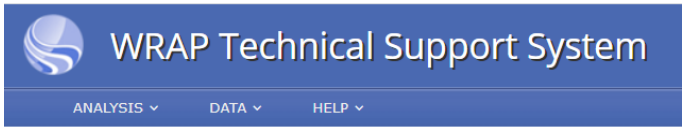


WRAP Technical Support System for Regional Haze Planning:

Emissions Methods, Results, and References

September 30, 2021 - Final

Contents **Page Number**

1.0 Purpose:

The Western Regional Air Partnership and Western Air Quality Study (WRAP-WAQS) 2014 Regional Haze modeling platform is the latest of a series of regional modeling efforts supporting western U.S. air quality planning and management. The WRAP technical analyses follow the Environmental Protection Agency's (EPA) Modeling Guidance for Demonstrating Air Quality Goals for Ozone, PM2.5, and Regional Haze (November 2018) and the Technical Support Document for EPA's updated 2028 regional haze modeling (September 2019). The analyses fulfill the objectives of the WRAP 2018-2019 Workplan as updated and approved by the WRAP Board on April 3, 2019 and have been collectively designed, implemented, and reviewed by the WRAP Technical Steering Committee and its workgroups and subcommittees.

The Western Regional Air Partnership (WRAP) Technical Support System (TSS) hosts the visibility monitoring, emissions, and air quality modeling analyses that support the 15 western states in developing regional haze state implementation plans (SIPs). This reference document describes the WRAP emissions and modeling analyses and illustrates how the TSS products can be applied and interpreted to support the 2028 visibility progress demonstrations for western U.S. Class I areas.

2.0 Background:

The Regional Haze Rule requires states to demonstrate progress every ten years toward the Clean Air Act goal of no manmade visibility impairment. EPA guidance for tracking visibility progress (December 2018) defines a visibility impairment tracking metric (measured in deciview) using observations from the Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring network sites that represent Class I areas. EPA defined in the Regional Haze Rule and guidance a Uniform Rate of Progress glidepath for the 20% most impaired days as the straight line from the 2000-2004 IMPROVE 5-year average baseline to EPA estimates of future natural visibility conditions, plotted at 2064. In the first regional haze planning period, 2000-2018, EPA guidance interpreted most impaired days as those days with highest total haze. States were required to demonstrate visibility progress by 2018 compared to the Uniform Rate of Progress glidepath for the haziest days and no degradation of visibility on the clearest days from the 2000-2004 IMPROVE 5-year average baseline. Visibility on the clearest days improved between 2000 and 2018 across the Class I areas in the western U.S. However, smoke from wildfire and wildland prescribed fire events and dust events on the haziest days made tracking the visibility benefits due to reducing U.S. anthropogenic emissions more difficult.

For the second regional haze implementation period, 2018-2028, states are required to demonstrate visibility progress by 2028 for the most impaired days and no visibility degradation for the clearest days. EPA guidance (December 2018) defined most impaired days as those days

with the highest fractional contribution to aerosol light extinction from anthropogenic sources. EPA statistical methods use IMPROVE measurements of carbon and crustal materials to separate contributions from episodic extreme natural events (e.g., wildfire or dust) from routine natural and anthropogenic contributions. Ammonium sulfate and ammonium nitrate are assigned primarily to anthropogenic emissions with smaller contributions from routine natural sources. This statistical approach does not separate contributions due to U.S. anthropogenic emissions from those of international anthropogenic emissions. Since states do not have authority to reduce international emissions, WRAP conducted source apportionment modeling analyses to evaluate U.S. anthropogenic contributions to haze and progress in reducing U.S. anthropogenic contributions to haze over time.

Table 1 summarizes the emissions and modeling scenarios, source apportionment runs, and alternative visibility progress analyses that were performed to support state regional haze planning.

Table 1. WESTAR-WRAP Emissions and Modeling Scenarios – update of January 18, 2021
Intermountain West Data Warehouse (IWDW) and Technical Support System (TSS) displays

Scenario Name	**Model Performance Evaluation** (2014v2 actual emissions / BCs and meteorology)	**Planning – Baseline** (mix of emissions inputs 2014-18 with 2014 meteorology)	**Planning – 2028 Projections** (2014 meteorology)	**Alternative Methods: 2028 Projections, Glidepath Endpoints, and Rate of Progress**	**Alternate Outcome Scenarios** (2014meteorology)
IWDW	Display emissions, model results, and site-level MPE results)	Display emissions and model results	Display emissions and model results		
TSS	Display emissions and model results	Display emissions and model results	Calculate and Display 2028 RPGs Display emissions and model results	Display alternative 2028 projections, glidepath endpoints, rate of progress	Calculate and Display 2028 RPGs. Display emissions and model results
Purpose	**Compare 2014v2 to RepBase2**	**Compare to RepBase2 to 2014v2, 2028OTBa2, 2028PAC2**	**Compare 2028OTBa2 to Repbase2, 2028PAC2, 2028FFS1, 2028FFS2**	**Focus on contributions of US anthropogenic emissions**	**Evaluate state source contributions and future fire scenarios**
CAMx Modeling Scenarios	**2014v2**	**RepBase2** Current Baseline (w/ RepFire). High-level CAMx PSAT source apportionment*	**2028OTBa2** (w/ RepFire) ** High-level PSAT source apportionment	**3 projection methods:** EPA default MID EPA MID w/o fires Modeled MID	**2028OTBa2 w/ SOxNOx PSAT** low-level (state by source sector contributions)
			2028PAC2 PotentialAddtlControls	Alternative 2064 glidepath endpoints	**2028FF1** Future Fire Sensitivity 1: Wildfire ****
			2028Adopted AddtlControls ***	U.S. Anthropogenic Modeled Rate of Visibility Progress ******	**2028FF2** Future Fire Sensitivity 2: WildlandRxFire *****

* 2014 International Anthro contribution adjustment option available from this modeling scenario (by difference)
** RepBase fires applied to 2028OTBa2
*** controls adopted by states in SIPs, this scenario is likely not possible until 2021 (*unfunded at present, not in Workplan*)
**** fire not paired in space or time with 2014 or RepFire activity, these sensitivity scenarios could give potential future wildfire contribution relative to 2028OTBa2
***** fire *is* paired in space *and* time with RepFire activity; this sensitivity scenario gives potential future Wildland Prescribed fire contribution relative to 2028OTBa2
******Dynamic Evaluation compare US anthropogenic contributions for 2002 Hindcast, RepBase2, and 2028OTBa2 to demonstrate alternative rate of visibility improvement

3.0 Emissions Scenarios:

2014v2 Base Year for WRAP Regional Haze Modeling

The WRAP 2014v2 inventory was based on the 2014v2 National Emissions Inventory (NEI) plus updates provided by western states through WRAP Regional Haze workgroup's Emissions and Modeling Protocol subcommittee.

Table 2 defines the WRAP 2014v2 sector-specific data sources. WRAP states replaced the 2014v2 NEI source sectors as listed below:

- California Air Resources Board (CARB) provided emissions for all anthropogenic sectors in California.
- WRAP states updated emissions for electric generating units (EGU), non-EGU point sources, and onroad mobile.
- The WRAP Oil and Gas Workgroup and its contractor Ramboll, Inc., defined a Roadmap for updating oil and gas inventories and delivered updated 2014 emissions (October 2018) for Colorado, Montana, New Mexico, North Dakota, South Dakota, Utah, and Wyoming (emissions for remaining WRAP states remain as in the EPA 2014v2 platform).
- The WRAP Fire and Smoke Work Group (FSWG) updated the 2014NEIv2 BlueSky/SmartFire emissions.
- Natural emissions were developed by WRAP for 2014v2 and held constant at 2014v2 levels for the Representative Baseline and future year scenarios.
- All other WRAP emissions sectors and all Non-WRAP emissions for WRAP 2014v2 were based on the EPA 2014 modeling platform.

Table 2. Data sources for WRAP emissions sectors for the 12-km 12WUS2 and 36-km US domains for the 2014v2, Representative Baseline (RepBase2) and 2028OTBa2 model scenarios.

Source Sector	2014v2	RepBase2	2028OTBa2
California All Sectors 12WUS2	CARB-2014v2	CARB-2014v2	CARB-2028
WRAP Fossil EGU w/ CEM	WRAP-2014v2	WRAP-RB-EGU [1]	WRAP-2028-EGU [1]
WRAP Fossil EGU w/o CEM	EPA-2014v2	WRAP-RB-EGU [1]	WRAP-2028-EGU [1]
WRAP Non-Fossil EGU	EPA-2014v2	EPA-2016v1	EPA-2028v1
Non-WRAP EGU	EPA-2014v2	EPA-2016v1	EPA-2028v1
O&G WRAP O&G States	WRAP-2014v2	WRAP-RB-O&G [2]	WRAP-2028-O&G [2]
O&G WRAP Other States	EPA-2014v2	EPA-2016v1	EPA-2016v1 [3]
O&G non-WRAP States	EPA-2014v2	EPA-2016v1	EPA-2016v1 [3]
WRAP Non-EGU Point	WRAP-2014v2	WRAP-2014v2 [4]	WRAP-2014v2 [4]
Non-WRAP non-EGU Point	EPA-2014v2	EPA-2016v1	EPA-2016v1
On-Road Mobile 12WUS2	WRAP-2014v2	WRAP-2014v2	WRAP-2028-Mobile [5]
On-Road Mobile 36US	EPA-2014v2	EPA-2016v1	EPA-2028v1
Non-Road 12WUS2	EPA-2014v2	EPA-2016v1	WRAP-2028-Mobile [5]
Non-Road non-WRAP 36US	EPA-2014v2	EPA-2016v1 [6]	EPA-2028v1 [6]
Other (Non-Point) 12WUS2	EPA-2014v2	EPA-2014v2 [7]	EPA-2014v2 [7]
Other (Non-Point) 36US	EPA-2014v2	EPA-2016v1	EPA-2016v1
Can/Mex/Offshore 12WUS2	EPA-2014v2	EPA-2016v1	EPA-2016v1
Fires (WF, Rx, Ag)	WRAP-2014-Fires	WRAP-RB-Fires [8]	WRAP-RB-Fires [8]
Natural (Bio, etc.)	WRAP-2014v2	WRAP-2014v2	WRAP-2014v2
Boundary Conditions (BCs)	WRAP-2014-GEOS	WRAP-2014-GEOS	WRAP-2014-GEOS

