an effect on DPF-equipped trucks may result from correlation of DPF and SCR, which are generally both present on modern trucks.

Renewable Diesel

Renewable diesel effects were drawn from UCR 2021, which tested one legacy and two modern high-sales engines. The engine specifications and their applicability for this study are summarized in Table 3.

Table 3. Engines Tested in UC Riverside Renewable Diesel Study

Engine Tested in UCR Study	Engine Application	Emissions Standard	EGR/DPF/SCR	Applicability for Portland RFS Analysis
2009 John Deere 115 HP	Nonroad (Construction)	EPA Tier 3	Yes/No/No	Offroad Tier 0-3 & Tier 4 without DPF and/or SCR
2018 Caterpillar 225 HP	Nonroad (Industrial)	EPA Tier 4	Yes/Yes/Yes	Offroad Tier 4 with DPF and/or SCR
2019 Cummins 450 HP	Onroad Class 7-8 Truck	EPA 2010	Yes/Yes/Yes	Onroad Model Year 2007 & later

The engines were tested on an engine dynamometer over a variety of duty cycles – the primary being the emission certification cycles for onroad (Federal Test Procedure, or FTP) or nonroad (Nonroad Transient Cycle, or NRTC) engines. Each engine was tested on at least one additional supplemental duty cycle used in the emissions certification for that engine. Each engine was tested on four fuels:

- Ultra-low Diesel Sulfur (ULSD) meeting California Air Resources Board (CARB) specifications and ASTM 975 (Base fuel, or B0);
- 100 percent renewable diesel fuel meeting ASTM 975 specifications (R100);
- A blend of 65 percent renewable diesel and 35 percent biodiesel meeting ASTM 6751 specifications (R65/B35); and,
- A blend of 50 percent renewable and 50 percent biodiesel (R50/B50).

Details on the duty cycles and test protocol are provided in the UCR study report, as are mass emission results for each engine, test cycle and fuel. For this analysis, the relative change in emissions switching from a conventional base fuel (B0) to renewable fuel were used as the basis for adjusting base emissions for the City of Portland. Only statistically significant emissions differences, summarized in Table 4, were used (cells with a dash indicate insignificant emissions changes). A range indicates the spread in results across different test cycles, and the midpoint of the range was used to estimate the fuel effects for this analysis.

Table 4. Emission Effects from UC Riverside Renewable Diesel Study

	Onroad	Nonroad	
	Modern (MY 2007+)	Legacy (Tier 3)	Modern (Tier 4)
R100			
NOx	-	↓5%	-
PM	-	↓27-38%	-
HC	-	↓35-45%	
CO	↓5%	↓14-22%	↓44%
R65/B35			
NOx	↑14-47%	-	↑55-88%
PM	-	↓52%	-
HC	-	↓49-58%	
CO	-	↓27%	↓98%
R50/B50			
NOx	↑15-50%	↑2-4%	↑119-147%
PM	-	↓58-63%	-
HC	↓71%	↓66-71%	-
CO	-	↓32%	↓100%

Key observations include:

- No emissions increase was observed for R100. This fuel reduced all four pollutants for the offroad legacy engine, and CO for the modern engines. While the UCR sample is limited to three engines, these results are consistent with prior studies on the effect of renewable diesel on legacy diesel engines.[5,6]
- While R100 resulted in a NOx decrease for the legacy offroad engine, blending RD with biodiesel led to NOx increases for the modern onroad and nonroad engines, and the legacy nonroad engine. The observed NOx increase is consistent with biodiesel studies summarized by ICCT, following the physical effects of biodiesel on combustion properties and cylinder temperature. However, the net impact of the high percentage increase in NOx emissions for modern engines is substantially offset by the fact that absolute emission levels from a modern engine are one-tenth those of a legacy engine.

[5] CARB 2015. Multimedia Evaluation of Renewable Diesel
[6] NREL 2018. Economy and Emissions Impacts from Solazyme Fuel in UPS Delivery Vehicles

- Though differences in PM mass emissions were not significant in the UCR program, there was a significant decrease in Particle Number (PN), which lends support to the conclusion that there is no apparent increase in PM mass emissions with the use of either renewable diesel or biodiesel.

The raw test results from UCR summarized in Table 4 were adapted to create multiplicative adjustment factors to be applied to base case emissions to estimate the impact of switching fuels. Generating these factors first required mapping study results to individual model years (for onroad engines) and technology groups (for nonroad engines) for application in the inventory analysis. These mappings are shown in Table 5 and 6 for onroad and nonroad engines, respectively. For onroad sources, MOVES uses engine model year to define technology evolution (aligned with shifts in emission standards), so study results were assigned based on model year and fuel blend combination. MOVES3 and ICCT 2021 were the basis for estimating biodiesel blend impacts (since adjustment was needed to reflect the actual B5 base case), and the UCR study was used for renewable diesel and renewable/biodiesel blend impacts. With no data available for legacy onroad engines, results from the legacy nonroad engine were used. The onroad analysis also accounts for EPA's heavy-duty "Glider" provisions, which permitted legacy emission standards to continue for a small percentage of trucks. Legacy engine fuel effects were applied to glider trucks for all model years.

