October 15, 2019

SPECIFICATION SHEET: RWC 2016v1 Platform

Description: Nonpoint residential wood combustion (RWC) emissions, for simulating 2016 and future year U.S. air quality

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1. EXECUTIVE SUMMARY

Residential Wood Combustion (RWC) emissions are projected from the 2014 National Emissions Inventory version 2 (NEI2014v2) to 2016, 2023, and 2028 using factors based on EPA's 2011v6.3 emissions modeling platform methods and implemented into spreadsheet tools by MARAMA. Day-of-year temporalization of RWC sources is based on daily minimum temperature by county and calculated by the SMOKE program Gentpro. Base and future year inventories were processed with the Sparse Matrix Operating Kernel Emissions (SMOKE) modeling system version 4.7. National and state-level emission summaries for key pollutants are provided.

2. INTRODUCTION

This document details the approach and data sources used for developing 2016, 2023, and 2028 emissions for the nonpoint residential wood combustion (RWC) sector. The 2016v1 platform RWC inventory was projected to 2016 from the U.S. EPA NEI2014v2[1] RWC inventory. The 2016 emissions are the same as they were in beta, except for Vermont which provided new factors. For the future year projections, North Carolina provided updated projection factors and MARAMA provided factors that projected data from 2016 to 2023 and 2028 instead of from 2014 as was done in beta, although the results of the two methods are the same except for Vermont and North Caroline due to their specific updates.

The RWC sector includes residential wood burning devices such as fireplaces, fireplaces with inserts, free standing woodstoves, pellet stoves, outdoor hydronic heaters (also known as outdoor wood boilers), indoor furnaces, and outdoor burning in firepits and chimneys. Free standing woodstoves and inserts are further differentiated into three categories: 1) conventional (not EPA certified); 2) EPA certified, catalytic; and 3) EPA certified, noncatalytic. Generally, the conventional units were constructed prior to 1988. Units constructed after 1988 had to meet EPA emission standards and they are either catalytic or non-catalytic. The source classification codes (SCCs) in the rwc sector are listed in Table 1.

Table 1. 2016 v1 platform SCCs for RWC sector

SCC	Tier 1 Description	Tier 2 Description	Tier 3 Description	Tier 4 Description
2104008100	Stationary Source Fuel Combustion	Residential	Wood	Fireplace: general
2104008210	Stationary Source Fuel Combustion	Residential	Wood	Woodstove: fireplace inserts; non-EPA certified
2104008220	Stationary Source Fuel Combustion	Residential	Wood	Woodstove: fireplace inserts; EPA certified; non-catalytic
2104008230	Stationary Source Fuel Combustion	Residential	Wood	Woodstove: fireplace inserts; EPA certified; catalytic
2104008310	Stationary Source Fuel Combustion	Residential	Wood	Woodstove: freestanding, non-EPA certified
2104008320	Stationary Source Fuel Combustion	Residential	Wood	Woodstove: freestanding, EPA certified, non-catalytic
2104008330	Stationary Source Fuel Combustion	Residential	Wood	Woodstove: freestanding, EPA certified, catalytic

[1] https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data

2104008400	Stationary Source Fuel Combustion	Residential	Wood	Woodstove: pellet-fired, general (freestanding or FP insert)
2104008510	Stationary Source Fuel Combustion	Residential	Wood	Furnace: Indoor, cordwood-fired, non-EPA certified
2104008610	Stationary Source Fuel Combustion	Residential	Wood	Hydronic heater: outdoor
2104008700	Stationary Source Fuel Combustion	Residential	Wood	Outdoor wood burning device, NEC (fire-pits, chimeas, etc)
2104009000	Stationary Source Fuel Combustion	Residential	Firelog	Total: All Combustor Types

3. Inventory Development Methods

For all of the states other than California, Washington, and Oregon RWC emissions from NEI2014v2 were projected to 2016 using projection factors derived by MARAMA based on implementing the projection methodology from EPA's 2011 platform[2] into a spreadsheet tool. Projection factors are by SCC and SCC-pollutant; SCC-only factors are applied to all pollutants without an SCC-pollutant factor. The 2016 RWC emissions were then projected to the 2023 and 2028 future years using a similar methodology. Projection factors for Volatile Organic Compounds (VOCs) were applied to both VOC and the VOC Hazardous Air Pollutants (HAPs) that are used in HAP integration. For all years, Vermont uses an alternate set of factors which are the same as the national factors, except that negative growth is replaced with flat growth (no change). North Carolina also uses an alternate set of factors for 2023 and 2028 provided by NCDAQ. Table 2 lists the SCC-based projection factors applied to RWC sources.

