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ENVIRONMENT
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MEMORANDUM

Date: **November 15, 2019**

To: **Tom Moore, WESTAR-WRAP**

From: **John Grant, Yesica Alvarez, Rajashi Parikh**

Subject: **Review of Off-Road Sector Emissions in 2016v1 Collaborative Platform for Implementation in WRAP Regional Haze modeling**

1. Introduction

The Western States Air Resources Council-Western Regional Air Partnership (WESTAR-WRAP) has requested Ramboll to develop a 2028 WESTAR-WRAP Mobile Source Emissions Inventory to for use in the WRAP Regional Haze analysis. WESTAR-WRAP has already developed a 2014 WRAP region emissions inventory that is being used in base year air quality modeling.

Under the Inventory Collaborative[1], the 2016 version 1 (2016v1) modeling platform was developed, including base year 2016 and future year 2028 (FY2028) emissions for the lower-48 states. 2016v1 is based on the 2014-2016 version 7 modeling platform[2] with updates per new data provided by agencies and methodology improvements. We reviewed the documentation published in the Collaborative wiki website[1] for the 2016v1 platform to obtain information on growth factors, methodology, data sources and any key assumptions used to develop the 2016 and 2028 emissions. Specifically, the following documents were reviewed:

- *Specification Sheet: Mobile Nonroad* (October 18, 2019) for off-road equipment
- *Specification Sheet: Airports* (October 15, 2019) for aircraft and airport ground support sources
- *Specification Sheet: CMV_C1C2 Platform* (October 12, 2019) for categories 1 and 2 commercial marine vessel sources
- *Building the National Rail Emissions Inventory* (Janssen and others, October 2019) describing rail emissions development

In addition, Ramboll downloaded[3] and summarized the 2016v1 platform 2016 and 2028 off-road sector emissions for the WRAP states in a companion spreadsheet to this memorandum.

Three states (California, Washington and Oregon) in the WRAP Regional Haze modeling domain have marine emissions. California off-road emissions (including marine sources) for baseline and future year WRAP Regional Haze modeling will be provided by the California Air Resources Board (CARB). For Oregon and Washington, we reached out to state agencies and based on their input, marine emissions from the 2016v1 platform are to be used as-is for WRAP Regional Haze modeling. Further discussion of marine emissions is not included in this memorandum.

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[1] http://views.cira.colostate.edu/wiki/wiki/9169/inventory-collaborative-wiki#What-is-the-Inventory-Collaborative

[2] https://www.epa.gov/air-emissions-modeling/2014-2016-version-7-air-emissions-modeling-platforms

[3] Source: ftp://newftp.epa.gov/Air/emismod/2016/v1/reports/

The goal of this study is to review 2016v1 methodologies used to develop mobile source emissions in the 2016v1 platform and based on this review to 1) summarize findings applicable to WRAP member agencies, 2) make recommendations on the inventories to use in WRAP baseline and future year modeling, and 3) to solicit input from WRAP member agencies to improve 2028 projections. Table 1 summarizes the resource inventories and the 2028 inventory to be developed as part of this work.

Table 1. Emissions inventories to be used in this work.

Purpose	Inventory Name	Description
To be reviewed	Collaborative 2016v1 platform Base Year 2016	2016v1 emissions will be reviewed for each mobile source category to determine whether they should be used for the WRAP baseline air quality modeling.
	Collaborative 2016v1 platform Future Year 2028	2028v1 emissions will be the primary basis for 2028 mobile source emissions developed in this work
To be improved	2028 WRAP modeling inventory	WRAP FY2028 mobile source emissions will be estimated by applying agency inputs to improve the 2016v1 inventory for WRAP states

1.1 Scope of Review

The scope of the 2016v1 methodology and emission inventory review is described below:

- **Geographical**: WRAP states
- **Temporal**: 2016, 2028
- **Pollutants**: nitrogen oxides (NOx), volatile organic compounds (VOCs), carbon monoxide (CO), particulate matter less than 10 microns (PM_{10}), particulate matter less than 2.5 microns ($PM_{2.5}$), sulfur dioxides (SO_x), ammonia (NH_3)
- **Sources**:
  - Off-road equipment (also referred to as nonroad)
  - Aircraft
  - Locomotives
  - Commercial marine[4]

1.2 Methodology and Emissions Overview

Emissions in the 2016v1 Collaborative Platform were developed for a 2016 base year, and 2028 future year. WRAP region-wide 2016v1 platform 2016 and 2028 off-road emissions are shown in Figure 1. These annual emissions (in tons per year) represent totals over 15 WRAP states (Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico,

[4] Commercial marine emissions methodology will not be included in this memorandum per input from Washington and Oregon. Please refer to introduction.

North Dakota, Oregon, South Dakota, Utah, Washington and Wyoming). As shown in Figure 1, nonroad (off-road equipment) emissions make up almost half of off-road sector NOx emissions in the base year and 36% of 2028 NOx emissions. Airport emissions contributions are 10% in 2016 and 19% in 2028. Nonroad is the largest contributor to regional PM_{10} and VOC emissions (63%-88%).

The following sections summarize the data sources, models used and major assumptions implemented to develop 2016v1 2016 and 2028 emissions for off-road source categories.