Table 5. Mapping of Study Results to Onroad Diesel Technologies

Fuel	Legacy	MY 2004-06	MY 2007+
B5	MOVES3	ICCT Modern	
R99 & R79/B20	UCR Offroad Legacy		UCR Onroad NTDE UCR Offroad Legacy (HD "Gliders" only)

Nonroad fuel effects from the same studies were applied on a technology-specific basis to align with categories used for developing the 2017 inventory and projection to 2028. Mappings were pollutant-specific to account for Tier 4 nonroad technology categories that include either SCR or DPF, but not both.

Table 6. Mapping of Study Results to Nonroad Diesel Technologies

Engine Technology	2028 County Population	B5 fuel effect source				R99 & R79/B20 effect source			
		NOx	PM	HC	CO	NOx	PM	HC	CO
Baseline Pre-1988 Diesel	32	MOVES3				UCR Legacy	UCR Legacy		
Tier0 Diesel	141.8	MOVES3				UCR Legacy	UCR Legacy		
Tier1 Diesel	761.7	MOVES3				UCR Legacy	UCR Legacy		
Tier2 Diesel	1185.4	MOVES3				UCR Legacy	UCR Legacy		
Tier3 Diesel	315.6	ICCT Modern				UCR Legacy	UCR Legacy		
Tier3 Transitional Diesel	360.3	ICCT Modern				UCR Legacy	UCR Legacy		

Engine Technology	2028 County Population	B5 fuel effect source				R99 & R79/B20 effect source			
		NOx	PM	HC	CO	NOx	PM	HC	CO
Tier4 Transitional Diesel	6452.2	ICCT Modern				Mix	Mix		
Baseline Pre-1988 Recreational Marine Diesel	4.7	MOVES3				UCR Legacy	UCR Legacy		
Tier 0 Recreational Marine Diesel	0.4	MOVES3				UCR Legacy	UCR Legacy		
Tier 1 Recreational Marine Diesel	0.3	MOVES3				UCR Legacy	UCR Legacy		
Tier 2 Recreational Marine Diesel	8.5	MOVES3				UCR Legacy	UCR Legacy		
Tier 3 Recreational Marine Diesel	57.7	ICCT Modern				UCR Legacy	UCR Legacy		
Tier 3 (Full Phase-in) Recreational Marine Diesel	7.7	ICCT Modern				UCR Legacy	UCR Legacy		
Interim Tier 4 - No DPF, No SCR	114.5	ICCT Modern				UCR Legacy	UCR Legacy		
Interim Tier 4 - No DPF, With SCR	23.2	ICCT Modern				UCR Modern	UCR Legacy		
Interim Tier 4 - With DPF, No SCR	200.3	ICCT Modern				UCR Legacy	UCR Modern		
Interim Tier 4 - With DPF, With SCR	0.4	ICCT Modern				UCR Modern	UCR Modern		
Full Tier 4 - No DPF, No SCR	4091.4	ICCT Modern				UCR Legacy	UCR Legacy		
Full Tier 4 - No DPF, With SCR	3740.2	ICCT Modern				UCR Modern	UCR Legacy		
Full Tier 4 - With DPF, No SCR	4424.4	ICCT Modern				UCR Legacy	UCR Modern		
Full Tier 4 - With DPF, With SCR	1872.7	ICCT Modern				UCR Modern	UCR Modern		

Drawing from the raw study results presented in Tables 2 and 4, the adjustments used for the Portland analysis were derived as shown in Table 7. The final fuel adjustments for onroad sources are presented in Table 8, and Appendix A for nonroad sources.

Table 7. Method for Developing Portland Fuel Adjustment from Study Results

Portland Blend	Fuel Adjustment Method
B5	0.25 × (B20 Percent change)
R99	Average R100 Percent change
R79/B20	**R65/B35 change not significant:** no effect **R65/B35 effect significant:** (20/35) × (Average R65/B35 Percent change)

Table 8. Fuel Adjustment Factors for Onroad Sources

Pollutant	Model Year	B5	R99	R79/B20
NO_x	1998-2003	1.005	0.949	1.000
	2004-2006	1.010	0.949	1.000
	2007-2028	1.010	1.000	1.089
$PM_{2.5}$	1998-2003	0.960	0.675	0.564
	2004-2006	1.000	0.675	0.564
	2007-2028	1.000	1.000	1.000