Table 2. Projection factors for RWC

SCC	SCC description	Pollutant	2014-to-2016	2016-to-2023	2016-to-2028
2104008100	Fireplace: general		2.00%	7.19%	12.36%
2104008210	Woodstove: fireplace inserts; non-EPA certified		-3.40%	-13.92%	-17.97%
2104008220	Woodstove: fireplace inserts; EPA certified; non-catalytic	PM10-PRI	2.29%	4.09%	5.08%
2104008220	Woodstove: fireplace inserts; EPA certified; non-catalytic	PM25-PRI	2.29%	4.09%	5.08%
2104008220	Woodstove: fireplace inserts; EPA certified; non-catalytic		5.25%	8.34%	10.28%
2104008230	Woodstove: fireplace inserts; EPA certified; catalytic	PM10-PRI	2.44%	6.06%	7.68%

[2] See section 4.2.3.9 of https://www.epa.gov/air-emissions-modeling/additional-updates-2011-and-2023-emissions-version-63-platform-technical

SCC	SCC description	Pollutant	2014-to-2016	2016-to-2023	2016-to-2028
2104008230	Woodstove: fireplace inserts; EPA certified; catalytic	PM25-PRI	2.44%	6.06%	7.68%
2104008230	Woodstove: fireplace inserts; EPA certified; catalytic		5.25%	12.08%	15.27%
2104008310	Woodstove: freestanding, non-EPA certified	CO	-2.35%	-12.09%	-15.72%
2104008310	Woodstove: freestanding, non-EPA certified	PM10-PRI	-2.17%	-12.67%	-16.52%
2104008310	Woodstove: freestanding, non-EPA certified	PM25-PRI	-2.17%	-12.67%	-16.52%
2104008310	Woodstove: freestanding, non-EPA certified	VOC	-2.06%	-11.40%	-14.84%
2104008310	Woodstove: freestanding, non-EPA certified		-2.35%	-12.09%	-15.72%
2104008320	Woodstove: freestanding, EPA certified, non-catalytic	PM10-PRI	2.29%	4.09%	5.08%
2104008320	Woodstove: freestanding, EPA certified, non-catalytic	PM25-PRI	2.29%	4.09%	5.08%
2104008320	Woodstove: freestanding, EPA certified, non-catalytic		5.25%	8.34%	10.28%
2104008330	Woodstove: freestanding, EPA certified, catalytic	PM10-PRI	2.47%	6.07%	7.69%
2104008330	Woodstove: freestanding, EPA certified, catalytic	PM25-PRI	2.47%	6.07%	7.69%
2104008330	Woodstove: freestanding, EPA certified, catalytic		5.25%	12.08%	15.27%
2104008400	Woodstove: pellet-fired, general (freestanding or FP insert)	PM10-PRI	14.40%	30.09%	38.02%
2104008400	Woodstove: pellet-fired, general (freestanding or FP insert)	PM25-PRI	14.40%	30.09%	38.02%
2104008400	Woodstove: pellet-fired, general (freestanding or FP insert)		14.38%	26.96%	33.85%
2104008510	Furnace: Indoor, cordwood-fired, non-EPA certified	CO	-9.70%	-64.93%	-84.78%
2104008510	Furnace: Indoor, cordwood-fired, non-EPA certified	PM10-PRI	-6.15%	-62.99%	-82.89%
2104008510	Furnace: Indoor, cordwood-fired, non-EPA certified	PM25-PRI	-6.15%	-62.99%	-82.89%
2104008510	Furnace: Indoor, cordwood-fired, non-EPA certified	VOC	-9.74%	-65.02%	-84.89%
2104008510	Furnace: Indoor, cordwood-fired, non-EPA certified		-9.70%	-64.93%	-84.78%
2104008610	Hydronic heater: outdoor	PM10-PRI	2.99%	0.06%	-0.40%
2104008610	Hydronic heater: outdoor	PM25-PRI	2.99%	0.06%	-0.40%
2104008610	Hydronic heater: outdoor		2.00%	-0.73%	-1.30%

SCC	SCC description	Pollutant	2014-to-2016	2016-to-2023	2016-to-2028
2104008700	Outdoor wood burning device, NEC (fire-pits, chimeas, etc)		2.00%	7.19%	9.25%
2104009000	Firelog total		2.00%	7.19%	9.25%

For California, Oregon, and Washington, the RWC emissions were held constant at NEI2014v2 levels for 2016, 2023, and 2028. This approach is consistent with the RWC projections used in the EPA's 2011 emissions modeling platform[3].