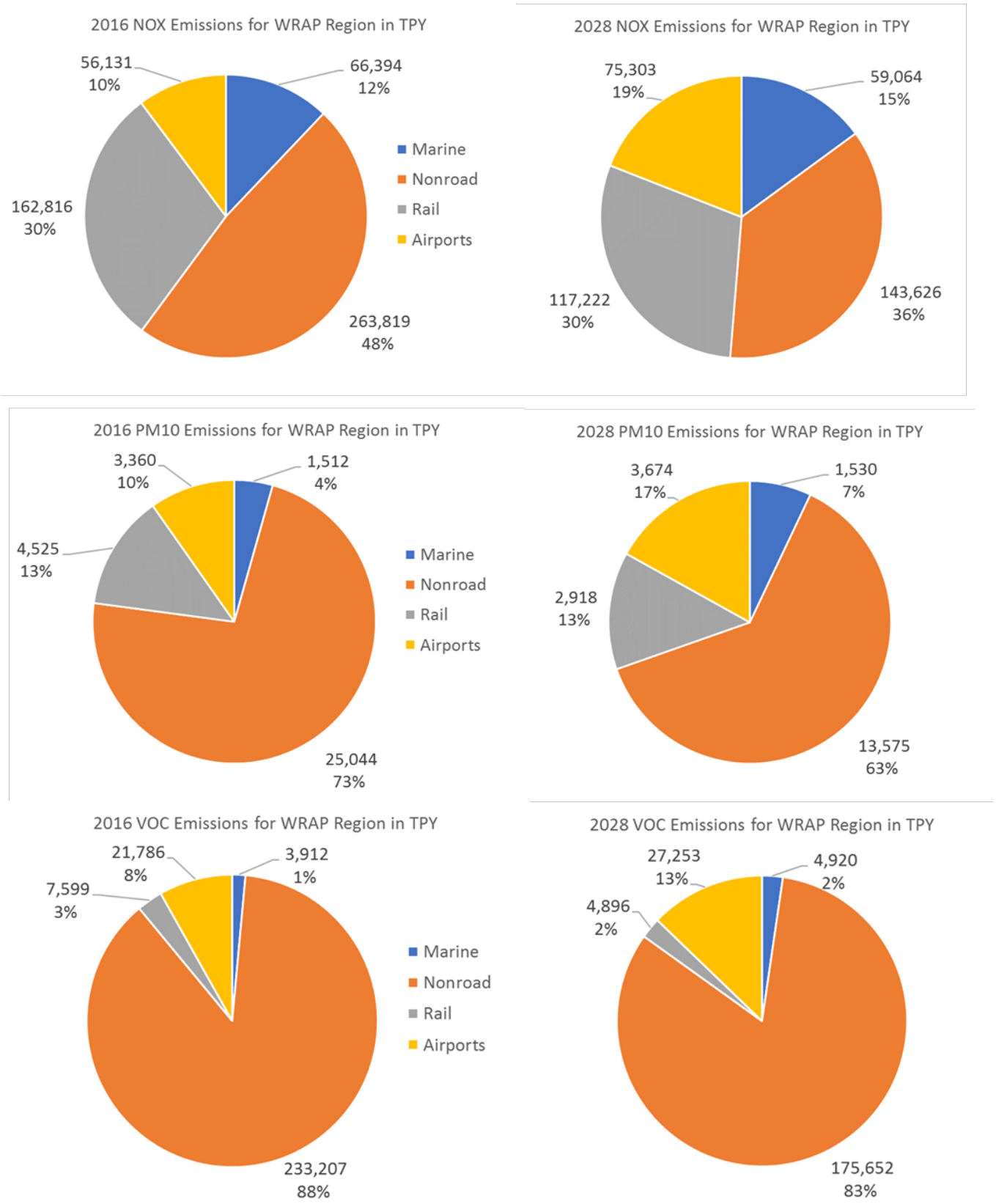

Figure 1. WESTAR-WRAP region-wide annual emissions from off-road sources in the 2016v1 platform.

2. Nonroad (Off-road equipment)

Off-road equipment includes various types of self-propelled vehicles designed for off-road use that change locations at least once each year (or in certain cases once each season) such as lawn mowers, forklifts, excavators, all-terrain vehicles, and agricultural tractors.

Baseline Year 2016:

- The MOVES2014b model was used to create the nonroad emissions inventories for all states except California. California emissions were provided by the California Air Resources Board (CARB).
- MOVES2014b replaced MOVES2014a in August 2018, and incorporates updated nonroad engine population growth rates, nonroad Tier 4 engine emission rates, sulfur levels of nonroad diesel fuels, and updated nonroad emission factors for hazardous air pollutants (HAPs). Recent previous national emission inventories (e.g., 2014 National Emission Inventory, version 2 [2014NEI v2]) were developed based on MOVES2014a.
- The 2016v1 platform included updates to the MOVES2014b defaults for allocating national populations of agricultural and construction equipment to states and counties. Updated spatial allocations for agricultural and construction equipment were not included in the previous 2014 National Emission Inventory (version 2; 2014NEI v2) nonroad inventory used in base year WRAP Regional Haze modeling.
- Several WRAP-states provided state-specific inputs that replaced default MOVES2014b inputs as shown in Table 2.

Table 2. Agency submitted nonroad input tables for the 2016v1 platform

Input	Arizona - Maricopa Co.	Idaho	Utah	Washington
Source populations	A		B	
Allocation to day type		C	D	
Allocation of fuels				
Population growth			D	
Allocation to diurnal pattern			D	
Seasonal allocation				
Yearly activity	D			
Allocations to counties	D		E	D
Stage II information	D			
Surrogate selection	D			D
Surrogate identification	D			D

[A] Submitted data with modification: based on 2017 NEI submission.
[B] Submitted data with modification: deleted records that were not snowmobile source types 1002-1010.
[C] 2014v2 NEI data used for 2016v1 platform.
[D] Agency submitted MOVES-NONROAD inputs were applied without modification.
[E] Submitted data with modification: deleted records that were not the snowmobile surrogate ID 14.

Future Year 2028:

- Outside California, state-supplied inputs (Table 2) and MOVES2014b defaults are used to generate future emissions.
  - Fuel supply and formulation inputs are based on MOVES2014b.
  - Meteorological inputs are for the year 2016.

- CARB provided emission datasets for California.

MOVES2014b Population Growth Factors

Population growth factors are used in the MOVES-NONROAD model to estimate annual equipment population growth or decline. MOVES2014b population growth factor surrogates (e.g., human population) are linked to specific off-road sectors (e.g., lawn and garden equipment, recreational equipment) as documented in the Nonroad Technical Report: "Nonroad Engine Population Growth Estimates in MOVES2014b"[5] and summarized below in Table 3. MOVES2014b annual hours for a given equipment type do not vary by year; therefore, activity changes from year-to-year are a function of equipment population changes only. MOVES2014b population growth factor surrogates were developed at the state, US census region, and national level. WRAP region US census regions are the West (Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming) and Midwest (North Dakota and South Dakota).

MOVES-NONROAD includes a dynamic age distribution which is a function of scrappage algorithms and population growth. Therefore, to incorporate a new population growth estimate the MOVES-NONROAD model must be re-run.

Table 3. Population growth surrogates and equipment sector.

Equipment Sector [a]	Surrogate Data Source [a]	Surrogate Data for Future Projections [a]	Applicable Geographic Area
Industrial	Moody's Analytics	GDP from warehousing sector	State
Commercial		Economy-wide GDP	
Lawn and Garden (residential and commercial)	U.S. Census Bureau	Human population	
Recreational		Human population	
Airport Service	Federal Aviation Administration, Terminal Area Forecast Model	Number of commercial aviation operations	
Rail Maintenance	Energy Information Administration, Annual Energy Outlook	Revenue ton miles	National
Recreational Marine		Fuel consumption (recreational marine)	
Construction		Energy consumption (construction sector)	Census Region
Agriculture		Energy consumption (agriculture sector)	
Logging		Energy consumption (other agriculture sector)	
Oil Field		Energy consumption (oil and gas mining sector)	
Underground Mining		Energy consumption (sum of the coal sector and metallic & non-metallic mining sector)	

[a] Source: EPA (2018)[5], Table 3.3

Figure 2 shows growth factors for construction, agriculture, and lawn and garden equipment; these equipment sectors contribute a majority of off-road equipment NOx, PM_{10}, and VOC emissions in the WRAP region.