Pollutant	Model Year	B5	R99	R79/B20
VOC	1998-2003	0.965	0.600	0.523
	2004-2006	1.018	0.600	0.523
	2007-2028	1.018	1.000	1.000
CO	1998-2003	0.968	0.820	0.769
	2004-2006	1.025	0.820	0.769
	2007-2028	1.025	0.950	1.000

Onroad Diesel Emissions

The first step in generating the onroad emissions inventory was running EPA's MOVES3 model (version 3.02) for Multnomah County in 2028, using default inputs for the county provided by EPA in the underlying default database. The one modification made to the default input set was to run the model without biodiesel fuel effects (the default database assumes a 3.4 percent biodiesel blend), to provide a B0 base case on which to apply the biodiesel and renewable diesel fuel adjustments described in the prior section. Figure 1 shows the contribution of different vehicle types (groups of MOVES source types) and model years to the 2028 estimate of onroad diesel consumption in 2028 for Multnomah County. Heavy-duty trucks (short and long haul) contribute over 80 percent of onroad diesel fuel consumed.

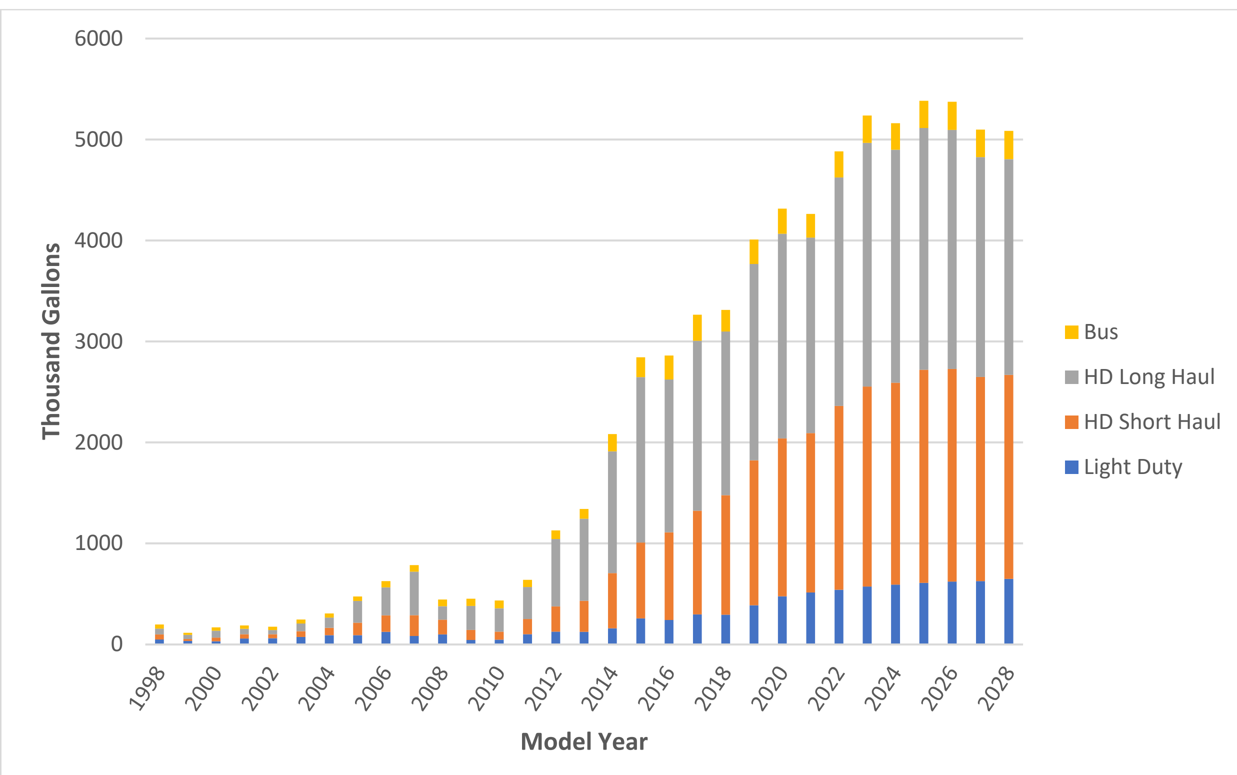

Figure 1. Multnomah County Onroad Diesel Consumption by Vehicle Type and Model Year

By 2028 less than 5 percent of fuel is projected to be consumed by “legacy” trucks lacking modern emissions technology (model years 2006 and earlier), but the contribution of these trucks to respirable pollutants will be higher due to the disparity in tailpipe standards – in particular VOC (21 percent) and $PM_{2.5}$ (52 percent). Therefore, the outsized contribution of legacy trucks to respirable emissions is an important factor in the overall effect of introducing higher renewable fuel blends.