1. WRAP-RepBase2-EGU and WRAP-2028OTBa2-EGU include changes/corrections/updates from WESTAR-WRAP states
2. WRAP-RepBase2-O&G and WRAP-2028OTBa2-O&G both include corrections for WESTAR-WRAP states.
3. O&G for other WRAP states and Non-WRAP states use EPA-2016v1 assumptions for 2028OTBa2 and unit-level changes provided by WESTAR-WRAP states.
4. WRAP-2014v2 Non-EGU Point is used for RepBase2 and 2028OTBa2, with source specific updates provided by WESTAR-WRAP states.
5. WRAP-2028-MOBILE is used for On-Road and Non-Road sources for the 12WUS2 domain.
6. EPA-2016v1 and EPA-2028v1 are used for On-Road and Non-Road Mobile for the 36km US domain.
7. Non-Point emissions use 2014v2 emissions for RepBase2 and 2028OTBa2 scenarios, including state-provided corrections.
8. RepBase fires are used for both RepBase2 and 2028OTBa2

Representative Baseline (RepBase2)

The Representative Baseline (RepBase2) emissions scenario updates the 2014v2 inventory to account for changes and variation in emissions between 2014 and 2018 for key WRAP source sectors, as defined by the WRAP Emissions and Modeling Protocol subcommittee. The RepBase inventory was delivered in February 2020 as listed below.

- California Air Resources Board (CARB) used the same source sector emissions as defined for 2014v2.
- The WRAP EGU Emissions Analysis Project developed a comprehensive database for fossil fuel electric generating units in 13 continental western states, including operating characteristics and emissions, for the period circa 2014-2018. Methods are defined in Center for New Energy Economy's analysis of WRAP fossil-fueled Electric Generating Units for Regional Haze Planning and Ozone Transport Contribution (June 2019.)
- The WRAP Oil and Gas Workgroup and its contractor, Ramboll, Inc., developed the circa-2014 baseline oil and gas inventory to apply to the RepBase inventory.
- The WRAP Fire and Smoke Work Group (FSWG) worked with states, tribes, federal land managers and Air Sciences, Inc., to define 2014 to 2018 wildfire emissions for the Continental U.S. (36-km modeling grid) to represent a broader range of fire conditions (Representative Fire) than the single year 2014, as reported in Fire Emissions Inventories for Regional Haze Planning: Methods and Results (April 2020).
- All other emissions sectors used the EPA 2016v1 platform for RepBase.

During state review of the Representative Baseline emissions, some errors and duplicate records were identified. WRAP states revised select EGU, non-EGU point, and oil and gas emissions for a revised Representative Baseline (RepBase2). Data sources for RepBase2 emissions, as delivered in September 2020, are defined in **Table 2.** Emissions sectors that changed between 2014v2 and RepBase2 are defined in **Table 4**.

The RepBase2 WRAP Point source emissions are available to download on the WRAP Regional Haze Planning Work Group webpage. Note that these point source emissions files are not identical to the SMOKE emissions model outputs that are posted on the TSS.

WRAP methods are further defined in Ramboll Inc.'s Run Specification Sheet for Representative Baseline (RepBase2) and 2028 On-the-Books (2028OTBa2) CAMx Simulations.

2028 On the Books Inventory (2028OTBa2)

The WRAP 2028OTBa emissions inventory projection followed the methods applied by EPA in the September 2019 Technical Support Document for updated 2028 regional haze modeling. The WRAP states updated source sectors to account for implementation by 2028 of all applicable federal and state requirements for U.S. anthropogenic emissions as listed below:

- California Air Resources Board (CARB) provided 2028OTB projections from 2014v2 for all anthropogenic source sectors.

- WRAP states worked with western utilities and the Center for New Energy Economy to project EGU emissions for 2028 On the Books, as reported in Analysis of EGU Emissions for Regional Haze Planning and Ozone Transport Contribution (June 2019).

- The WRAP Oil and Gas workgroup and its contractor, Ramboll, Inc., projected 2028 Oil and Gas area and point source emissions for WRAP states as reported in Revised Final Report: 2028 Future Year Oil and Gas Emission Inventory for WESTAR-WRAP States, March 2020 version.

  Table 3. 2028 On the Books Oil and Gas emissions by WESTAR-WRAP State split into Tribal and Non-Tribal mineral ownership, for Nitrogen Oxides and Volatile Organic Compounds (tons/year) from Revised Final Report: 2028 Future Year Oil and Gas Emission Inventory for WESTAR-WRAP States, March 2020

State	NOx Emissions (tons/year)		VOC Emissions (tons/year)	
	Non-tribal	Tribal	Non-tribal	Tribal
AK	37,663	-	23,880	-
AZ	1,960	-	280	-
CO	28,580	14,970	75,122	2,214
ID	889	-	34	-
MT	4,843	290	28,048	1,217
ND	64,306	9,053	274,187	45,480
NM	90,658	3,592	219,765	8,568
NV	156	-	269	-
OR	454	-	73	-
SD	763	-	4,786	-
UT	4,812	5,739	15,770	52,108
WA	444	-	36	-
WY	24,162	171	109,152	438
Total	**259,690**	**33,815**	**751,403**	**110,023**

- WRAP 2028 CAMx-ready emissions for on-road and non-road mobile sources, including off-shore shipping, rail and airports are reported in Mobile Source Emissions Inventory 2028 Projections Project.

- Wildfire, Wildland Prescribed fire, and agricultural fires for the 2028OTBa inventory were identical to RepBase fires.

In September 2020, the WRAP states made revisions to select EGU, non-EGU, and oil and gas emissions for the WRAP states in the updated 2028OTBa2 projection. EPA 2016v1 emissions were

assigned to some source sectors for WRAP, non-WRAP, Canada and Mexico in lieu of EPA 2028v1 emissions to provide more conservative assumptions for the 2028OTBa2 projection. 2028OTBa2 data sources are listed in **Table 2** and 2028OTBa2 emissions sectors that changed emissions compared to RepBase2 are listed in **Table 4**.

Table 4: WRAP Emissions Data Sources across WRAP Modeling Scenarios

TSS Sector Name	TSS Selection Menu Label	WRAP Representative Base2 data source	WRAP Rep Base2 changes from 2014v2	WRAP 2028OTBa2 changes from RepBase2	WRAP 2028OTBa2 +PAC2 changes	WRAP 2028OTBa2 +Wildfire changes	WRAP 2028OTBa2 +Wildland Prescribed fire changes
California All Sectors		CARB-2014v2[1]		X	X		
Electric Generating Units (EGU)	**pt_egu**	WRAP-RB-EGU[2]	X	X[8]	X		
Oil&Gas- point -WRAP O&G states	**pt_oilgas**	WRAP-RB-O&G[3]	X	X[8]	X		
Oil&Gas - point - WRAP other states		EPA-2016v1[4]	X	X[8]	X		
Industrial and Non-EGU Point	**pt_nonegu**	EPA-2014v2[5]	X	X[8]	X		
Oil&Gas - nonpoint -WRAP O&G states	**np_oilgas**	WRAP-RB-O&G[3]					
Oil&Gas - nonpoint -WRAP other states		EPA-2016v1[4]					
Residential Wood Combustion	**rwc**	EPA-2014v2[5]		-			
Fugitive Dust	**afdust**	EPA-2014v2[5]					
Agriculture	**ag**	EPA-2014v2[5]					
Remaining Nonpoint	**nonpt**	EPA-2014v2[5]					
On-road Mobile	**onroad**	WRAP-2014v2[6]	X	X	CA only		
Non-road Mobile	**nonroad**	EPA-2016v1[4]	X	X			
Rail	**rail**	EPA-2014v2[5]		X			
Commercial Marine	**cmv_c1c2c3**	EPA-2016v1[4]	X	X			
Agricultural Fire	**ag-flaming**	WRAP-2014v2[6]					
Wildland Prescribed Fire	**rxfire**	WRAP-RB-fires[7]	X				X
Wildfire	**wildfire**	WRAP-RB-fires[7]	X			X	
Biogenic	**biogenic**	WRAP-2014v2[6]					
Other non-WRAP 12WUS2, 36US		EPA-2016v1[4]	X	X			

WRAP methods are further defined in the Run Specification Sheet for Representative Baseline (RepBase2) and 2028 On-the-Books (2028OTBa2) CAMx Simulations. Note that these point source emissions files are not identical to the SMOKE emissions model outputs that are posted on the TSS. Also, point sources on Tribal lands are listed separately from state point sources.