After the 2014NEIv2 was published, it was determined that the 2014NEIv2 RWC inventory was missing woodstove emissions for certain pollutants in Idaho. The missing emissions for woodstove SCCs 2104008210, 2104008230, 2104008310, 2104008330 were added to the inventory prior to projecting it to 2016 for the beta platform and were retained for the v1 platform.

4. ANCILLARY DATA

Spatial Allocation

Spatial allocation of RWC emissions to the national 36km and 12km grids used for air quality modeling is accomplished using spatial surrogates. Spatial surrogates map county polygons to the uniformly spaced grid cells of a modeling domain. The RWC sector used the 2011 National Land Cover Database (NLCD) Low Intensity Development surrogate (300) to allocate the inventory to modeling grid cells. Figure 1 is a graphic of the 4-km resolution surrogate fractions for the Low Intensity Development surrogate.

[3] https://www.epa.gov/air-emissions-modeling/2011-version-6-air-emissions-modeling-platforms

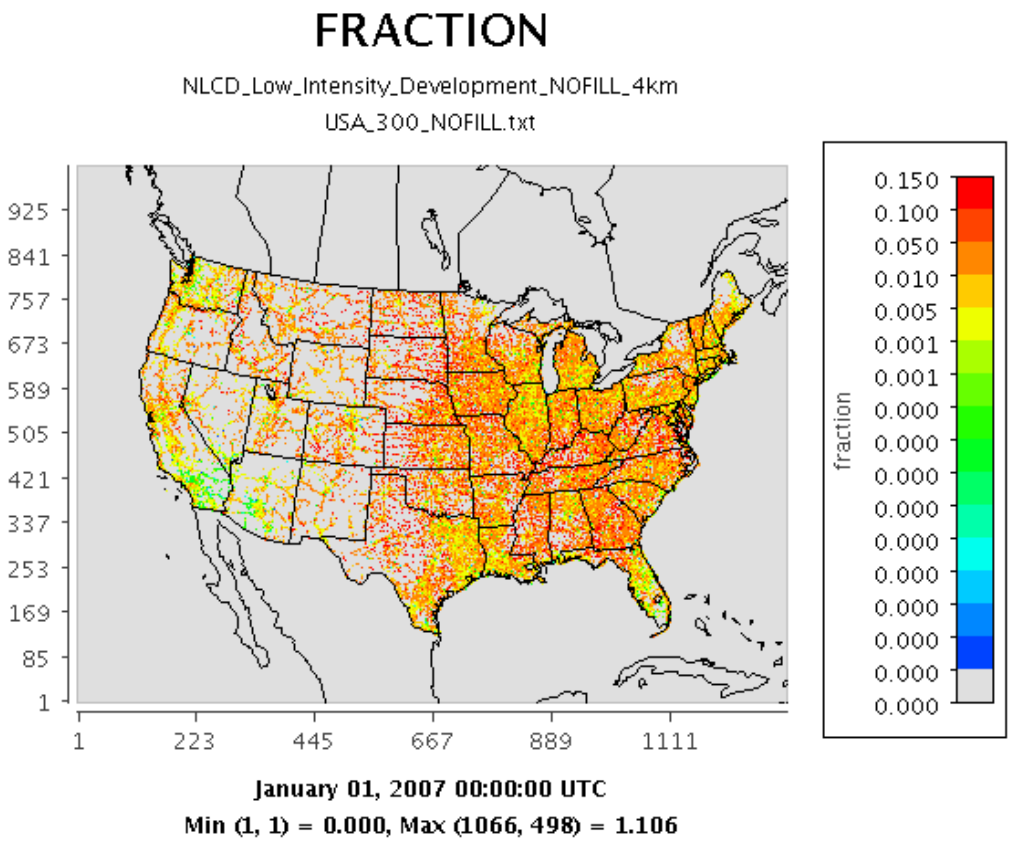

Figure 1. 4-km resolution low intensity development (ID=300) spatial surrogate

Temporal Allocation

Day-of-year temporalization for most RWC sources is based on meteorology, as calculated by the SMOKE program GenTPRO[4]. For the RWC algorithm, Gentpro uses the daily minimum temperature to determine the temporal allocation of annual emissions to days. Gentpro was used to create an annual-to-day temporal profile for the RWC sources. These profiles distribute the annual RWC emissions to the coldest days of the year. On days where the minimum temperature does not drop below a user-defined threshold, RWC emissions for most sources in the sector are zero. Conversely, the program temporally allocates the largest percentage of emissions to the coldest days. In a similar fashion to other temporal allocation profiles, the total annual emissions do not change, only the distribution of the emissions within the year is affected. The temperature threshold for RWC emissions was 50 ˚F for most of the country, and 60 ˚F for the following states: Alabama, Arizona, California, Florida, Georgia, Louisiana, Mississippi, South Carolina, and Texas. Day-of-year temporal profiles from Gentpro are county-specific. Gentpro profiles based on EPA 12km Weather Research Forecast (WRF) modeled meteorology were used for all modeling domains and resolutions to ensure consistency between emissions simulations.