[5] EPA, 2018. Accessed November 2019 at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100UXJK.pdf

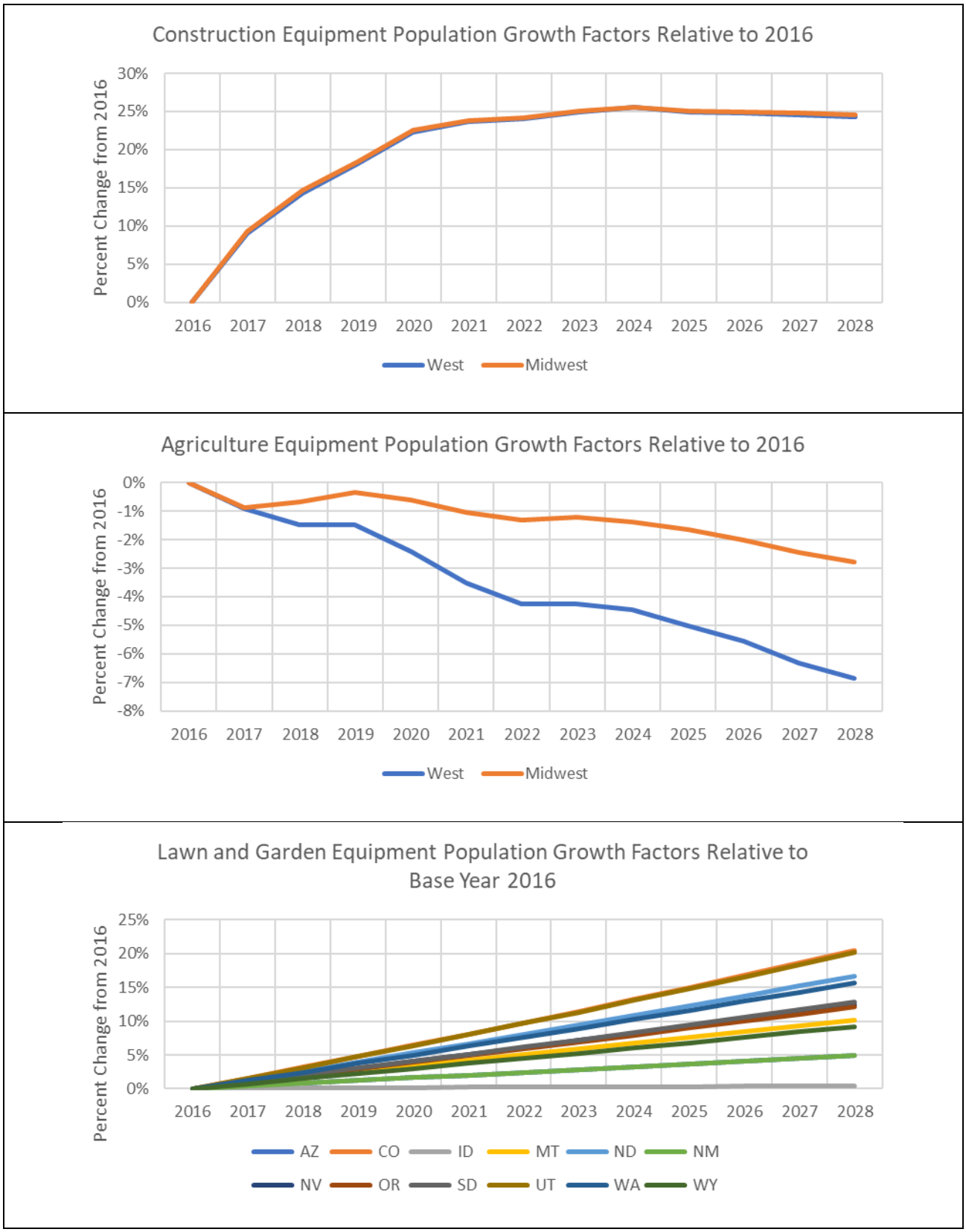

Figure 2. WESTAR-WRAP region MOVES2014b default population growth factors for construction (top), agricultural (middle) and lawn and garden (bottom) equipment.

Recommendation for Agencies:

- Review change in emissions from base to future year and assess if emissions trends and orders of magnitude are as expected.
- Review population growth estimates relative to 2016. Agencies may provide revised state specific growth factors. Schedule and availability of project resources will determine the extent to which updated population growth factors can be integrated into the emission inventory given that MOVES-NONROAD must be re-run to incorporate a non-default growth factor.
- If applicable, agencies may provide the following updates:
    - Revised off-road equipment emissions by county and source classification code (SCC). Please contact Ramboll if you intend to submit updated emissions so that we can provide formatting instructions.
    - Revised population growth factors by off-road sector.

2.1 Emissions by State

Figures 3, 4 and 5 show 2016v1 off-road equipment emissions for 2016 and 2028 for each WRAP state with the exception of California which submits its own inventory and Hawaii and Alaska which are outside of the WRAP Regional Haze modeling domain. For more detailed emissions, see the companion spreadsheet associated with this memorandum.