The 2028OTBa2 WRAP Point source emissions are available to download on the WRAP Regional Haze Planning Work Group (wrapair2.org) webpage. Note that these point source emissions files are not identical to the SMOKE emissions model outputs that are posted on the TSS.

2028 Potential Additional Controls (PAC2)

Some, but not all, western states defined Potential Additional Controls beyond the On the Books controls to evaluate the potential visibility response in 2028. The states and source categories for additional potential controls are defined in **Table 5**.

Table 5. WESTAR-WRAP States and source sectors modified in the 2028 Potential Additional Controls (PAC2) modeling scenario compared to 2028OTBa2.

2028PAC2 changes to 2028OTBa2	AZ	CA	CO	ID	MT	NV	NM	ND	OR	SD	UT	WA	WY
EGU - point	x				x	x	x	x	x				
Non-EGU point				x		x	x		x			x	
O&G- point	x						x		x				
On-road Mobile		x											

Point source emissions spreadsheets for the 2028OTBa2 and PAC2 emissions scenarios, after data review by WESTAR-WRAP states completed October 9,2020, are found on the WRAP Regional Haze Planning Workgroup webpage.

Future Wildfire Sensitivity 1

In addition to the 2014v2 and Representative Baseline/2028 On the Books fire scenarios, the WRAP Fire and Smoke Work Group (FSWG) defined a future wildfire sensitivity (FFS1) (not specific to any single future year) as an alternative to using 2014-2018 wildfire activity data for 2028 visibility projections. The future wildfire emissions are used with 2028OTBa2 emissions for all other emissions sectors.

Modeling a range of future fire emissions will help visualize potential future impacts from this sector. The purposes of this sensitivity are to determine:

- how changes in wildfire activity change the projected 2028 visibility response to US anthropogenic emissions using the regional haze tracking metric
- monthly variation in future wildfire impacts compared to the 2028OTBa2 reference case.

Methods for the future wildfire sensitivity (FFS1) are described in Air Sciences' report Fire Emissions Inventories for Regional Haze Planning: Methods and Results (April 2020) and summarized in the modeling Specification Sheet for Future Fire Sensitivities (August 2021). As summarized in **Table 6**, future wildfire acreage and emissions may be greater than or less than those of the RepBase2/2028OTBa2 emissions scenarios. Emissions from wildland prescribed fire and agricultural burns were the same in FFS1 as for the RepBase2/2028OTBa2 scenarios.

Table 6. Comparison of fire emissions in continental WESTAR-WRAP states for the Wildfire (FFS1) modeling sensitivity, relative to the RepBase2/2028OTBa2 scenarios by fire event, acres burned, tons of fuel consumed, and $PM_{2.5}$ emissions, as well as differences in percent.

	Wildfire (FFS1)				RepBase2 / 2028OTBa2				Percent Difference			
State	Events	Acres	Tons Fuel Consumed	Tons $PM_{2.5}$	Events	Acres	Tons Fuel Consumed	Tons $PM_{2.5}$	Events	Acres	Tons Fuel Consumed	Tons $PM_{2.5}$
AZ	2,461	278,146	565,862	7,168	2,810	219,779	554,371	7,238	-12%	27%	2%	-1%
CA	6,502	1,058,201	29,353,059	434,630	7,004	822,112	30,274,941	450,970	-7%	29%	-3%	-4%
CO	1,816	88,746	1,343,955	19,970	2,103	209,106	6,014,389	89,965	-14%	-58%	-78%	-78%
ID	1,908	350,939	1,333,867	17,495	2,082	331,911	2,977,946	42,601	-8%	6%	-55%	-59%
MT	3,016	585,817	5,645,173	75,799	3,443	345,932	3,368,691	43,866	-12%	69%	68%	73%
NV	1,233	221,413	730,140	9,169	1,540	268,607	643,098	7,437	-20%	-18%	14%	23%
NM	3,298	914,977	1,116,799	11,131	4,418	543,192	893,910	9,760	-25%	68%	25%	14%
ND	317	7,582	89,675	784	377	8,007	90,876	774	-16%	-5%	-1%	1%
OR	2,453	822,417	16,240,735	239,672	2,583	558,944	10,731,358	157,441	-5%	47%	51%	52%
SD	740	292,610	4,146,708	43,847	891	321,681	4,649,179	49,242	-17%	-9%	-11%	-11%
UT	1,194	478,045	1,771,838	24,057	1,382	295,023	1,257,384	17,174	-14%	62%	41%	40%
WA	1,500	243,934	12,817,841	192,062	1,566	184,553	9,378,215	140,516	-4%	32%	37%	37%
WY	2,187	347,097	1,065,757	10,175	2,478	367,253	1,098,031	10,982	-12%	-5%	-3%	-7%
Total	28,625	5,689,923	76,221,409	1,085,959	32,677	4,476,101	71,932,389	1,027,966	-12%	27%	6%	6%

Future Wildland Prescribed Fire Sensitivity 2

The WRAP Fire and Smoke workgroup defined a no-year future wildland prescribed fire sensitivity (FFS2) as an alternative to using 2014-2018 RepBase2 activity data for 2028 visibility projections.

U.S. land management agencies intend to increase the acres burned by wildland prescribed fire in future years to reduce the vegetation that fuels high-intensity wildfires. The purposes of this sensitivity were to determine:

- how changes in wildland prescribed fire could change the 2028 visibility projections that are used in regional haze planning.
- monthly variation in future wildfire impacts compared to the 2028OTBa2 reference case.

Methods for the future wildland prescribed fire sensitivity (FFS2) are described in Air Sciences' report Fire Emissions Inventories for Regional Haze Planning: Methods and Results (April 2020) and summarized in the modeling Specification Sheet for Future Fire Sensitivities. The FFS2 wildland prescribed fire events were tied to the same geographic ecoregions and dates as the RepBase2 burns. The acreages of the FFS2 events were randomly selected and emissions were recalculated. As summarized in **Table 7**, future wildland prescribed fire acreage and emissions may be greater than or less than those defined for the RepBase2/2028OTBa2 emissions scenarios. Wildfire events and agricultural burns are held the same as for RepBase2/2028OTBa2 scenarios.

Table 7. Comparison of fire emissions in continental WESTAR-WRAP states for the Wildland Prescribed fire (FFS2) modeling sensitivity, relative to the RepBase2/2028OTBa2 scenarios by fire event, acres burned, tons of fuel consumed, $PM_{2.5}$ emissions, and percent differences.

	Prescribed Burning (FFS2)				RepBase2 / 2028OTBa2				Percent Difference			
State	Events	Acres	Tons Fuel Consumed	Tons $PM_{2.5}$	Events	Acres	Tons Fuel Consumed	Tons $PM_{2.5}$	Events	Acres	Tons Fuel Consumed	Tons $PM_{2.5}$
AZ	595	185,102	1,239,269	18,491	595	141,195	907,285	13,533	0%	31%	37%	37%
CA	993	184,688	3,280,671	48,672	993	130,965	2,197,780	32,518	0%	41%	49%	50%
CO	374	88,032	983,959	14,674	374	48,732	475,867	7,070	0%	81%	107%	108%
ID	1,824	268,469	3,600,038	53,594	1,824	137,990	1,905,385	28,367	0%	95%	89%	89%
MT	1,480	201,931	2,507,741	35,679	1,481	161,093	1,837,448	25,822	0%	25%	36%	38%
NV	95	22,369	130,444	1,872	95	16,270	72,430	1,013	0%	37%	80%	85%
NM	258	113,215	745,557	11,039	258	88,247	511,013	7,530	0%	28%	46%	47%
ND	214	47,591	232,775	2,375	214	39,193	197,939	2,013	0%	21%	18%	18%
OR	2,525	378,621	5,298,344	77,827	2,525	302,136	4,218,348	61,808	0%	25%	26%	26%
SD	394	112,840	2,287,843	33,795	394	64,568	1,062,962	15,449	0%	75%	115%	119%
UT	224	220,746	1,565,240	22,939	224	71,512	486,573	7,116	0%	209%	222%	222%
WA	1,278	147,728	1,890,834	28,087	1,278	123,228	1,540,525	22,864	0%	20%	23%	23%
WY	283	70,749	867,832	12,624	283	43,306	421,667	6,021	0%	63%	106%	110%
Total	10,537	2,042,079	24,630,545	361,670	10,538	1,368,436	15,835,221	231,125	0%	49%	56%	56%

2002 Hindcast Emissions

The purposes of the Dynamic Evaluation and 2002 Hindcast emissions were:

- test the CAMx 2014v2 model platform's ability to project observed air quality changes in response to observed emissions changes between the 2000-2004 baseline and the 2014-2018 (RepBase2) planning period at western U.S. IMPROVE monitors.
- evaluate U.S. Anthropogenic emissions rate of progress between 2002 and 2028OTBa2 to define a modeled U.S. Anthropogenic visibility rate of progress by 2028.

Methods for the 2002 Hindcast are described in the Run Specification Sheet for Dynamic Evaluation – 2002 CAMx Simulation and Analysis. TheRepBase2 emissions were hindcast to the 2002 base year using the current inventory methods and 2002 activity data. Natural and non-US emissions were held the same as RepBase2 so that all changes in air concentrations and visibility between 2002 and RepBase2 were attributable to changes in U.S. anthropogenic emissions.