To better represent the emissions affected by changes to diesel sold within Portland as per the RFS, the base case 2028 emissions generated for Multnomah County was adjusted by subtracting out emissions from rural roads and long-haul trucks (assumed to consume fuel purchased outside of Portland). Remaining emissions were then reduced 20 percent to estimate emissions within Portland city limits, using Portland vs. Multnomah County human population as a surrogate for the scaling of vehicle activity. Emissions for the RFS fuel scenarios were then calculated using the following equation:

$$E_{Poll,Fuel} = \sum_{MY=1998}^{2028} E_{Poll,MY,Base} \times A_{Poll,MY,Fuel}$$

Where:

E = Annual Onroad Emissions in Portland (Tons)
Poll = Pollutant (VOC, CO, NO_x or $PM_{2.5}$)
Fuel = B5, R99, or R79/B20
MY = Model Year
A = Fuel Adjustment

Nonroad Diesel Emissions

ERG estimated the emissions impacts associated with fuel switching in nonroad diesel engines following three steps:

1. Project emissions from the 2017 baseline developed for ODEQ to 2028
2. Adjust fuel effects to account for ODEQ inventory assumptions
3. Apply fuel adjustment factors to sector-specific emissions estimates and compile adjusted emissions

Emission Inventory Projections

The 2017 ODEQ diesel emissions inventory was developed at the state level for 21 different operation “sectors” (e.g., commercial construction, agriculture), with totals allocated to the county level using a variety of activity surrogates. Emissions for 20 of the 21 sectors were modeled based on sector-specific engine age distributions. To estimate the impact of fleet turnover and the adoption of new emission standards over time ERG simply increased the model year of each diesel engine unit by 11, shifting the age profile to calendar year 2028 without altering the "shape" of the age distribution.[7,8] The age adjustments were applied in the sector-specific emission calculation Excel worksheets developed for the ODEQ study.

Once the model year distribution was projected forward, total emissions were increased to account for the expected growth in equipment population and activity over time. The projected population growth for Multnomah County between 2017 and 2028 (ratio of 1.155)[9] was applied to the 2028 sector-specific emissions projections to account for the expected activity increase. Next, sector-specific activity was reduced by 20 percent to adjust for Multnomah County emissions occurring outside the city limits, with the following exceptions:

- City Fleet, City Highway Construction, Air and Marine Port Sector emissions were assumed to occur completely within the city limits
- Agriculture, Agricultural Services, and Logging Sector emissions within the county were assumed to occur completely outside the city limits

Fuel Effects Mapping Adjustments

The ODEQ nonroad emissions inventory study assumed B5 use for all operations excluding recreational marine diesel and railroad maintenance operations. The emissions adjustments for B5 were based on MOVES estimates for B20 use in onroad engines. However, these adjustments were not applied to engines meeting full Tier 4 standards.[10] Accordingly, a small additional linear adjustment was made to the fuel effects mapping for Tier 4 engines.

An additional adjustment was necessary to apply the fuel effect factors developed using the MOVES (version 3.02) B5 baseline referenced in Table 6 to the emissions developed for the ODEQ study, which were developed using an earlier version of MOVES. The earlier MOVES version output a single emission factor for each pollutant for Transitional Tier 4 engines (Technology Type 173), while the latest model version outputs disaggregated emission factors for these engines accounting for emission control combinations (Technology Type 174 with/without DPFs and SCR systems). ERG used the default equipment population estimates for the four emission control combinations (no DPF/no SCR, with DPF/no SCR, no DPF/with SCR, and with DPF/with SCR) in order to calculate a single weighted average adjustment factor for the Technology Type 173 values included in the ODEQ emission calculation worksheets. The final fuel adjustment factor lookup table for nonroad engines is presented in Appendix A.

[7] For example, a model year 2000 diesel engine included in the 2017 emission inventory was assumed to operate the same number of hours in 2028, but as a model year 2011 engine.
[8] The 21st sector included equipment that was too difficult to survey comprehensively, such as compressors and generator sets. The 2017 and 2028 model year distributions and emissions for these units were based on MOVES model defaults.
[9] See https://www.macrotrends.net/cities/23102/portland/population.
[10] See ERG 2020, Section 6.3.5.

Apply Fuel Adjustment Factors and Compile Emission Results

ERG multiplied the nonroad fuel adjustment factors by the zero-hour emission rates (i.e., the gram per hp-hr emission rates associated with new diesel engines) in the sector-specific ODEQ worksheets. The zero-hour emission factors were matched with the fuel adjustment factors by engine technology type/pollutant combination. Next, the adjusted statewide SCC-level emissions estimates for each sector were compiled into the Master Emissions Modeling Summary worksheets (one for R99, one for R79/B20, and one for the B5 baseline). The Master Summary worksheets apply further adjustments to avoid double-counting and allocate emissions back to the county level, then apply final adjustments to estimate city-specific emissions as described above.

Results

Table 9 summarizes the emissions results for onroad sources operating in the City of Portland in 2028, excluding rural roads and long-haul truck emissions.