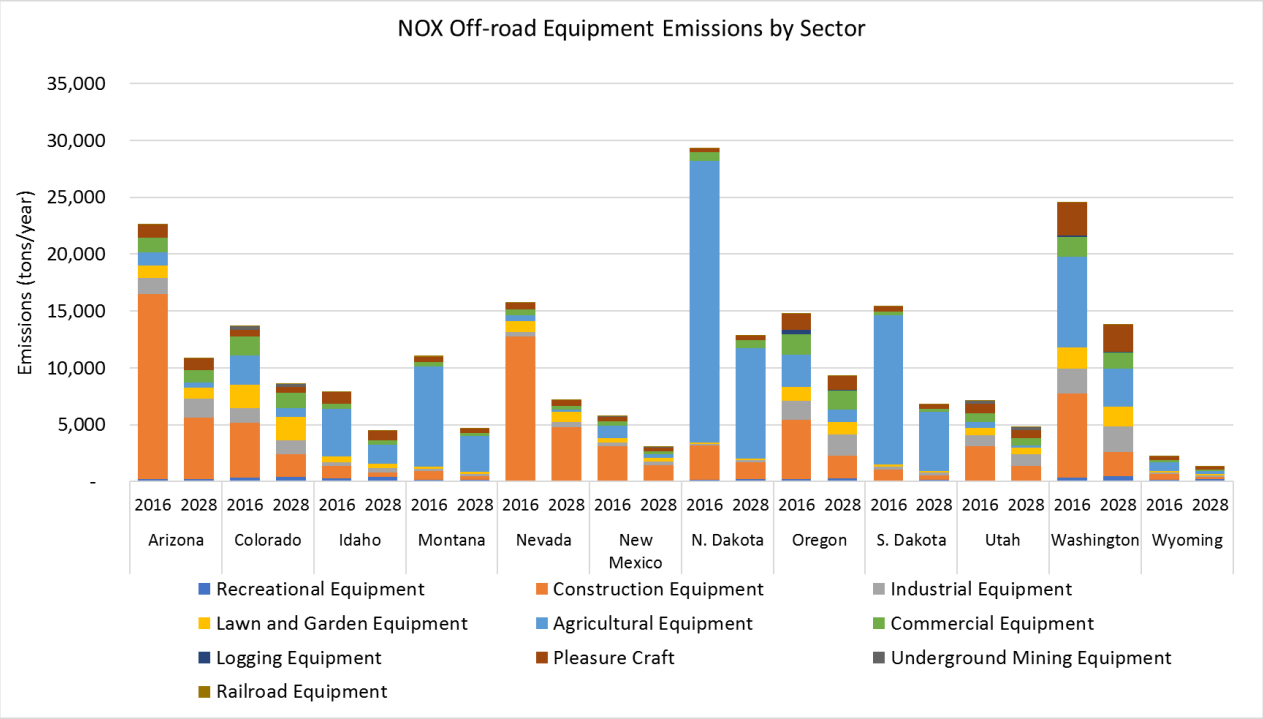

Figure 3. Off-road equipment 2016 and 2028 NOx emissions.

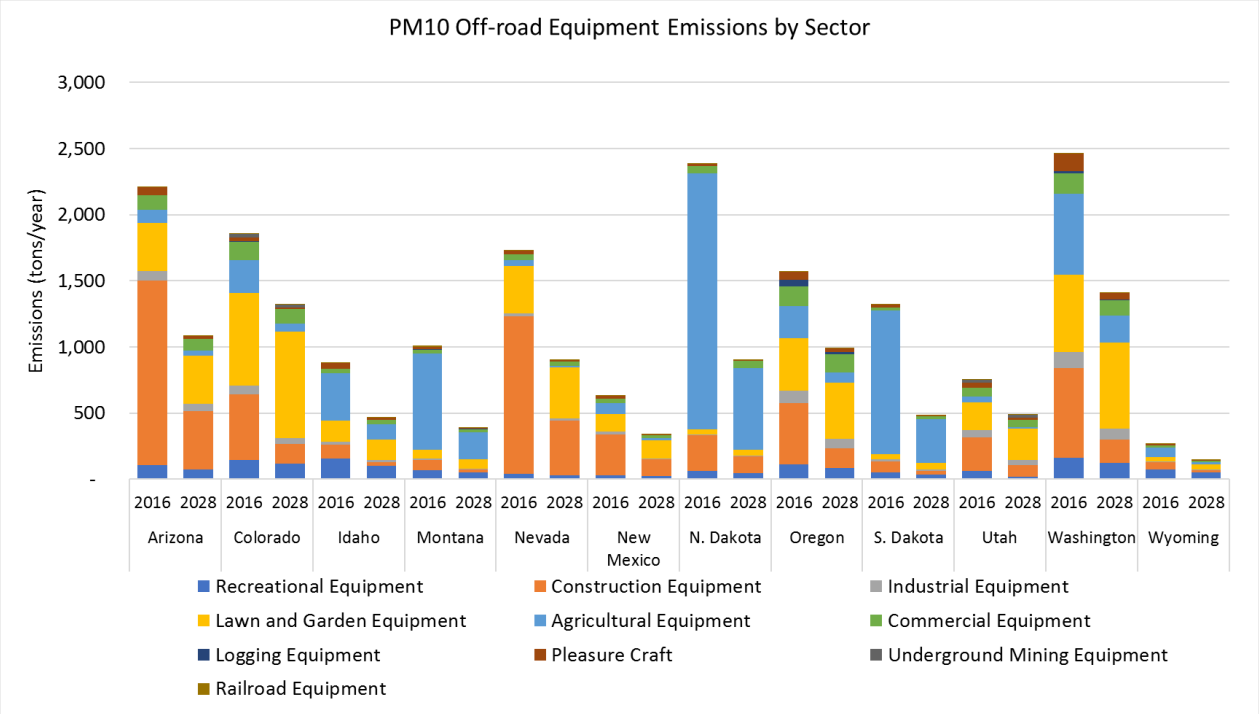

Figure 4. Off-road equipment 2016 and 2028 PM_{10} emissions.