Emission Scenarios Comparison:

Annual emissions (tons per year) for ammonia (NH3), carbon monoxide (CO), nitrogen oxides (NOx), particulate matter less than 2.5 micrometers (PM2.5), particulate matter less than 10 micrometers (PM10), sulfur dioxide (SO2), and volatile organic compounds (VOC) for 13 continental U.S. western states, 14 anthropogenic source groups, and 6 natural source categories for the 2014v2, RepBase2, 2028OTBa2, and 2028PAC2 emissions scenarios can be downloaded from the TSS Emissions Express Tools. The emissions data displayed on the Technical Support System are composited from more detailed pollutant emissions records (to be displayed on the Intermountain West Data Warehouse), as defined in **Table 8** below.

Table 8. Pollutant Emissions displayed on the WRAP Technical Support System and summarized on Intermountain West Data Warehouse.

Final – January 2021

Modeled Pollutant Emissions	Pollutant Code	Technical Support System (TSS) Pollutant Emissions	Pollutant Code
Carbon Monoxide	CO	Carbon Monoxide	CO
Nitrogen Oxides	NOx = NO+NO2+HONO	Nitrogen Oxides	NOx
Sulfur Dioxide	SO2	Sulfur Oxides	SO2
Volatile Organic Compound	VOC	Volatile Organic Compound	VOC
Ammonia	NH3	Ammonia	NH3
Sulfuric Acid	SULF		
Total Particulate Matter less than 2.5 mm (PM2.5)	PM2.5 = POA + PEC + PNO3 + PSO4 + PNH4 + Elements + FPRM	Total Particulate Matter less than 2.5 mm	PM2.5

Particulate Organic Carbon	POA		
Particulate Elemental Carbon	PEC		
Nitrate	PNO3		
Sulfate	PSO4		
Ammonium	PNH4		
Elements	PFE + PMN + PK + PCA + PMG + PAL + PSI + PTI		
"Remaining" Fine Particulate Matter	FPRM		
Coarse Particulate Matter	CPRM		
Particulate Matter less than 10 mm	CPRM + PM2.5	Particulate Matter less than 10 mm	PM10
Sea salt	PCL + NA		

Examples of emissions results that are displayed in TSS Emissions Express Tools # 1-4 are illustrated below.

2017 National Emissions Inventory (NEI) data also can be displayed in TSS Emissions Express Tools # 1-3.

- To display emissions values, below each chart # 1-3, select to show "+ chart data".

Figures 1a-1c illustrate NOx, SO2, and PM2.5 emissions, respectively, for all anthropogenic emissions sectors for WESTAR-WRAP states for the 2014v2, RepBase2, 2028OTBa2, and 2028PAC2 emission scenarios (TSS Emissions Express Tool # 1).

Figures 2a-2c illustrate NOx, SO2, and PM2.5 emissions, respectively, for Oil and Gas Point sources (one of 14 anthropogenic source sectors that can be selected for display) for WESTAR-WRAP states and the 2014v2, RepBase2, 2028OTBa2, and 2028PAC2 emission scenarios (TSS Emissions Express Tool # 2)**.**

Figures 3a-3d illustrate total NOx emissions for the 2014v2, RepBase2, and 2028OTBa2 scenarios, and the 2017 National Emissions Inventory, respectively, for the 13 continental WESTAR-WRAP states as pie charts of the 14 anthropogenic source sectors (TSS Emissions Express Tool # 3). SO2 and PM2.5 charts are similar format, not displayed in this document.

Tables 8 and 10 display State Emissions Totals (tons/year) for NOx and SO2, respectively, for 16 emissions sectors and the 2014v2, RepBase2, 2028OTBa2 and 2028PAC2 emissions scenarios (TSS Emissions Express Tool # 4).

Figure 1a. Annual Nitrogen oxide (NOx) emissions (tons per year) for the 13 continental WESTAR-WRAP states and 14 anthropogenic source groups for the 2014v2, RepBase2, 2028OTBa2, and 2028PAC2 scenarios. TSS Emissions Express Tool # 1.

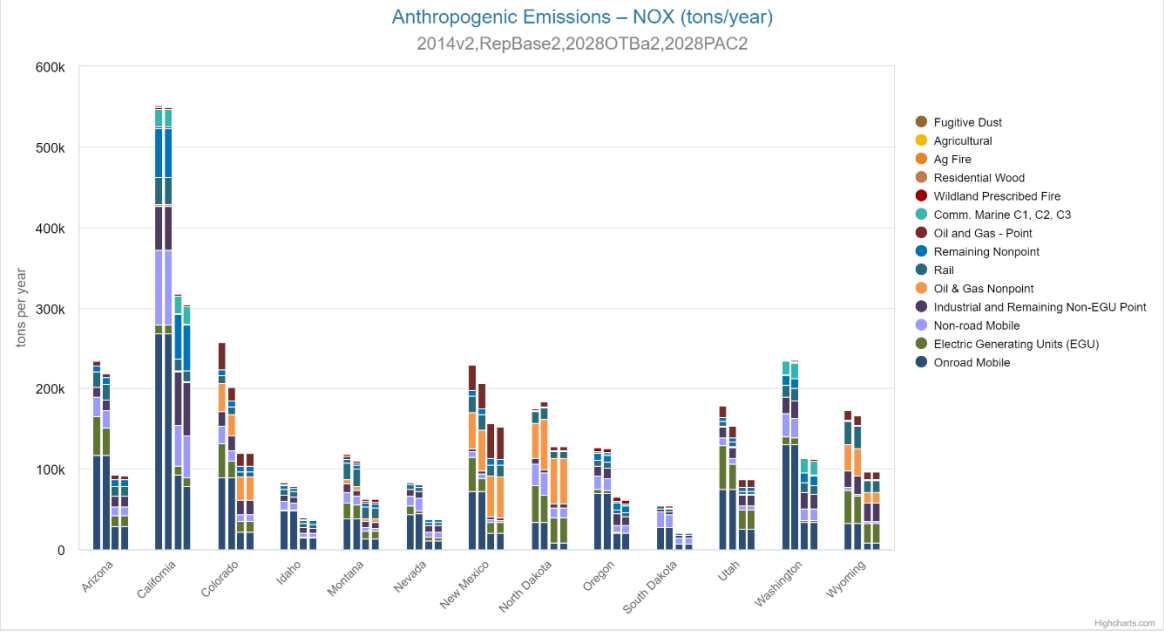


Figure 1b. Annual Sulfur dioxide (SO2) emissions (tons per year) for the 13 continental WESTAR-WRAP states and 14 anthropogenic source groups for the 2014v2, RepBase2, 2028OTBa2, and 2028PAC2 scenarios. TSS Emissions Express Tool # 1.

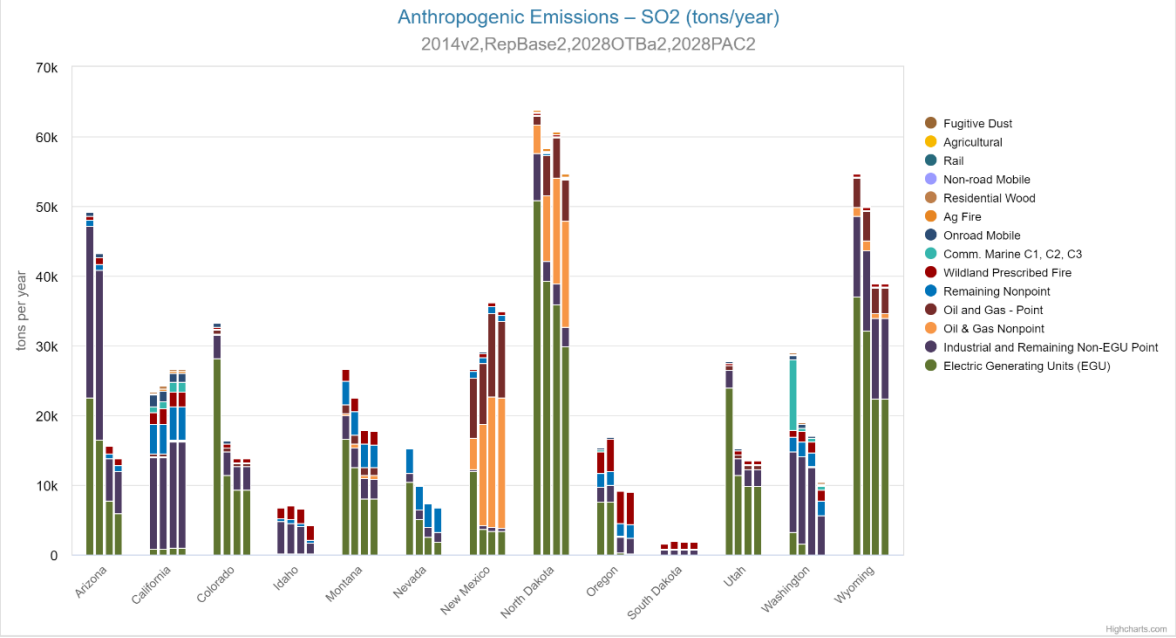


Figure 1c. Annual emissions (tons per year) for Particulate matter less than 2.5 micrometers (PM2.5) for the 13 continental WESTAR-WRAP states and 14 anthropogenic source groups for the 2014v2, RepBase2, 2028OTBa2, and 2028PAC2 scenarios. TSS Emissions Express Tool # 1.