Table 9. 2028 Portland Onroad Diesel Annual Tons by Fuel Scenario

Portland Annual Tons – Onroad Diesel				
Scenario	**CO**	**NOx**	**PM2.5**	**VOC**
B5	552.1	631.4	8.9	64.0
R99	504.5	618.7	6.7	57.0
R79/B20	524.4	669.3	5.9	55.8

Delta Tons (vs. B5)				
Scenario	**CO**	**NOx**	**PM2.5**	**VOC**
R99	-47.6	-12.7	-2.2	-7.0
R79/B20	-27.7	+37.9	-3.0	-8.2

% Change (vs. B5)				
Scenario	**CO**	**NOx**	**PM2.5**	**VOC**
R99	-8.6%	-2.0%	-24.7%	-10.9%
R79/B20	-5.0%	+6.0%	-33.7%	-12.8%

Onroad diesel emissions using the RFS fuel blends where lower than the B5 case for all pollutants and fuels, except NOx on R79/B20. The NOx increase for the RD/BD blend tracks results from the UCR RD/BD blends on modern diesel engines. Emission reductions for the R99 and R79/B20 blends for VOC, CO and $PM_{2.5}$ are driven by legacy engines, which showed large drops in the UCR study. The $PM_{2.5}$ reductions are particularly large because legacy trucks are projected to contribute over half of fleetwide emissions in 2028.

Table 10 summarizes the emissions results for nonroad sources operating in the City of Portland in 2028. The 2017 baseline scenario is provided for reference, reflecting the significant reductions resulting from emission standard penetration.

Table 10. 2028 Portland Nonroad Diesel Annual Tons by Fuel Scenario

Portland Annual Tons – Total Diesel				
Scenario	**CO**	**NOx**	**PM2.5**	**VOC**
2017 Baseline	350.3	649.3	51.7	69.0
B5	142.3	386.2	20.5	26.9
R99	117.1	365.7	14.4	16.8
R79/B20	108.6	390.8	12.1	14.8

Delta Tons (vs. B5)				
Scenario	**CO**	**NOx**	**PM2.5**	**VOC**
R99	-25.2	-20.5	-6.1	-10.0
R79/B20	-33.7	+4.6	-8.4	-12.0

% Change (vs. B5)				
Scenario	**CO**	**NOx**	**PM2.5**	**VOC**
R99	-17.7%	-5.3%	-29.9%	-37.3%
R79/B20	-23.7%	+1.2%	-41.1%	-44.8%

Appendix B includes a detailed breakout of nonroad source emission impacts by operation sector.

Figure 2 shows the projected relative contribution of onroad and nonroad sources to the 2028 Portland diesel emissions inventory. Nonroad is a substantial source, contributing roughly 20 percent of CO, 30 percent of VOCs, 40 percent of NOx, and the majority of mobile source $PM_{2.5}$ at 70 percent.

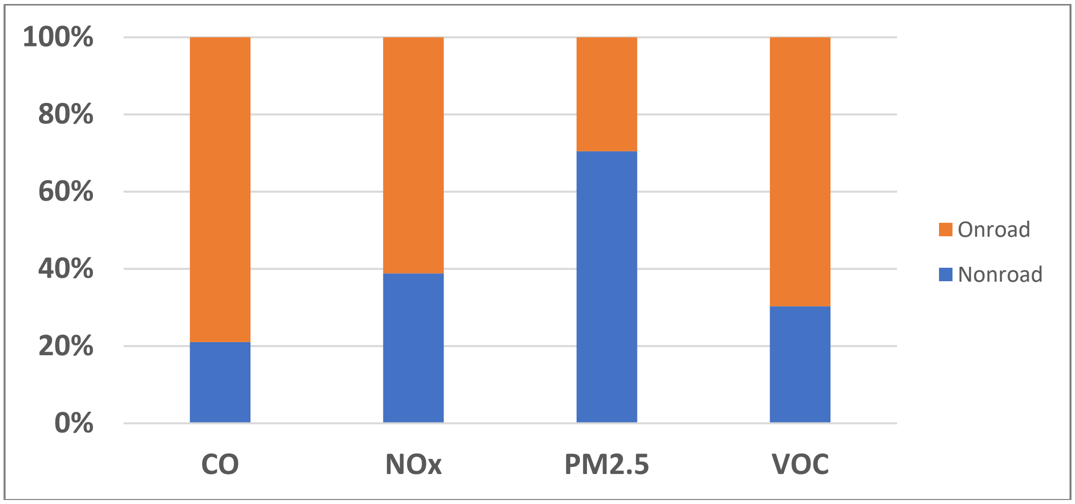

Figure 2. Contribution to Portland Diesel Emissions (B5)

Combined emission results for both sectors are presented in Table 11, by fuel scenario.