[4] https://www.cmascenter.org/smoke/documentation/4.6/html/ch05s03s05.html

The temporal allocation for Outdoor Hydronic Heaters (OHH; SCC=2104008610) and outdoor recreational wood burning devices (e.g., fire-pits, chimneys; SCC=2104008700) was not based on temperature data, because the meteorological-based temporal allocation used for the rest of the RWC sector did not agree with observational data regarding how these appliances are used. These two SCCs used static, non-temperature dependent monthly and daily temporal profiles.

For hour-of-day temporalization, the RWC sources used a profile which allocates most emissions to the mornings and evenings. OHH sources used a different diurnal profile from other RWC sources. The hour-of-day temporalization approach used for the 2016v1 emissions is described in further detail in the 2014v7.1 emissions modeling platform TSD[5].

Table 3 lists the annual total 2016 RWC emissions assigned to different temporal profiles. Diurnal profile 600 was applied to most of the RWC sources and is illustrated in Figure 2. Diurnal profile 1500, which was applied to OHH sources, is shown in Figure 2. Figure 4 illustrates weekly profile 61500, which was applied to recreational RWC sources. The monthly temporal profiles for OHH sources and fire pits are illustrated in Figure 5.

Table 3. 2016 RWC emissions by temporal profile (tons/yr)

Monthly profile	Weekly profile	Diurnal profile	CO	NH3	NOX	PM10	PM2.5	SO2	VOC
17001x	**7**	**600**	606	3	15	97	96	1	129
17005x	**7**	**600**	3,524	27	58	477	477	9	552
17750x	**61500**	**600**	136,300	1,647	2,378	21,588	21,588	366	17,288
17751x	**7**	**1500**	433,990	2,058	2,395	77,899	77,899	2,447	81,252
met-based	**met-based**	**600**	1,554,219	11,769	26,599	218,701	218,174	4,906	243,226

[5] See section 3.5.4 of https://www.epa.gov/air-emissions-modeling/2014-version-71-technical-support-document-tsd

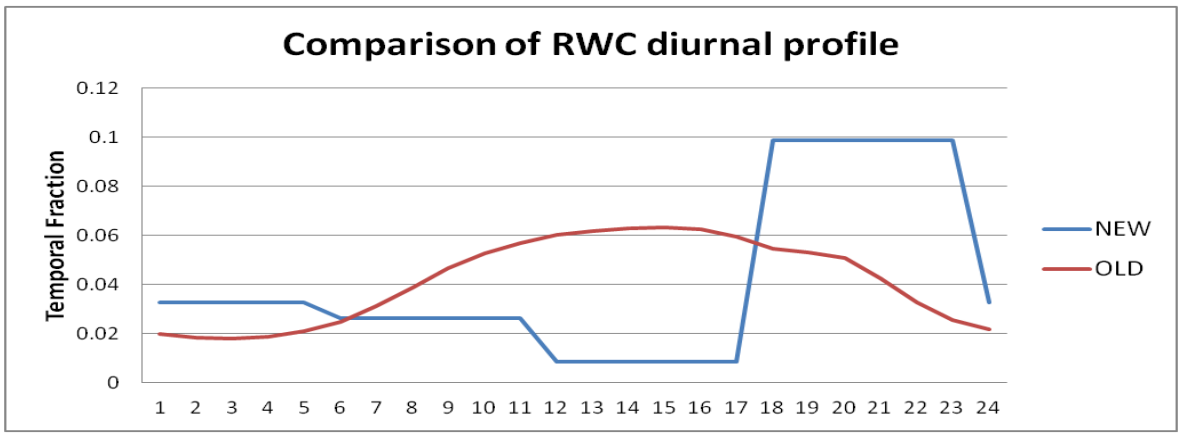

Figure 2. RWC diurnal temporal profile for woodstoves and firesplaces; NEW = 2016v1 platform profile