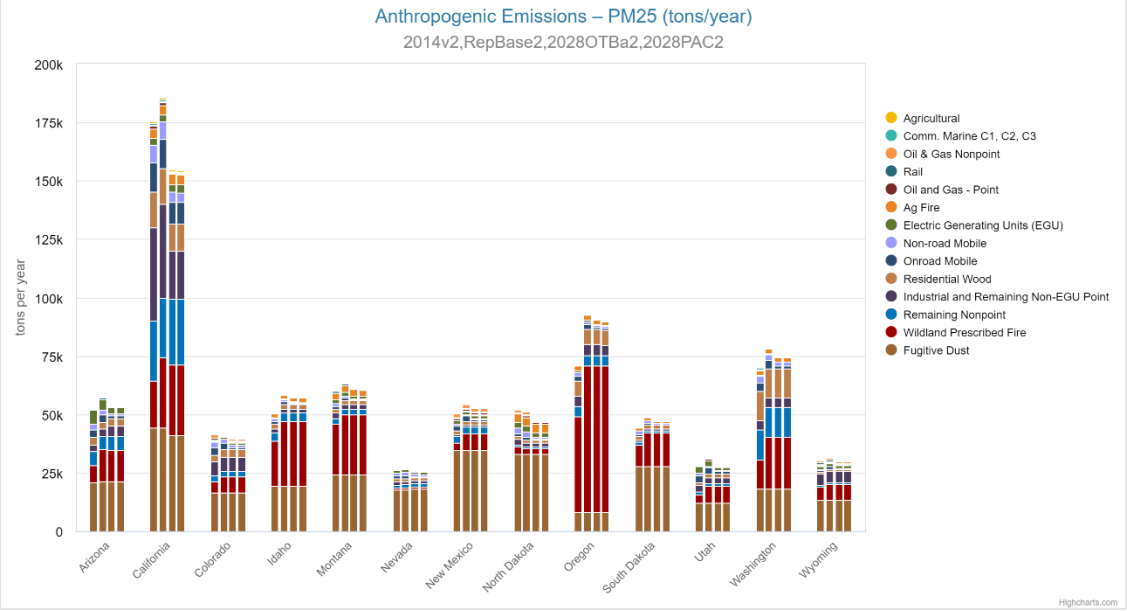


Figure 2a. Annual Nitrogen Oxide (NOx) emissions (tons per year) for Oil and Gas Point sources (1 of 14 anthropogenic source group selection options) in the 13 continental WESTAR-WRAP states for the 2014v2, RepBase2, 2028OTBa2, and 2028PAC2 scenarios. TSS Emissions Express Tool # 2.

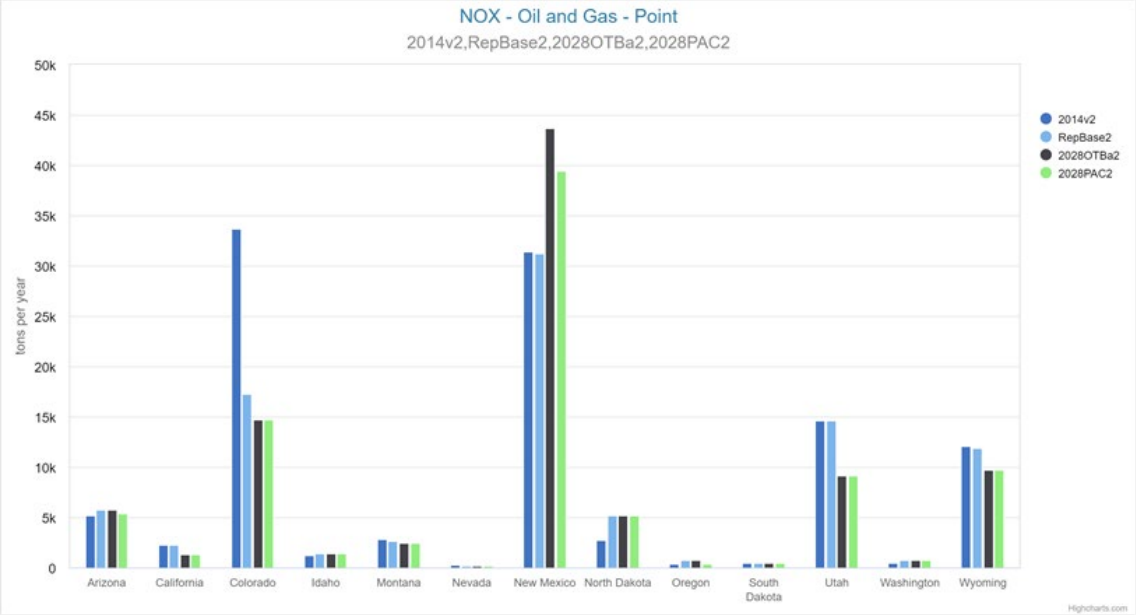


Figure 2b. Annual Sulfur dioxide (SO2) emissions (tons per year) for Oil and Gas Point sources (1 of 14 anthropogenic source group selection options) in the 13 continental WESTAR-WRAP states for the 2014v2, RepBase2, 2028OTBa2, and 2028PAC2 scenarios. [TSS Emissions Express Tool] # 2.

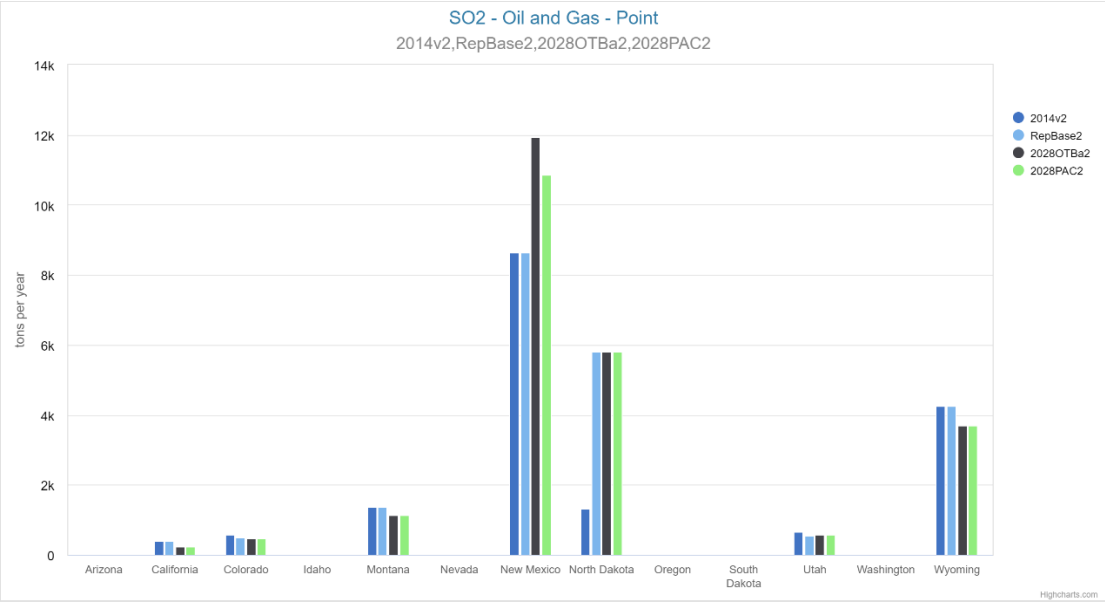


Figure 2c. Annual emissions (tons per year) for Particulate matter less than 2.5 micrometers (PM2.5) for Oil and Gas Point sources (1 of 14 anthropogenic source group selection options) in the 13 continental WESTAR-WRAP states for the 2014v2, RepBase2, 2028OTBa2, and 2028PAC2 scenarios. [TSS Emissions Express Tool] # 2.

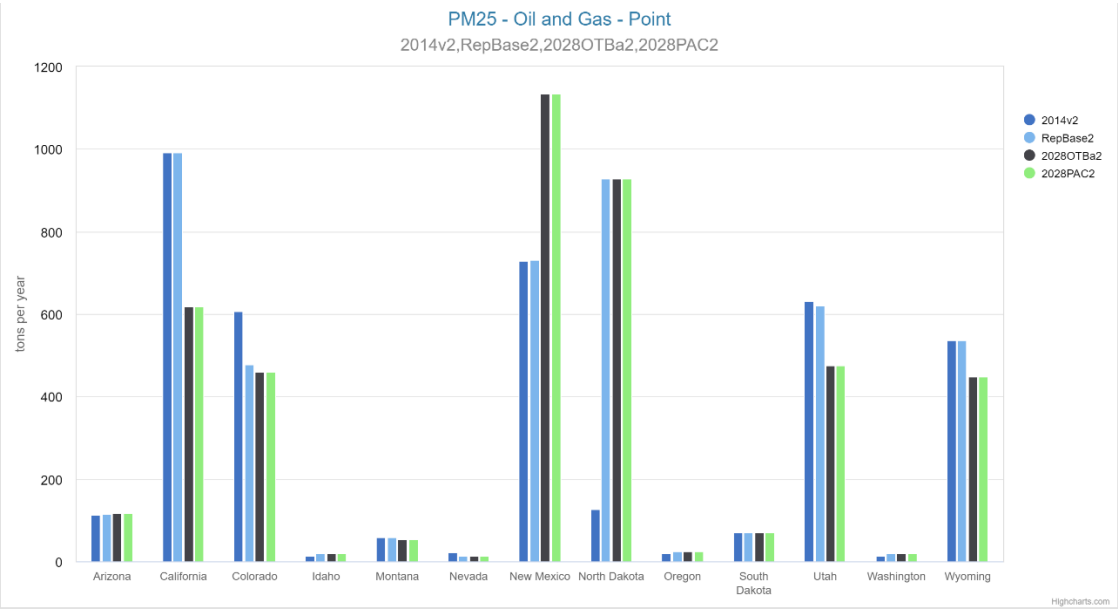


Figure 3a. 2014v2 annual Nitrogen oxide (NOx) emissions (tons per year) totaled for the 13 continental WESTAR-WRAP states for 14 anthropogenic source groups, [TSS Emissions Express Tool] # 3.