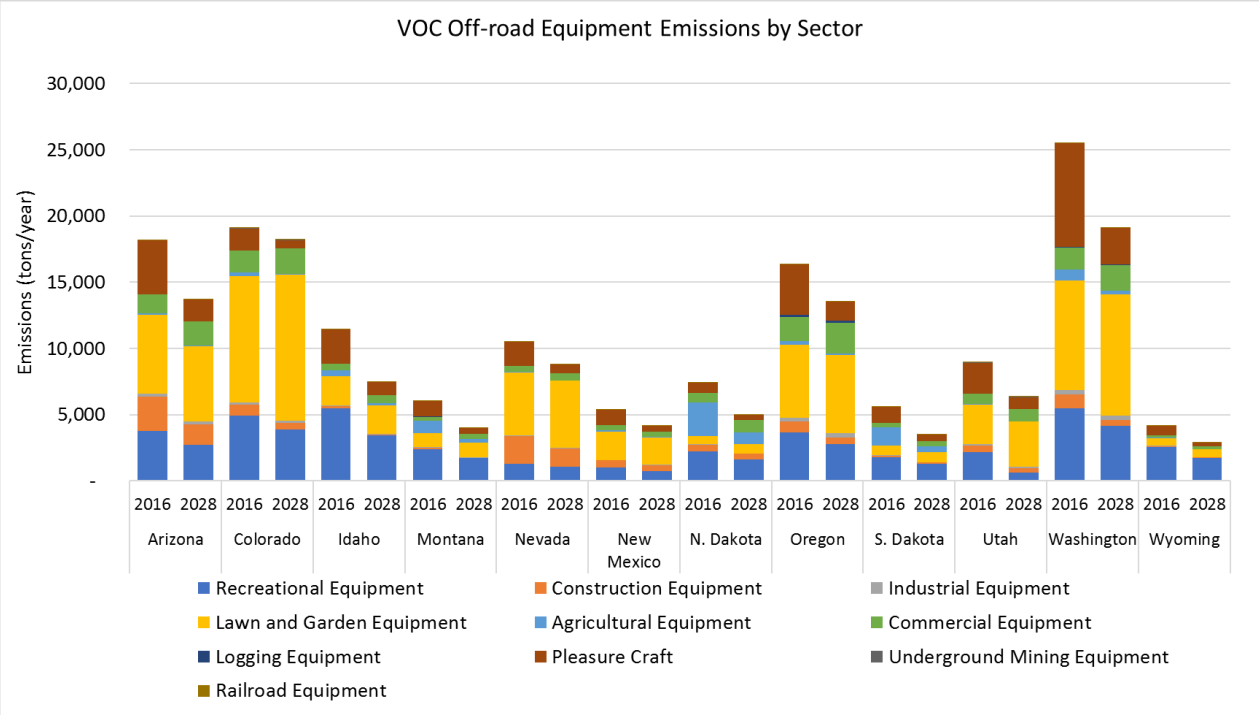

Figure 5. Off-road equipment 2016 and 2028 VOC emissions.

3. Rail

The rail category includes nonpoint emissions from Class I and Class II/III linehaul locomotives, rail yard (switching engine) locomotives, passenger trains and commuter line trains. Formal documentation of the 2016v1 base year and future year emissions was not available at the time that this memorandum was developed; available documentation of the 2016 beta emission inventory and a presentation given at the 2018 Railroad Environmental Conference[6] is the basis of the information presented below.

Baseline Year 2016:

- 2016v1 Emissions Inventory Collaborative developed a 2016 national inventory based on existing Eastern Regional Technical Advisory Committee (ERTAC) rail emissions inventory developed for various NEI inventories.
- Emissions were estimated for Class I and Class II/III linehaul locomotives, railyard locomotives and commuter/passenger line trains using data submitted by rail companies. Such data include fuel consumption information by link (in the rail network) and company fleet technology tier mix (if available).
- Emission rates and by-Tier fleet mix data from the Association of American Railroads[7] is used for companies that do not provide such information.
- Analysis of Google Earth imagery was used to identify railyards and switch engine population.

Future Year 2028:

- The 2016 inventory was projected to 2028 using national projection factors, shown in Table 4. Projection factors were applied to forecast all pollutant emissions. The passenger train projection factor is based on 2018 Annual Energy Outlook (AEO2018)and the freight projection factor is based on 2016-to-2017 fuel use and AEO2018 projections for 2017 to 2028[7].

Table 4. National projection factors for rail

Rail Type	Growth 2016-to-2028
Passenger trains	+16.2%
Freight	+4.7%

Source: Janssen et al, 2019.

- 2028 emission rates were based on extrapolation of emission rates trends from ERTAC railroad inventories developed for historical years 2007, 2014, 2016, and 2017. Emission rates are approximately two-thirds higher in the 2016v1 2028 emission inventory compared to forecasts from EPA's 2008 locomotive engine rulemaking[8]. Higher 2028 emission rates indicate that companies are not buying Tier 4 engines as fast as estimated in the 2008 rulemaking Regulatory Impact Analysis.

[6] Janssen, 2019. "Building the National Rail Emissions Inventory". October.

[7] https://www.aar.org/data-center/rail-traffic-data/

[8] Final Rule for Control of Emissions of Air Pollution From Locomotive Engines and Marine Compression-Ignition Engines Less Than 30 Liters per Cylinder

Recommendation for States:

- Review step change of rail emissions and assess if emissions trend and orders of magnitude are as expected.
- If applicable, provide revised rail emissions or rail activity growth rate. Please contact Ramboll if you intend to submit updated emissions so that we can provide formatting instructions.

3.1 Emissions by State

Figures 6, 7 and 8 show 2016v1 rail emissions for 2016 and 2028 for each WRAP State with the exceptions of California which submits its own inventory and Hawaii and Alaska which are outside of the WRAP Regional Haze modeling domain. For more detailed emissions, see the companion spreadsheet associated with this memorandum.

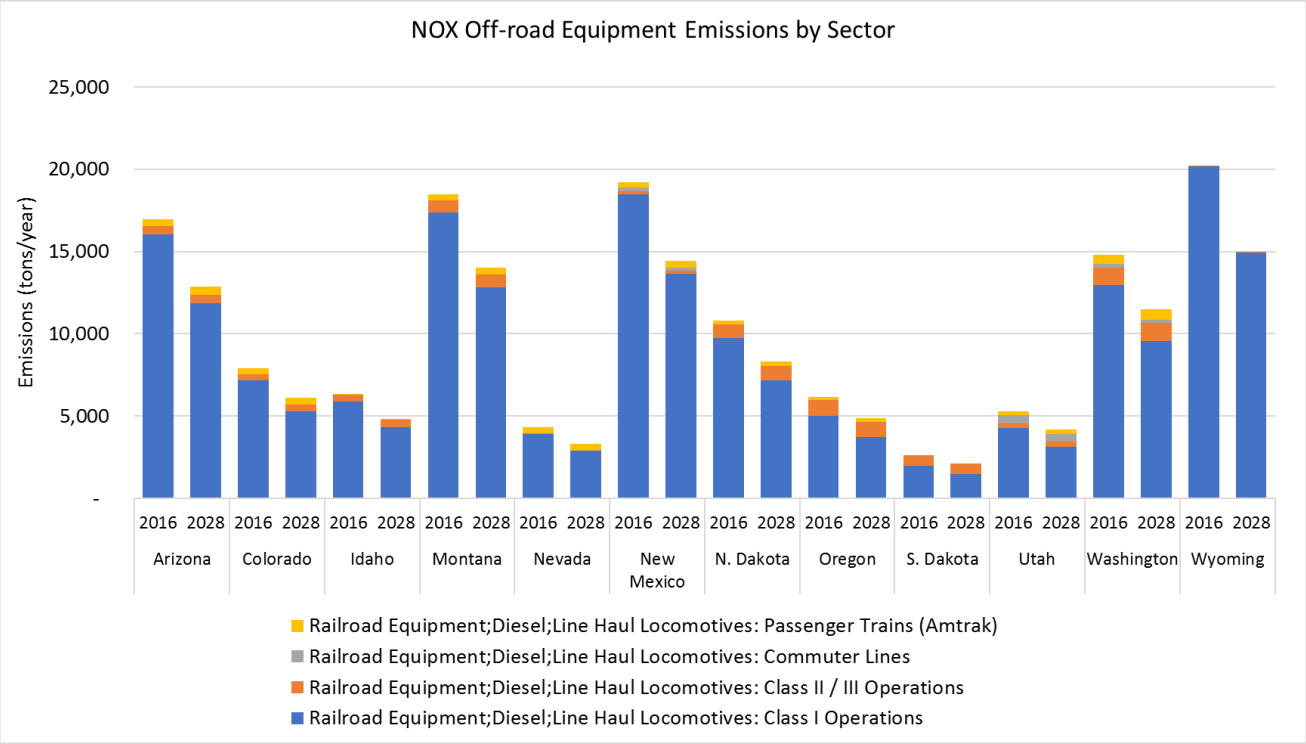

Figure 6. Rail 2016 and 2028 NOx emissions.