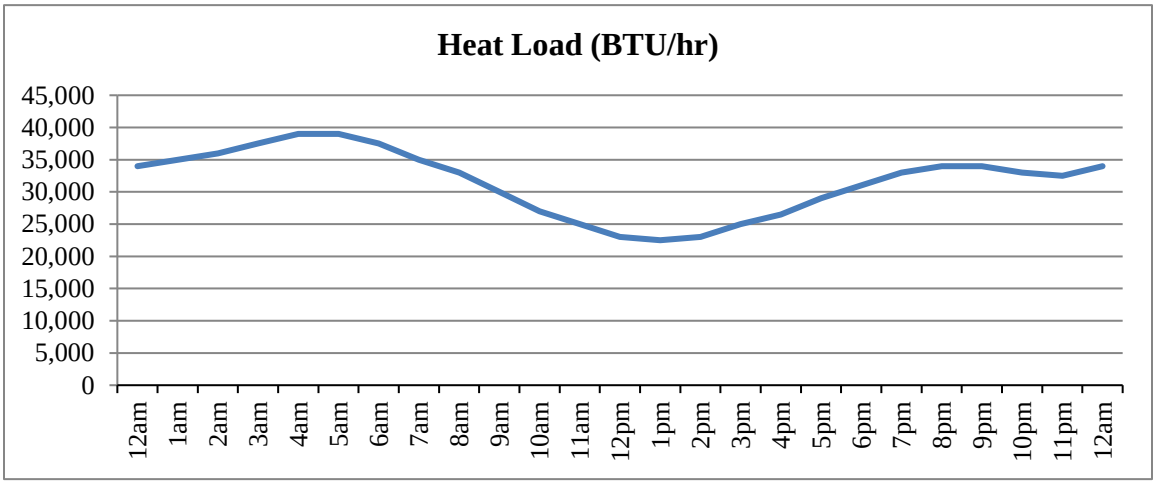

Figure 3. Diurnal temporal profile 600 for OHH sources, based on heat load (BTU/hr)