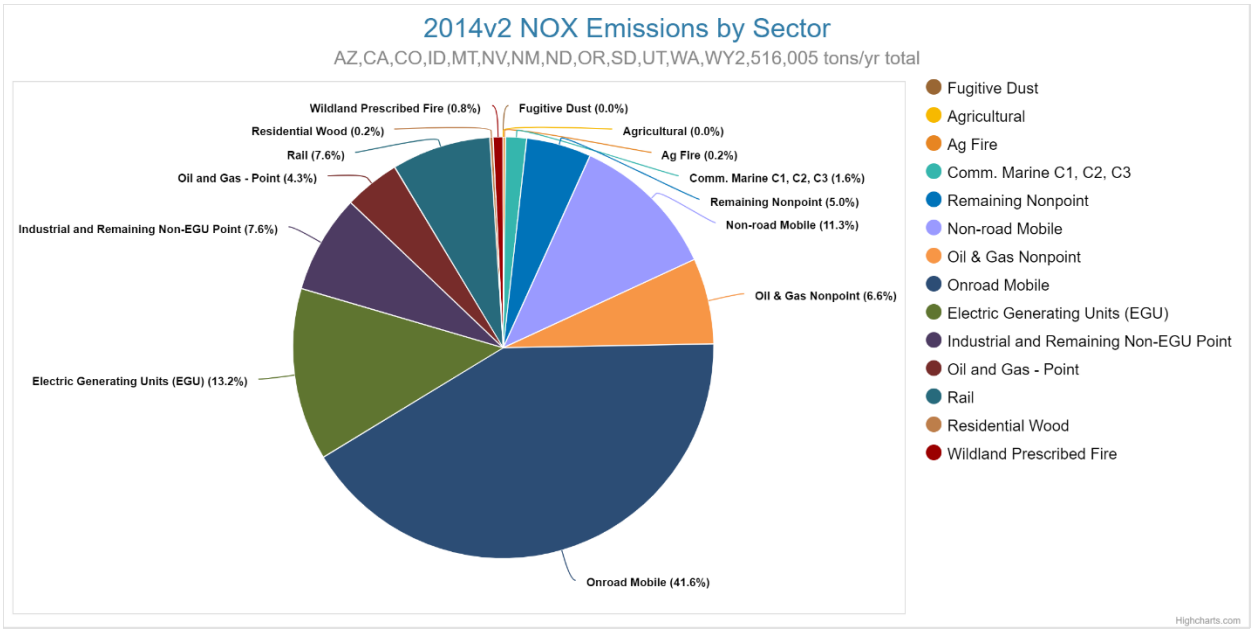


Figure 3b. Representative Baseline (RepBase2) annual Nitrogen oxide (NOx) emissions (tons per year) totaled for the 13 continental WESTAR-WRAP states for 14 anthropogenic source groups, [TSS Emissions Express Tool] # 3.

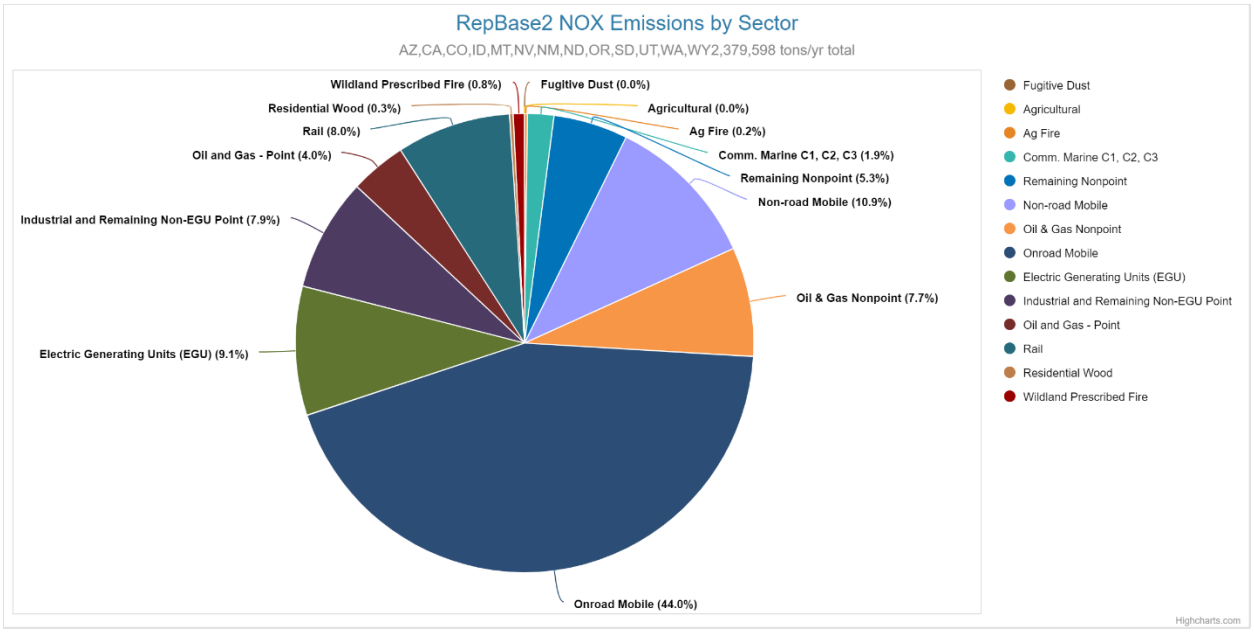


Figure 3c. 2028 On the Books (2O28OTBa2) annual Nitrogen oxide (NOx) emissions (tons per year) totaled for the 13 continental WESTAR-WRAP states for 14 anthropogenic source groups, [TSS Emissions Express Tool]# 3.

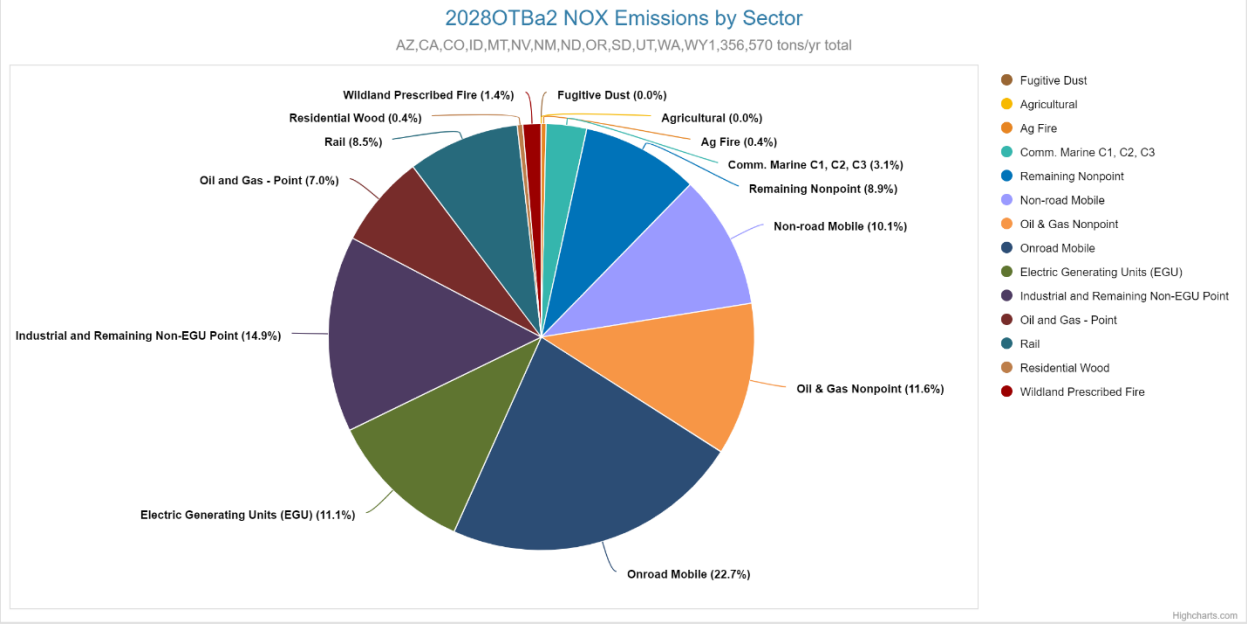


Figure 3d. National Emissions Inventory 2017 (NEI_2017) annual Nitrogen oxide (NOx) emissions (tons per year) totaled for the 13 continental WESTAR-WRAP states for 14 anthropogenic source groups, [TSS Emissions Express Tool]# 3.