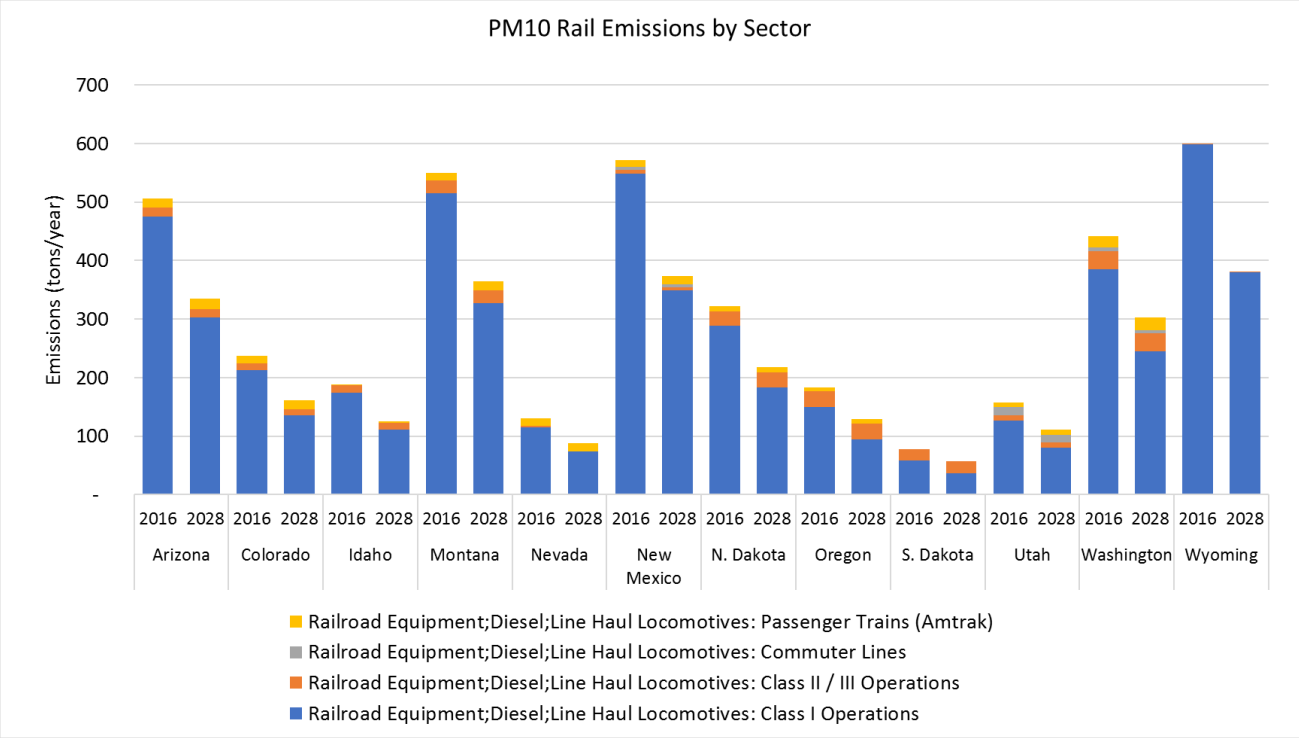

Figure 7. Rail 2016 and 2028 PM_{10} emissions.

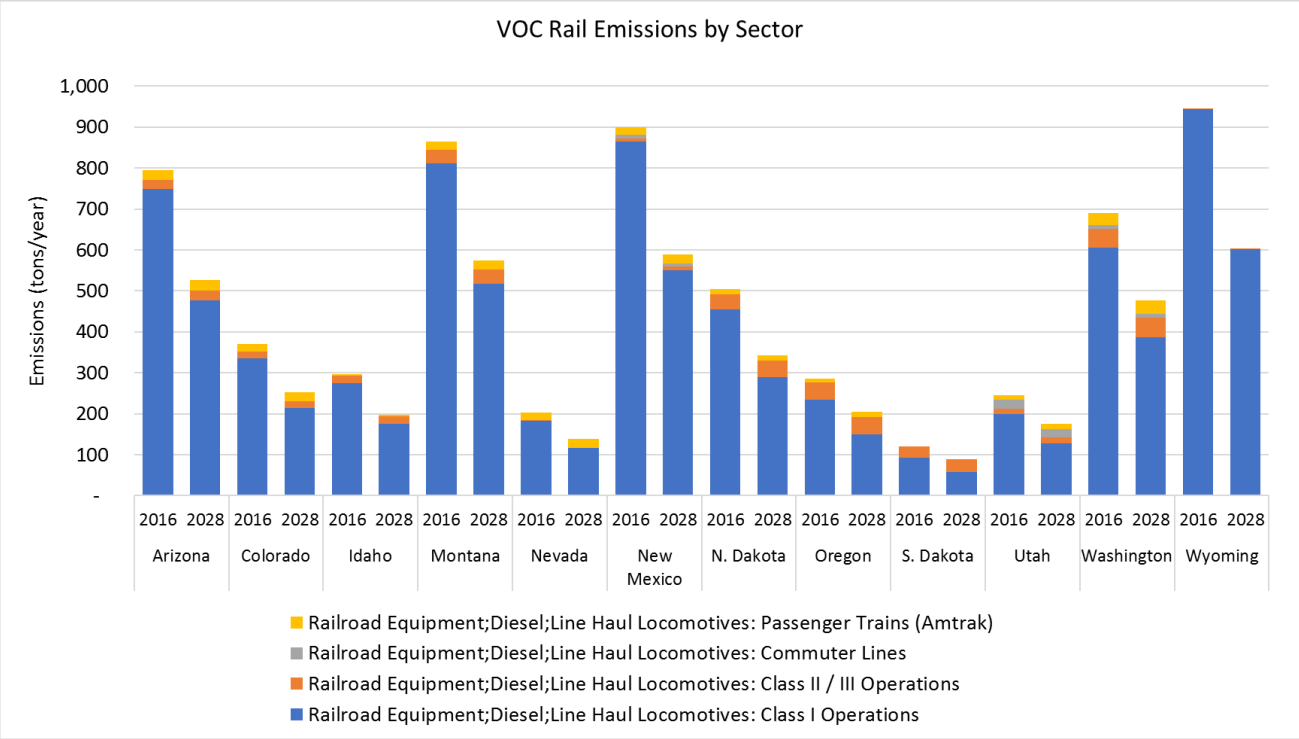

Figure 8. Rail 2016 and 2028 VOC emissions.