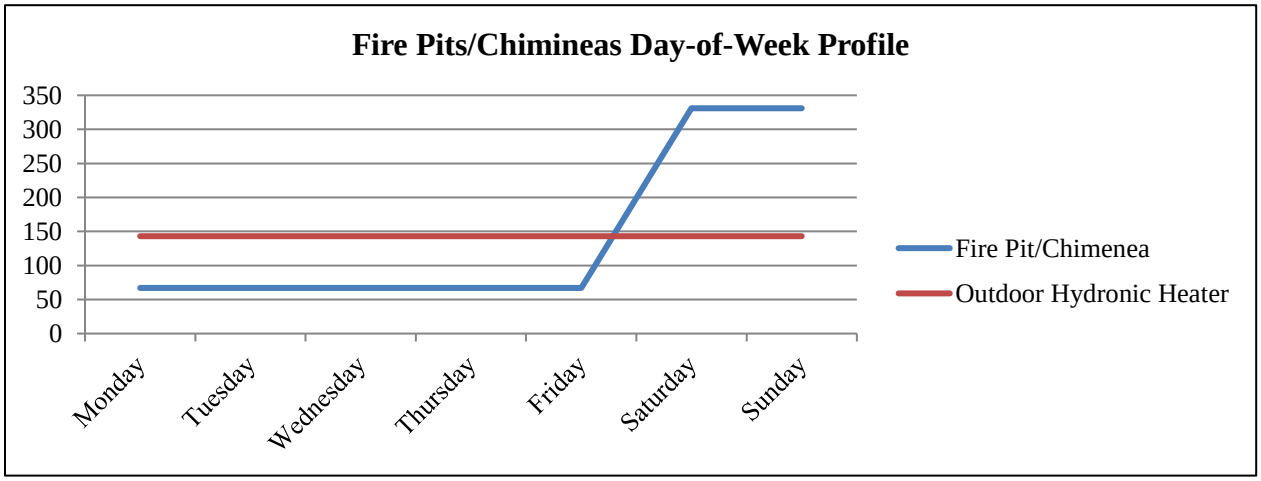

Figure 4. Weekly temporal profile 1500 for recreational wood combustion sources

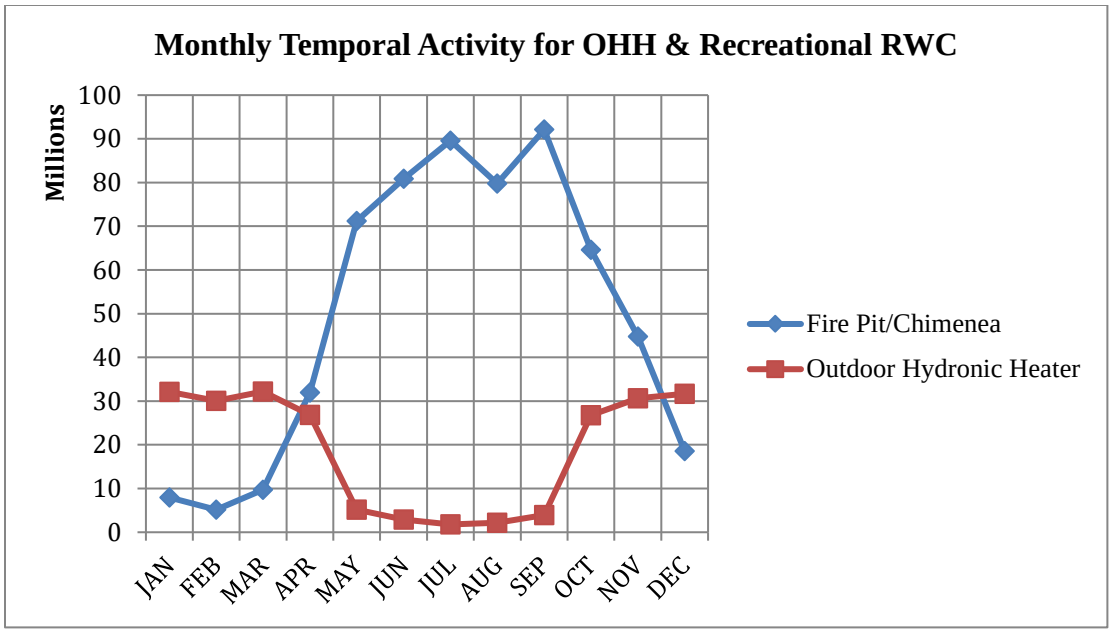

Figure 5. Annual-to-monthly temporal profiles for OHH and recreational wood combustion sources

Chemical Speciation

The RWC sector includes emissions for particulate matter < 2.5 μm ($PM_{2.5}$), oxides of nitrogen (NOx), and VOC, among other criteria pollutants. These three inventory pollutants must be converted to air quality modeling species through an emissions processing step referred to as "chemical speciation". The U.S. EPA SPECIATE[6] database was used to develop factors to map the inventory species to the chemical species required for air quality modeling. The emissions in the RWC sector all use $PM_{2.5}$ speciation profile 91105 (Residential Wood Combustion) shown in Table 7. Two VOC speciation profiles were applied to these sources: 1084 (Residential Wood Combustion) and 4642 (Fireplace Wood Combustion – Pine Wood). The VOC profiles are shown in Table 5 and Table 6. The NONHAPTOG profiles are used for sources that are integrated and the TOG profiles are used for sources that are not integrated. The RWC Nox emissions were speciated using a 90:10 split for NO:NO2. Note that there is no HONO included for RWC NOx speciation as there is for many mobile-source sectors.

Table 4. PM2.5 Speciation Profile for RWC

Specie	Factor
PAL	0.00011
PCA	0.0001
PCL	0.002965
PEC	0.0558
PFE	0.00009
PK	0.009671

[6] https://www.epa.gov/air-emissions-modeling/speciate-version-45-through-40

Specie	Factor
PMG	0.000113
PMOTHR	0.0245
PNA	0.00094
PNCOM	0.3697
PNH4	0.0015
PNO3	0.0019
POC	0.5282
PSI	0.00034
PSO4	0.0041