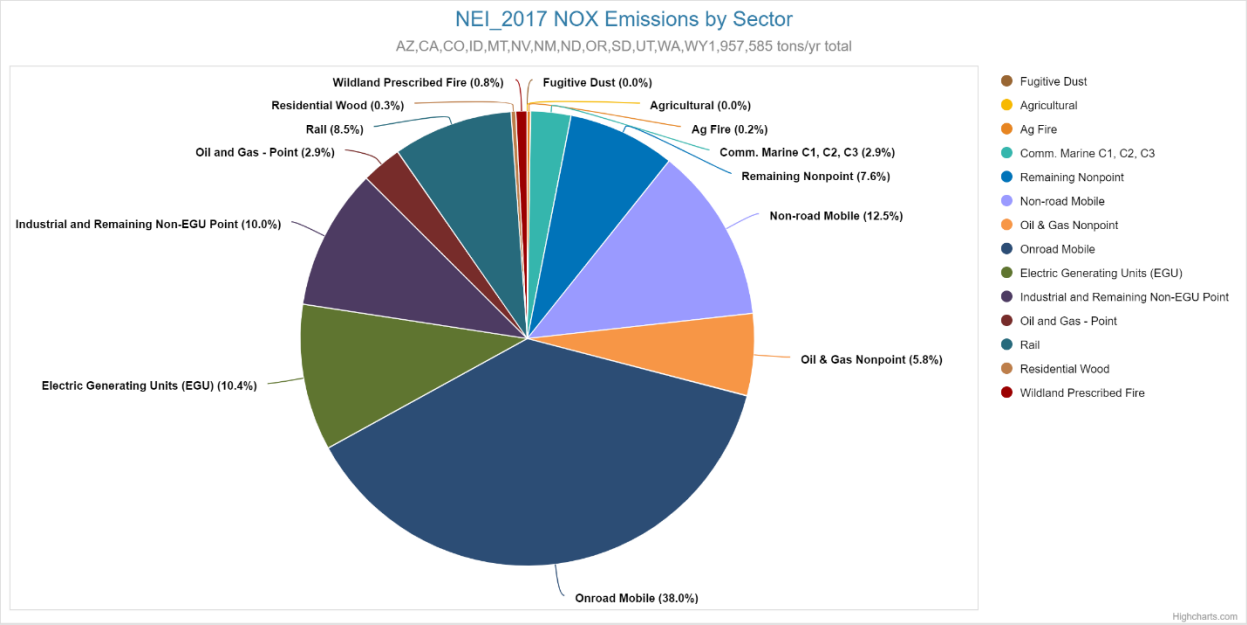


Table 9. Colorado Nitrogen oxide (NOx) emissions (tons/year) for 2014v2, Representative Baseline 2, 2028 On the Books (2028OTBa2), and 2028 Potential Additional Controls (2028PAC2) scenarios and 16 emissions sectors TSS Emissions Express Tool #4.

State: **Colorado**

Pollutant: **Nitrogen Oxides (NOx)** tons/year

State Emissions	Source Category	2014v2 Actual	Representative Baseline 2	2028 OTB a2 [1]	2028 PAC2
Anthropogenic	Electric Generating Units (EGU)	41,596	19,854	13,356	13,356
Anthropogenic	Oil and Gas - Point	33,694	17,226	14,677	14,677
Anthropogenic	Industrial and Non-EGU Point	17,613	17,686	18,007	18,007
Anthropogenic	Oil and Gas - Non-point	35,373	26,987	29,062	29,062
Anthropogenic	Residential Wood Combustion	446	446	446	446
Anthropogenic	Fugitive dust [3]	0	0	0	0
Anthropogenic	Agriculture [2]	0	0	0	0
Anthropogenic	Remaining Non-point	7,209	7,209	7,209	7,209
Anthropogenic	On-Road Mobile	89,776	89,776	22,097	22,097
Anthropogenic	Non-road Mobile	22,355	13,463	8,462	8,462
Anthropogenic	Rail	9,833	9,833	6,103	6,103
Anthropogenic	Commercial Marine [4]	0	0	0	0
Anthropogenic	Agricultural Fire	96	96	96	96
Anthropogenic	Wildland Prescribed Fire	667	517	517	517
Natural	Wildfire	132	6,429	6,429	6,429
Natural	Biogenic [5]	48,405	48,405	48,405	48,405

1) 2028OTBa2 refers to the On the Books assumptions for US anthropogenic emissions in 2028. 2028OTBa2 fire emissions are the same as Represent
2) The Agricultural emissions sector includes only NH3 emissions from nonpoint livestock and fertilizer application.
3) The Fugitive Dust sector contains only PM10 and PM2.5 emissions from area-source anthropogenic dust sources.
4) Commercial Marine Shipping C1, C2, and C3 emissions within and offshore of the state.
5) Biogenic emissions are reported for CO, NOx, and VOC.

Table 10. Colorado Sulfur dioxide (SO2) emissions (tons/year) for 2014v2, Representative Baseline 2, 2028 On the Books (2028OTBa2), and 2028 Potential Additional Controls (2028PAC2) scenarios and 16 emissions sectors TSS Emissions Express Tool # 4.

State: **Colorado**

Pollutant: **Sulfur Dioxide** tons/year

State Emissions	Source Category	2014v2 Actual	Representative Baseline 2	2028 OTB a2 [1]	2028 PAC2
Anthropogenic	Electric Generating Units (EGU)	28,158	11,425	9,309	9,309
Anthropogenic	Oil and Gas - Point	583	514	478	478
Anthropogenic	Industrial and Non-EGU Point	3,335	3,343	3,349	3,349
Anthropogenic	Oil and Gas - Non-point	182	22	24	24
Anthropogenic	Residential Wood Combustion	48	48	48	48
Anthropogenic	Fugitive dust [3]	0	0	0	0
Anthropogenic	Agriculture [2]	0	0	0	0
Anthropogenic	Remaining Non-point	81	81	81	81
Anthropogenic	On-Road Mobile	458	458	180	180
Anthropogenic	Non-road Mobile	53	34	24	24
Anthropogenic	Rail	6	6	5	5
Anthropogenic	Commercial Marine [4]	0	0	0	0
Anthropogenic	Agricultural Fire	30	30	30	30
Anthropogenic	Wildland Prescribed Fire	401	519	519	519
Natural	Wildfire	66	6,684	6,684	6,684
Natural	Biogenic [5]	0	0	0	0

1) 2028OTBa2 refers to the On the Books assumptions for US anthropogenic emissions in 2028. 2028OTBa2 fire emissions are the same as Represent
2) The Agricultural emissions sector includes only NH3 emissions from nonpoint livestock and fertilizer application.
3) The Fugitive Dust sector contains only PM10 and PM2.5 emissions from area-source anthropogenic dust sources.
4) Commercial Marine Shipping C1, C2, and C3 emissions within and offshore of the state.
5) Biogenic emissions are reported for CO, NOx, and VOC.

Maps of total state or county emissions for 4 emissions scenarios and 7 pollutant emissions can be downloaded using [TSS Emissions Express Tools] #8 and 9.

Figure 4a. Total anthropogenic NOx emissions for the western continental U. S. states for the 2014v2 emissions scenario. [TSS Emissions Express Tool] # 8.

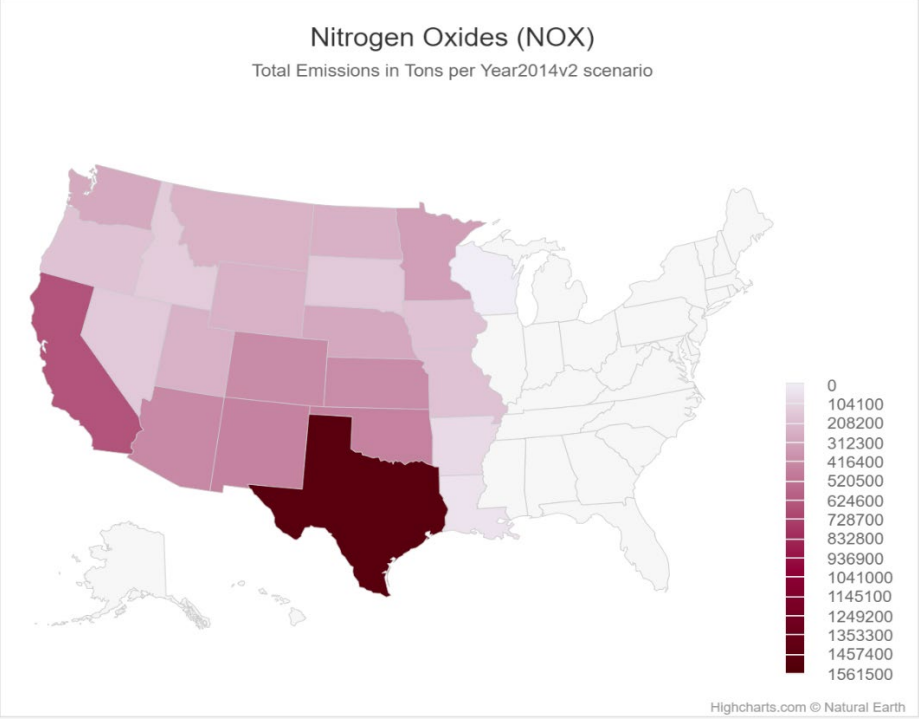
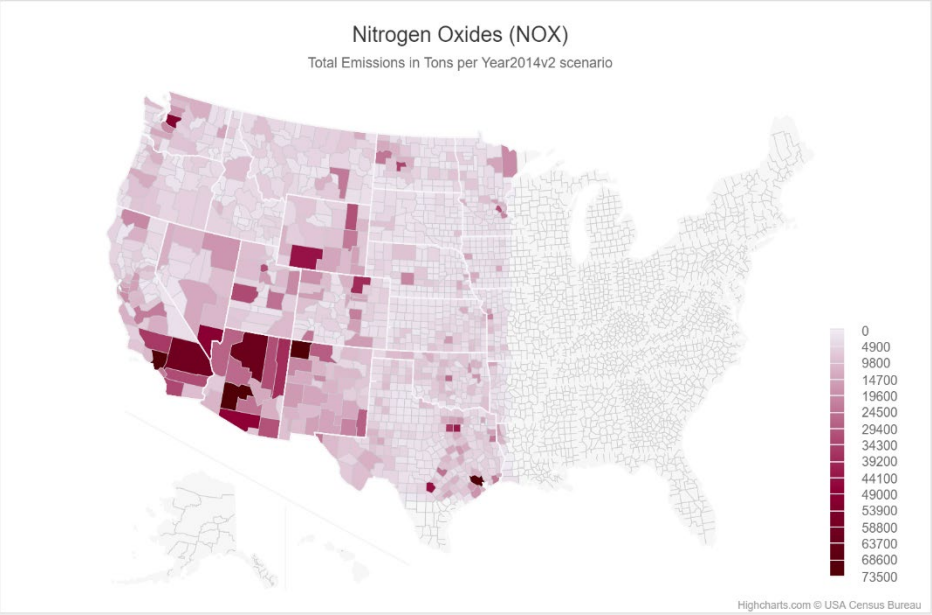
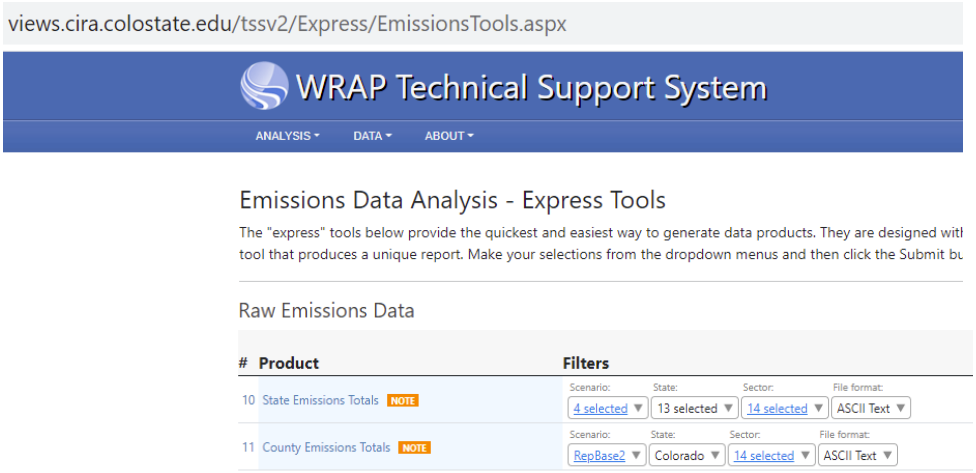