4. Airports

The airport sector contains aircraft emissions, categorized by itinerant class (i.e., commercial, air taxi, military, or general), as well as emissions from airport ground support equipment.

Baseline Year 2016:

- 2016v1 airport emissions are based on the 2017 draft National Emissions Inventory (NEI), back-projected to 2016 using Federal Aviation Administration (FAA) data.
- 2017NEI airport emissions were estimated using the FAA's Aviation Environmental Design Tool (AEDT).[9]
    - Two approaches were used to estimate emissions from the compiled activity data. For activity that included aircraft-specific data, the AEDT was used.
    - When aircraft specific data was not available, a general approach was used in which generic emission rates by different aircraft types (i.e., air taxis, general aviation, and military aircraft) were applied following the EPA's available generic emission estimating procedures for the NEI[10].
- 2017-to-2016 adjustment factors were created based on airport-specific activity, where available, or based on FAA state-level activity by itinerant class.

Future Year 2028:

- The approach used for developing future year emissions under the 2016v1 platform was to scale emissions; the AEDT model was not rerun. Airport-specific emissions were projected to 2028 based primarily on 2018 Terminal Area Forecast (TAF) data available from the FAA for 2016 and 2028.
- For airports not in the FAA TAF, state-level default projection factors for commercial, air taxi, and general aircraft were estimated based on the 2028 to 2016 ratio of itinerant class activity. Military projection factors were kept flat (i.e., equal to 1.0).
- Facility-level emission growth from 2016 to 2028 is capped at 500% and the state default growth is capped at 200%.

Recommendation for States:

- Review step change of airport emissions and assess if emissions trend and orders of magnitude are as expected.
- Provide new airport emissions by airport and SCC, if available. Please contact Ramboll if you intend to submit updated emissions so that we can provide formatting instructions.

4.1 Emissions by State

Figures 9, 10 and 11 show 2016v1 airport sector emissions for 2016 and 2028 for each WRAP State with the exceptions of California which submits its own inventory and Hawaii and Alaska which are outside of the WRAP Regional Haze modeling domain. For more detailed emissions, see the companion spreadsheet associated with this memorandum.

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[9] Additional information about the 2017NEI airport inventory and the AEDT can be found in the 2017 National Emissions Inventory Technical Support Document (https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-technical-support-document-tsd)

[10] Document "2017Aircraft_main_19aug2019.pdf" on the 2017 Supplemental data FTP site ftp://newftp.epa.gov/air/nei/2017/doc/supporting_data/point/

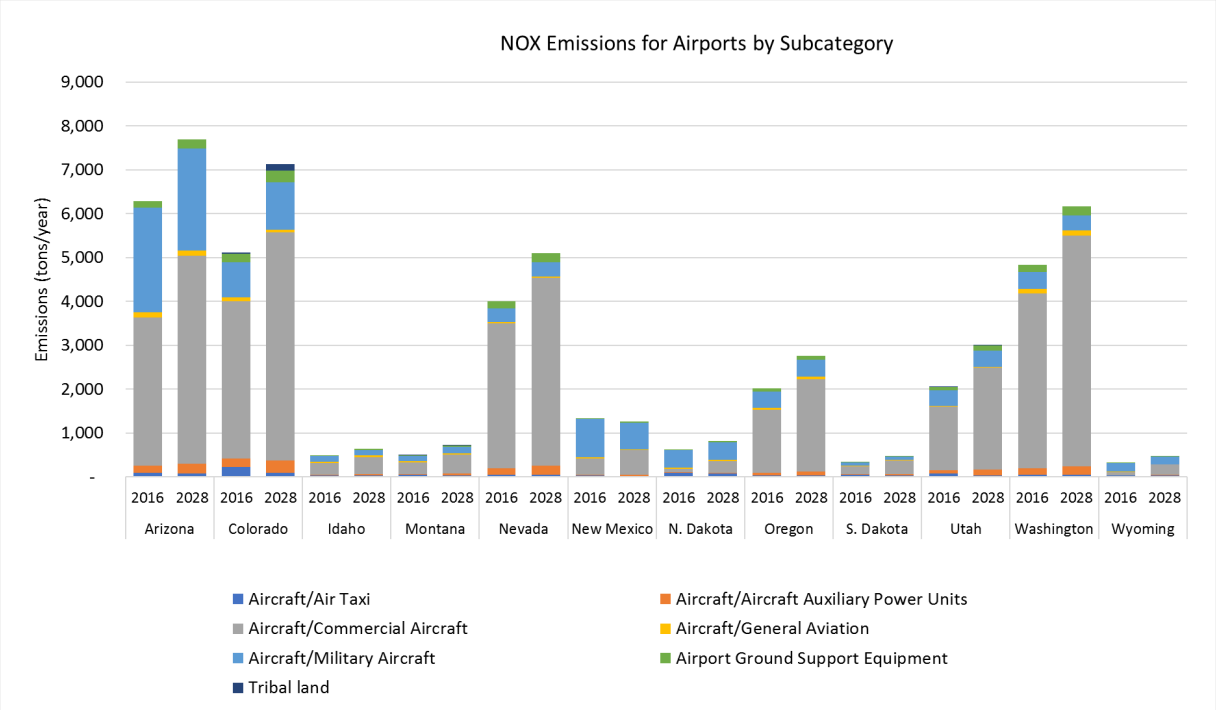

Figure 9. Airport sector 2016 and 2028 NOx emissions.