Table 5. VOC factors for Profile 1084 RWC SCCs 2104008230 and 2014008330

Specie	NONHAPTOG	TOG	Molecular Weight
BENZ	n/a	0.1891	78.1118
CH4	0.4734	0.3839	16.0425
ETH	0.202	0.1638	28.0532
ETHA	0.0642	0.0521	30.069
ETOH	0.2031	0.1647	46.0684
IOLE	6.59E-06	5.27E-06	65.9229
OLE	0.0197	0.016	28.101
PAR	0.0178	0.0144	14.727
PRPA	0.0169	0.0137	44.0956
TOL	0.000701	0.000569	115.3651
UNR	0.001554	0.00126	16.4807
XYLMN	0.000605	0.00049	131.8458
VOC-to-TOG	2.1629	1.7730	

Table 6. VOC factors for Profile 4642 – Remaining RWC SCCs

Specie	NONHAPTOG	TOG	Molecular Weight
ACET	0.0481	0.0393	58.0791
ALD2	n/a	0.0895	44.0526
ALDX	0.1468	0.12	44.6392
BENZ	n/a	0.0201	78.1118
CH4	0.2647	0.2163	16.0425
ETH	0.0719	0.0588	28.0532
ETHA	0.0275	0.0225	30.069
ETHY	0.0451	0.0369	26.0373
FORM	n/a	0.0612	30.026
IOLE	0.0172	0.014	55.1683
ISOP	0.002634	0.002153	68.117

Specie	NONHAPTOG	TOG	Molecular Weight
KET	0.007449	0.006088	19.6066
NAPH	n/a	0.0119	128.1705
NVOL	0.0141	0.0115	0.9999
OLE	0.0405	0.0331	31.1249
PAR	0.1273	0.1041	17.3524
PRPA	0.0109	0.008873	44.0956
SOAALK	0.004218	0.003447	94.5895
TOL	0.0977	0.0798	111.1621
UNR	0.0534	0.0437	16.8384
XYLMN	0.0248	0.0203	121.8475
VOC-to-TOG	1.5158	1.3852	

5. Emissions Projection Methods

As described in Section 3, for the states other than California, Oregon, and Washington, RWC emissions from 2016 were projected to 2023 and 2028 using projection factors derived using the MARAMA tool that is based on the projection methodology from EPA's 2011v6.3 platform. Table 2 contains the factors to adjust the emissions from 2016 to 2023 and 2028. California, Oregon, and Washington RWC were held constant at NEI2014v2 levels for 2016, 2023, and 2028 due to the unique control programs those states have in place. Figure 6 shows the percent change in emissions from 2016 to 2028.