Figure 4b. Total anthropogenic NOx emissions for the western continental U. S. counties (for the 2014v2 emissions scenario. [TSS Emissions Express Tool] # 9.



State and county emissions datasets for 4 emissions scenarios and 16 anthropogenic plus 6 natural emission sectors can be downloaded through [TSS Emissions Express Tools](views.cira.colostate.edu/tssv2/Express/EmissionsTools.aspx) #10 and 11.



As of September 16, 2021, TSS Emissions Express Tools are still under development for:

- Table comparing by state of 2017 National Emissions Inventory (NEI) to 2014v2, RepBase2 and 2028OTBa2 emissions sectors.
    - These data are available for download as data tables displayed with TSS Emissions Express Tools 1-3.
- Comparison by state of 2002 Hindcast to RepBase2 and 2028OTBa2 emissions sectors.

4.0 References

Section 1.0 Introduction

Intermountain West Data Warehouse Western Regional Air Partnership and Western Air Quality Study (IWDW WRAP-WAQS) 2014v2 Modeling Platform Description and Model Performance Evaluation (2020) https://views.cira.colostate.edu/iwdw/docs/WRAP_WAQS_2014v2_MPE.aspx

U.S. Environmental Protection Agency (EPA) Modeling Guidance for Demonstrating Air Quality Goals for Ozone, PM2.5, and Regional Haze (November 2018) https://www.epa.gov/sites/default/files/2020-10/documents/o3-pm-rh-modeling_guidance-2018.pdf

U.S. Environmental Protection Agency (EPA) Technical Support Document for EPA's updated 2028 regional haze modeling (September 2019) https://www.epa.gov/visibility/technical-support-document-epas-updated-2028-regional-haze-modeling

Western Regional Air Partnership (WRAP) 2018-2019 Workplan (updated and approved April 2019) http://www.wrapair2.org/pdf/2018-2019%20WRAP%20Workplan%20update%20Board%20Approved%20April.3.2019.pdf

Western Regional Air Partnership (WRAP) Technical Steering Committee webpage. http://www.wrapair2.org/TSC.aspx

The Western Regional Air Partnership (WRAP) Technical Support System (TSS) https://views.cira.colostate.edu/tssv2/

Section 2.0 Background

U.S. Environmental Protection Agency (EPA) Technical Guidance on Tracking Visibility Progress for the Second Implementation Period of the Regional Haze Program (December 2018)) https://www.epa.gov/sites/default/files/2018-12/documents/technical_guidance_tracking_visibility_progress.pdf

Interagency Monitoring of Protected Visual Environments http://vista.cira.colostate.edu/Improve/

Section 3.0 Emissions Scenarios

U.S. Environmental Protection Agency (EPA) 2014v2 National Emissions Inventory (NEI) https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data

Western Regional Air Partnership (WRAP) western state updates to 2014v2 National Emissions Inventory. February 2019. https://www.wrapair2.org/pdf/WRAP%20Regional%20Haze%20SIP%20Emissions%20Inventory%20Review%20Documentation_for_Docket%20Feb2019.pdf

Western Regional Air Partnership (WRAP) Regional Haze Planning workgroup http://www.wrapair2.org/RHPWG.aspx

Western Regional Air Partnership (WRAP) Emissions and Modeling Protocol subcommittee meetings and reports. https://views.cira.colostate.edu/wiki/wiki/9191/western-us-regional-analysis-2014-neiv2-emissions-inventory-review-for-regi

Western Regional Air Partnership (WRAP) EGU Emissions Analysis Project http://www.wrapair2.org/EGU.aspx

Center for New Energy Economy – Analysis of fossil-fueled WRAP region Electric Generating Units for Regional Haze Planning and Ozone Transport Contribution http://www.wrapair2.org/pdf/Final%20EGU%20Emissions%20Analysis%20Report.pdf

Western Regional Air Partnership (WRAP) Oil and Gas Workgroup
http://www.wrapair2.org/ogwg.aspx

Western Regional Air Partnership (WRAP) Oil and Gas Workgroup Roadmap for updating oil and gas inventories
http://www.wrapair2.org/pdf/OGWG_Roadmap_FinalPhase1Report_Workplan_13Apr2018.pdf

Ramboll – Representative Baseline Revised Final Report: Circa-2014 Baseline Oil and Gas Emission Inventory for the WESTAR-WRAP Region (September 2019) for Western Regional Air Partnership (WRAP) Oil and Gas Workgroup
http://www.wrapair2.org/pdf/WRAP_OGWG_Report_Baseline_17Sep2019.pdf

Ramboll – Revised Final Report: 2028 Future Year Oil and Gas Emission Inventory for WESTAR-WRAP States – Scenario #1: Continuation of Historical Trends, March 2020.
http://www.wrapair2.org/pdf/WRAP_OGWG_2028_OTB_RevFinalReport_05March2020.pdf

Western Regional Air Partnership (WRAP) Fire and Smoke Work Group
http://www.wrapair2.org/fswg.aspx

Air Sciences Inc., Fire Emissions Inventories for Regional Haze Planning: Methods and Results, April 2020.
http://www.wrapair2.org/pdf/fswg_rhp_fire-ei_final_report_20200519_FINAL.PDF

U.S. Environmental Protection Agency (EPA) 2014 modeling platform.
https://www.epa.gov/air-emissions-modeling/2014-version-71-platform

U.S. Environmental Protection Agency (EPA) Technical Support Document (TSD) Preparation of Emissions Inventories for the 2016v1 North American Emissions Modeling Platform March 2021
https://www.epa.gov/air-emissions-modeling/2016-version-1-technical-support-document

Ramboll – Mobile Source Emissions Inventory Development for Implementation in WRAP Regional Haze modeling, March 2020
https://views.cira.colostate.edu/docs/wrap/mseipp/WRAP_MSEI_Summary_Memo_13Mar2020.pdf

Ramboll – Run Specification Sheet for Representative Baseline (RepBase2) and 2028 On-the-Books (2028OTBa2) CAMx Simulations
https://views.cira.colostate.edu/docs/iwdw/platformdocs/WRAP_2014/EmissionsSpecifications_WRAP_RepBase2_and_2028OTBa2_RegionalHazeModelingScenarios_Sept30_2020.pdf

WRAP Regional Haze Workgroup, Point Source Emissions Files for Representative Baseline 2, 2028 On the Books a2, and Potential Additional Emissions Controls 2, September 2020 and October 2020. http://www.wrapair2.org/RHPWG.aspx

Ramboll – WESTAR WRAP Modeling Specification Sheet for Future Fire Sensitivities Simulations, August 2021.
https://views.cira.colostate.edu/docs/iwdw/platformdocs/WRAP_2014/Run_Spec_WRAP_Future_Fire_Sensitivities_August4_2021_final.pdf

Ramboll – Dynamic Evaluation – 2002 CAMx Simulation and Analysis, February 2020.
https://views.cira.colostate.edu/docs/iwdw/platformdocs/WRAP_2014/Run_Spec_WRAP_2014_Task3_Dynamic-Evaluation_v1.pdf

WRAP Technical Support System Emissions Express Tools.
https://views.cira.colostate.edu/tssv2/Express/EmissionsTools.aspx