Table 11. 2028 Portland Diesel Annual Tons by Fuel Scenario – All Sources

Portland Annual Tons – Total Diesel				
Scenario	**CO**	**NOx**	**PM2.5**	**VOC**
B5	694.4	1,017.6	29.4	90.9
R99	621.6	984.4	21.0	73.8
R79/B20	633.1	1,060.1	17.9	70.6

Delta Tons (vs. B5)				
Scenario	**CO**	**NOx**	**PM2.5**	**VOC**
R99	-72.8	-33.2	-8.4	-17.1
R79/B20	-61.3	+42.4	-11.5	-20.3

% Change (vs. B5)				
Scenario	**CO**	**NOx**	**PM2.5**	**VOC**
R99	-10%	-3%	-28%	-19%
R79/B20	-9%	+4%	-39%	-22%

Conclusions

Our analysis of Portland's diesel emissions inventory in 2028 indicates that, relative to B5, introduction of R100 would reduce ozone-forming pollutants (VOC and NOx), carbon monoxide and particle emissions ($PM_{2.5}$) from Portland's diesel fleet. Though not directly modeled, these reductions would extend to air toxics as well since gaseous toxics are emitted in proportion to VOC, and particulate toxics in proportion to $PM_{2.5}$. Our analysis found that introduction of a R79/B20 blend would also reduce VOC, CO, and $PM_{2.5}$ relative to B5, but would increase NOx due to the well-documented effects of biodiesel on engine combustion, as well as on SCR performance reported UCR 2021. While much of the diesel fleet in Portland will be replaced by modern technology engines by 2028, the outsized emissions contribution of legacy engines will still be a driving factor in how renewable diesel or RD/BD blends will affect Portland's emissions inventory. For onroad engines, this is especially true for $PM_{2.5}$, for which legacy engines are projected to contribute roughly half of onroad diesel inventory by 2028 despite consuming less than five percent of the onroad diesel fuel.

While reductions in CO, PM2.5, and VOC are estimated for nonroad sources for both fuel scenarios, relatively large NOx increases are associated with modern diesel engines equipped with SCR systems. However, the NOx increase associated with use of the R79/B20 blend in nonroad sources is relatively small for two reasons. First, many operation sectors utilize few, if any, of the higher hp diesel engines that may be equipped with SCR at the Tier 4 emission standard level (e.g., large excavators and dozers). Second, much of the nonroad diesel fleet is still expected to be pre-Tier 4 well into the future. For example, less than half of the Airport sector fleet is projected to be Tier 4 in 2028. The result is a relatively small NOx increase of 1.2% for the R79/B20 blend scenario.

Appendix A – Nonroad Fuel Adjustment Factors

Engine Tech #	Technology Description	Pollutant	B5	R99	R79/B20
167	Baseline Pre-1988 Diesel	CO	1.000	0.848	0.794
167	Baseline Pre-1988 Diesel	NOx	1.000	0.944	0.995
167	Baseline Pre-1988 Diesel	PM2.5	1.000	0.703	0.587
167	Baseline Pre-1988 Diesel	VOC	1.000	0.622	0.542
168	Tier0 Diesel	CO	1.000	0.848	0.794
168	Tier0 Diesel	NOx	1.000	0.944	0.995
168	Tier0 Diesel	PM2.5	1.000	0.703	0.587
168	Tier0 Diesel	VOC	1.000	0.622	0.542
169	Tier1 Diesel	CO	1.000	0.848	0.794
169	Tier1 Diesel	NOx	1.000	0.944	0.995
169	Tier1 Diesel	PM2.5	1.000	0.703	0.587
169	Tier1 Diesel	VOC	1.000	0.622	0.542
170	Tier2 Diesel	CO	1.000	0.848	0.794
170	Tier2 Diesel	NOx	1.000	0.944	0.995
170	Tier2 Diesel	PM2.5	1.000	0.703	0.587
170	Tier2 Diesel	VOC	1.000	0.622	0.542
171	Tier3 Diesel	CO	1.000	0.800	0.750
171	Tier3 Diesel	NOx	1.000	0.939	0.990
171	Tier3 Diesel	PM2.5	1.000	0.675	0.564
171	Tier3 Diesel	VOC	1.000	0.590	0.514
172	Tier3 Transitional Diesel	CO	1.000	0.800	0.750
172	Tier3 Transitional Diesel	NOx	1.000	0.939	0.990
172	Tier3 Transitional Diesel	PM2.5	1.000	0.675	0.564
172	Tier3 Transitional Diesel	VOC	1.000	0.590	0.514
173	Tier4 Transitional Diesel	CO	1.000	0.650	0.451
173	Tier4 Transitional Diesel	NOx	1.000	0.943	1.018
173	Tier4 Transitional Diesel	PM2.5	1.000	0.868	0.822
173	Tier4 Transitional Diesel	VOC	1.000	0.823	0.792
2000	Interim Tier 4 - No DPF, No SCR	CO	1.000	0.800	0.750
2000	Interim Tier 4 - No DPF, No SCR	NOx	1.000	0.939	0.990