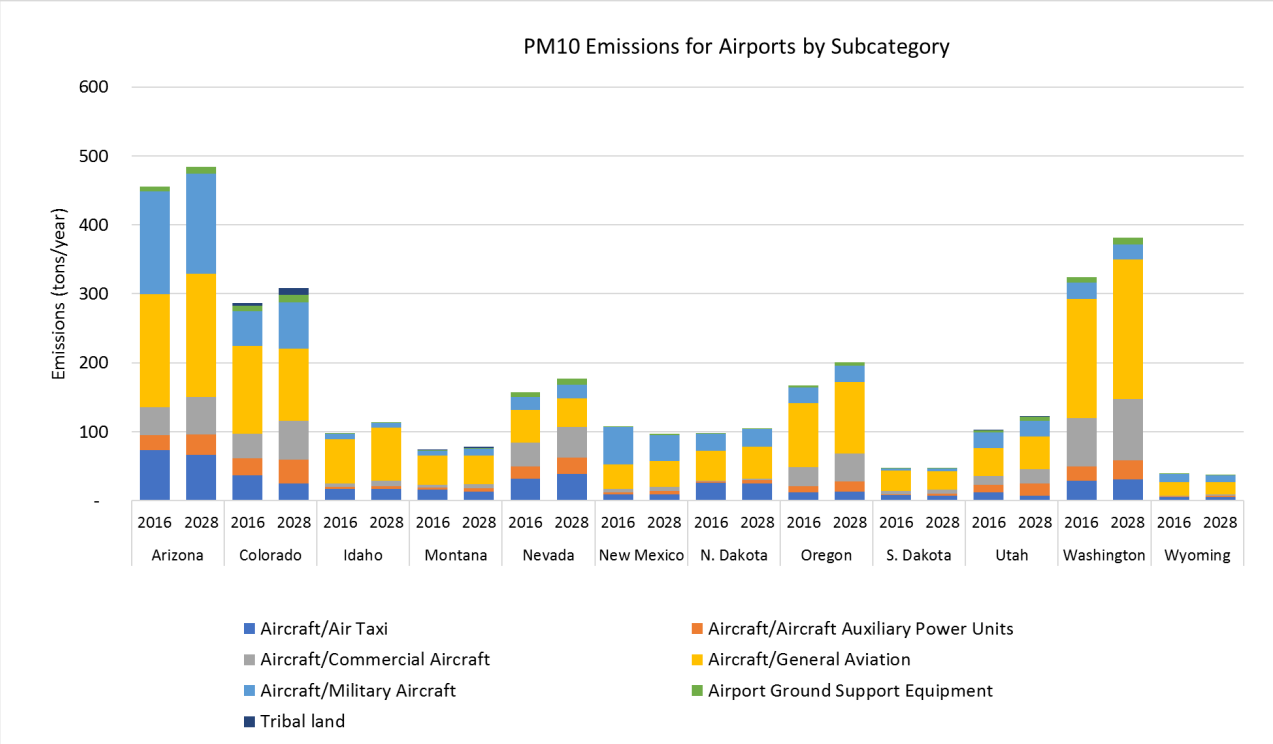

Figure 10. Airport 2016 and 2028 PM_{10} emissions.

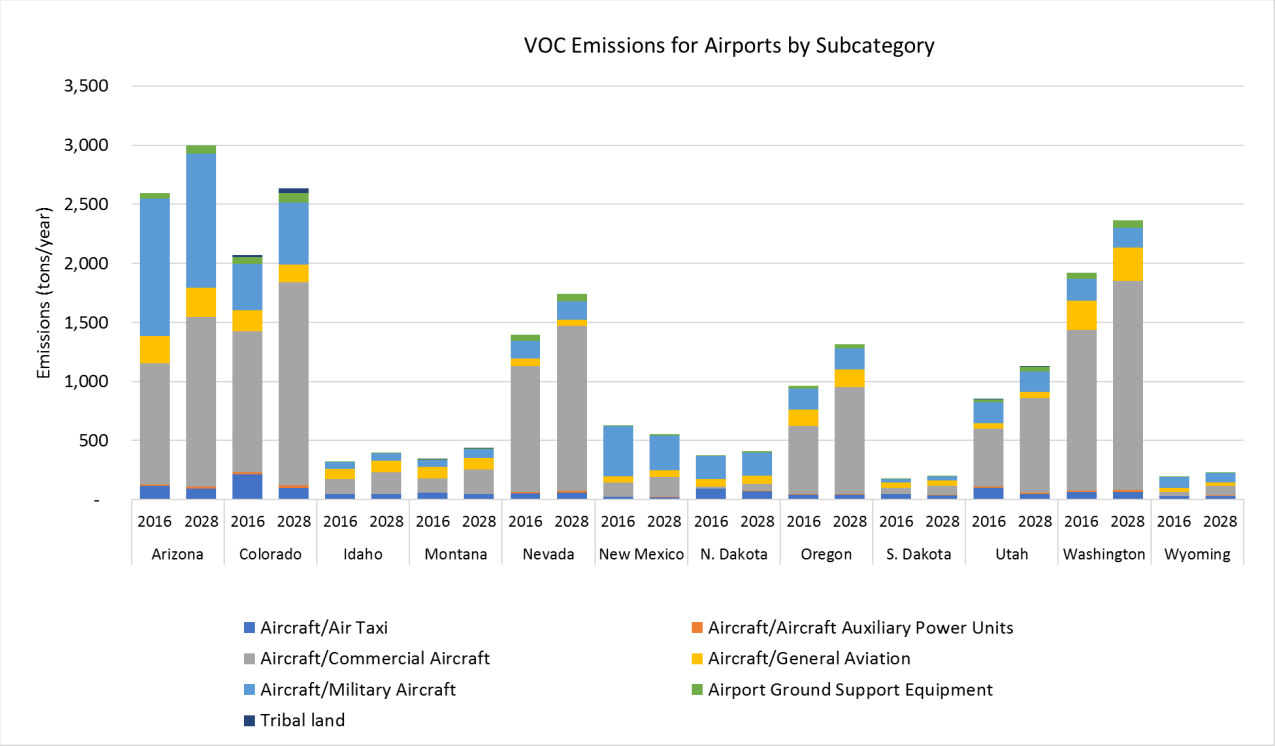

Figure 11. Airport 2016 and 2028 VOC emissions.

5. Recommendations

Based on Ramboll's review of available documentation of off-road sector emissions in the 2016v1 platform, we recommend the following actions related to off-road sources in the WRAP regional haze modeling:

- Use 2028 emissions from the 2016v1 Modeling Platform for future year 2028 WRAP mobile source inventory, with updates to nonroad, rail and aircraft emissions, per agency provided inputs.
- Use 2016 emissions from the 2016v1 Modeling Platform for the WRAP Regional Haze baseline emission inventory. 2016v1 emissions incorporate more up-to-date data and methodology, including improvements to Nonroad and rail emissions.

Using 2016 and 2028 off-road sector emission inventories (with any agency updates to 2028 emissions) from the 2016v1 Modeling Platform in WRAP Regional Haze modeling will allow for consistency in inventory methodology between the baseline and future year. Emission changes from 2016 to 2028 in 2016v1 are expected to be the result of activity and control changes rather than inventory development methodology differences which will be important when interpreting model results. In contrast to on-road vehicles, off-road sector emissions are less sensitive to meteorological inputs, therefore, it is reasonable to use emissions that were developed based on 2016 meteorological inputs in the Regional Haze air quality modeling which uses 2014 meteorological inputs.