Engine Tech #	Technology Description	Pollutant	B5	R99	R79/B20
2000	Interim Tier 4 - No DPF, No SCR	PM2.5	1.000	0.675	0.564
2000	Interim Tier 4 - No DPF, No SCR	VOC	1.000	0.590	0.514
2001	Interim Tier 4 - No DPF, With SCR	CO	1.025	0.820	0.769
2001	Interim Tier 4 - No DPF, With SCR	NOx	1.010	1.000	1.409
2001	Interim Tier 4 - No DPF, With SCR	PM2.5	1.000	0.675	0.564
2001	Interim Tier 4 - No DPF, With SCR	VOC	1.018	0.600	0.523
2002	Interim Tier 4 - With DPF, No SCR	CO	1.025	0.560	0.251
2002	Interim Tier 4 - With DPF, No SCR	NOx	1.010	0.949	1.000
2002	Interim Tier 4 - With DPF, No SCR	PM2.5	1.000	1.000	1.000
2002	Interim Tier 4 - With DPF, No SCR	VOC	1.018	1.000	1.000
2003	Interim Tier 4 - With DPF, With SCR	CO	1.025	0.560	0.251
2003	Interim Tier 4 - With DPF, With SCR	NOx	1.010	1.000	1.409
2003	Interim Tier 4 - With DPF, With SCR	PM2.5	1.000	1.000	1.000
2003	Interim Tier 4 - With DPF, With SCR	VOC	1.018	1.000	1.000
2004	Full Tier 4 - No DPF, No SCR	CO	1.025	0.820	0.769
2004	Full Tier 4 - No DPF, No SCR	NOx	1.010	0.949	1.000
2004	Full Tier 4 - No DPF, No SCR	PM2.5	1.000	0.675	0.564
2004	Full Tier 4 - No DPF, No SCR	VOC	1.018	0.600	0.523
2005	Full Tier 4 - No DPF, With SCR	CO	1.025	0.820	0.769
2005	Full Tier 4 - No DPF, With SCR	NOx	1.010	1.000	1.409
2005	Full Tier 4 - No DPF, With SCR	PM2.5	1.000	0.675	0.564
2005	Full Tier 4 - No DPF, With SCR	VOC	1.018	0.600	0.523
2006	Full Tier 4 - With DPF, No SCR	CO	1.025	0.560	0.251
2006	Full Tier 4 - With DPF, No SCR	NOx	1.010	0.949	1.000
2006	Full Tier 4 - With DPF, No SCR	PM2.5	1.000	1.000	1.000
2006	Full Tier 4 - With DPF, No SCR	VOC	1.018	1.000	1.000
2007	Full Tier 4 - With DPF, With SCR	CO	1.025	0.560	0.251
2007	Full Tier 4 - With DPF, With SCR	NOx	1.010	1.000	1.409
2007	Full Tier 4 - With DPF, With SCR	PM2.5	1.000	1.000	1.000
2007	Full Tier 4 - With DPF, With SCR	VOC	1.018	1.000	1.000

Appendix B – Nonroad Emission Impacts by Operations Sector

Sector	CO Tons/Year				
	Base	Adj (R79)	Percent	Adj (R99)	Percent
Other SCCs	81.66	61.55	75.4%	66.67	81.6%
Commercial Sector	31.25	24.48	78.3%	26.14	83.7%
Airport	9.69	7.30	75.3%	7.94	81.9%
Utility Sector	5.09	3.98	78.2%	4.26	83.6%
Single-Family Homes	3.60	2.82	78.3%	3.02	83.7%
City Highway Construction	3.36	2.61	77.7%	2.80	83.2%
ODOT Construction Program	2.58	2.01	77.9%	2.15	83.3%
Cranes	1.08	0.82	75.7%	0.89	81.9%
Surface Mining	0.88	0.67	75.4%	0.72	81.5%
Permitted Facilities	0.79	0.58	73.7%	0.63	80.1%
City Fleets	0.63	0.48	76.5%	0.52	82.5%
Marine Ports	0.41	0.32	77.3%	0.34	83.0%
Well Drilling	0.41	0.31	76.4%	0.34	82.1%
Other Government Agencies	0.37	0.28	77.2%	0.30	82.9%
ODOT Maintenance Program	0.20	0.15	77.7%	0.16	83.1%
SDAO Fleets	0.13	0.10	78.2%	0.11	83.9%
Other Agency Highway Construction	0.08	0.07	77.9%	0.07	83.3%
Schools/Universities	0.07	0.05	75.9%	0.06	82.4%
Total	**142.30**	**108.59**	**76.3%**	**117.11**	**82.3%**

Sector	NOx Tons/Year				
	Base	Adj (R79)	Percent	Adj (R99)	Percent
Other SCCs	244.59	245.62	100.4%	231.53	94.7%
Commercial Sector	66.20	67.93	102.6%	62.72	94.7%
Airport	24.19	24.38	100.8%	22.87	94.5%
Utility Sector	11.78	12.29	104.4%	11.19	95.0%
Single-Family Homes	8.01	8.30	103.7%	7.60	94.9%
City Highway Construction	6.89	6.93	100.6%	6.51	94.5%
Cranes	5.30	5.47	103.2%	5.03	94.8%
ODOT Construction Program	5.27	5.43	103.0%	4.99	94.8%
Surface Mining	3.52	3.67	104.4%	3.34	95.0%
Permitted Facilities	2.97	3.15	106.0%	2.83	95.2%
City Fleets	2.30	2.35	101.9%	2.18	94.8%
Marine Ports	1.43	1.44	101.2%	1.35	94.6%
Well Drilling	1.40	1.47	105.0%	1.33	95.1%
Other Government Agencies	1.27	1.29	101.7%	1.21	94.7%
ODOT Maintenance Program	0.39	0.40	102.7%	0.37	94.8%
SDAO Fleets	0.31	0.31	100.2%	0.29	94.5%
Schools/Universities	0.21	0.21	101.2%	0.20	94.7%
Other Agency Highway Construction	0.17	0.18	103.0%	0.16	94.8%
Total	**386.19**	**390.83**	**101.2%**	**365.69**	**94.7%**

Sector	PM2.5 Tons/Year				
	Base	Adj (R79)	Percent	Adj (R99)	Percent
Other SCCs	11.4656	6.7725	59.1%	8.0364	70.1%
Commercial Sector	4.5245	2.6402	58.4%	3.1575	69.8%
Airport	1.6961	1.0219	60.3%	1.2068	71.2%
Utility Sector	0.7447	0.4338	58.2%	0.5188	69.7%
Single-Family Homes	0.5164	0.3011	58.3%	0.3601	69.7%
City Highway Construction	0.4349	0.2545	58.5%	0.3039	69.9%
ODOT Construction Program	0.3286	0.1920	58.4%	0.2294	69.8%
Cranes	0.1750	0.1028	58.7%	0.1223	69.9%
Permitted Facilities	0.1467	0.0856	58.4%	0.1015	69.2%
Surface Mining	0.1218	0.0714	58.7%	0.0849	69.7%
City Fleets	0.0942	0.0556	59.0%	0.0661	70.2%
Marine Ports	0.0735	0.0431	58.6%	0.0515	70.0%
Other Government Agencies	0.0615	0.0361	58.8%	0.0431	70.1%
Well Drilling	0.0548	0.0323	59.0%	0.0384	70.0%
ODOT Maintenance Program	0.0242	0.0141	58.4%	0.0169	69.8%
SDAO Fleets	0.0202	0.0119	59.1%	0.0143	70.5%
Other Agency Highway Construction	0.0107	0.0062	58.4%	0.0075	69.8%
Schools/Universities	0.0096	0.0058	60.0%	0.0068	71.0%
Total	**20.50**	**12.08**	**58.9%**	**14.37**	**70.1%**

	VOC Tons/Year				
Sector	**Base**	**Adj (R79)**	**Percent**	**Adj (R99)**	**Percent**
Other SCCs	16.113	8.918	55.3%	10.121	62.8%
Commercial Sector	5.486	2.982	54.3%	3.410	62.2%
Airport	1.667	0.944	56.7%	1.067	64.0%
Utility Sector	0.930	0.505	54.3%	0.578	62.1%
Single-Family Homes	0.635	0.345	54.3%	0.395	62.1%
City Highway Construction	0.533	0.291	54.5%	0.332	62.2%
ODOT Construction Program	0.405	0.220	54.4%	0.252	62.2%
Cranes	0.281	0.159	56.5%	0.179	63.8%
Surface Mining	0.175	0.100	57.1%	0.112	64.3%
Permitted Facilities	0.166	0.096	57.8%	0.107	64.7%
City Fleets	0.133	0.074	55.8%	0.084	63.3%
Marine Ports	0.095	0.052	55.0%	0.059	62.7%
Well Drilling	0.077	0.043	55.8%	0.048	63.1%
Other Government Agencies	0.075	0.041	55.0%	0.047	62.7%
ODOT Maintenance Program	0.030	0.016	54.4%	0.018	62.2%
SDAO Fleets	0.028	0.015	54.9%	0.017	62.7%
Schools/Universities	0.015	0.008	57.0%	0.009	64.4%
Other Agency Highway Construction	0.013	0.007	54.4%	0.008	62.2%
Total	**26.86**	**14.82**	**55.2%**	**16.85**	**62.7%**