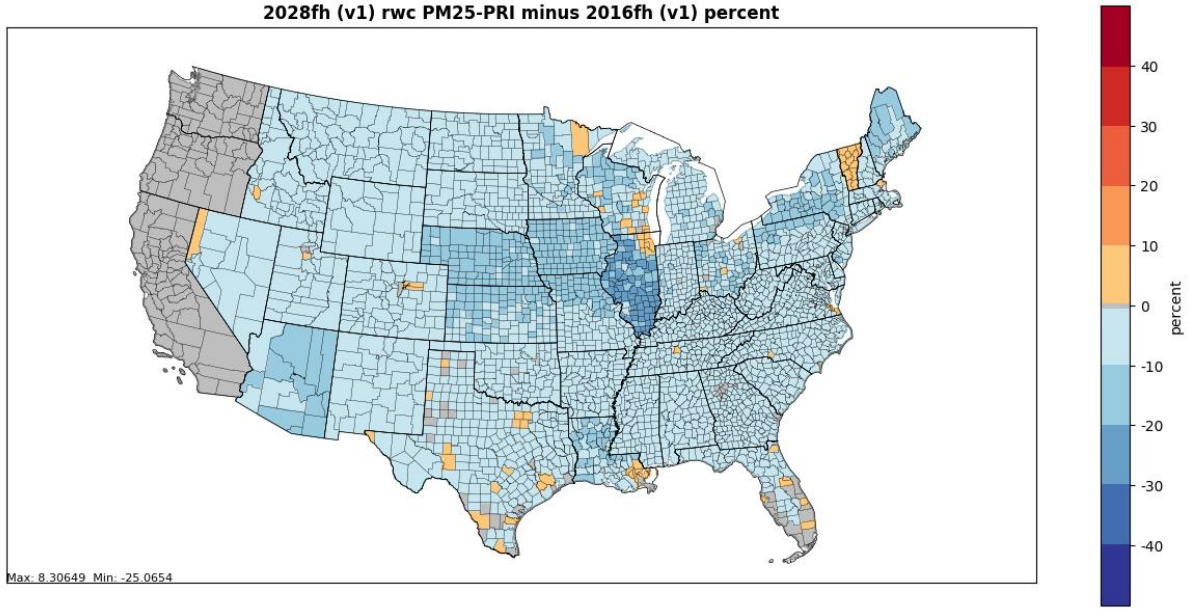

Figure 6. Percent change in $PM_{2.5}$-Primary from 2016 to 2028

6. EMISSIONS PROCESSING REQUIREMENTS

RWC emissions were processed for air quality modeling using the Sparse Matrix Operator Kernel Emissions (SMOKE[7]) modeling system. The Temporal program used monthly and daily profiles developed by Gentpro. Because the temporalization is different for every day of the year, separate emissions files are generated for every day, not just for representative days. This is a 2-D sector in which all emissions are output to a single layer, gridded emissions file.

7. EMISSIONS SUMMARIES

Table 7 compares annual, national total RWC emissions for the 2016 v1 platform to RWC emissions from previous modeling platforms. Table 8 and Table 9 show similar comparisons for state total RWC NOx and $PM_{2.5}$ emissions, respectively. Figure 7 is a gridded plot of Annual 2016v1 RWC PM2.5 emissions. Figure 8 is a plot of January 2016 county total RWC PM2.5 emissions. Figure 9 is a plot of July 2016 county total RWC PM2.5 emissions. Figures 8 and 9 are from the 2016 beta platform, but the emissions have not changed much, so the seasonal illustration is still valid. Additional plots and maps are available online through the LADCO website[8] and the Intermountain West Data Warehouse[9].

Descriptions of the emissions platform cases shown in the tables and plots below are as follows:

2014fd = 2014NEIv2 and 2014 NATA

2016fe = 2016 alpha platform (grown from 2014NEIv2)

2016ff, 2023ff, and 2028ff = 2016, 2023, and 2028 cases from the 2016 beta platform

2016fh, 2023fh, and 2028fh = 2016, 2023, and 2028 cases from the 2016 v1 platform

Table 7. Comparison of national total annual RWC emissions (tons/yr)

Pollutant	2014fd	2016fe	2016ff	2016fh	2023ff	2023fh	2028ff	2028fh
CO	2,108,068	2,108,068	2,127,310	2,128,639	2,045,939	2,055,805	2,020,504	2,032,839
NH3	15,394	15,394	15,491	15,503	14,765	14,855	14,561	14,673
NOX	30,652	30,652	31,432	31,446	31,944	32,072	32,066	32,220
PM10	315,758	315,758	318,627	318,762	304,361	305,697	299,884	301,593
PM2.5	315,234	315,234	318,099	318,234	303,814	305,150	299,332	301,041
SO2	7,709	7,709	7,717	7,729	6,947	7,034	6,702	6,811
VOC	339,972	339,972	342,318	342,447	329,528	330,449	325,640	326,800

[7] http://www.smoke-model.org/index.cfm
[8] https://www.ladco.org/technical/modeling-results/2016-inventory-collaborative/
[9] http://views.cira.colostate.edu/iwdw/eibrowser2016

Table 8. Comparison of state total annual NOx RWC emissions (tons/yr)

State	2014fd	2016fe	2016ff	2016fh	2023ff	2023fh	2028ff	2028fh
Alabama	330	330	341	341	356	356	361	361
Alaska	87	87	90	90	92	92	93	93
Arizona	379	379	387	387	394	394	397	397
Arkansas	143	143	147	147	152	152	154	154
California	740	740	740	740	740	740	740	740
Colorado	447	447	462	462	490	490	497	497
Connecticut	523	523	540	540	560	560	564	564
Delaware	54	54	56	56	58	58	59	59
District of Columbia	8	8	8	8	9	9	9	9
Florida	424	424	435	435	454	454	461	461
Georgia	509	509	525	525	549	549	557	557
Hawaii	64	64	66	66	70	70	71	71
Idaho	118	118	205	205	215	215	218	218
Illinois	921	921	924	924	871	871	857	857
Indiana	1,047	1,047	1,072	1,072	1,077	1,077	1,077	1,077
Iowa	588	588	601	601	601	601	599	599
Kansas	368	368	378	378	379	379	379	379
Kentucky	464	464	480	480	502	502	507	507
Louisiana	117	117	118	118	119	119	119	119
Maine	526	526	542	542	550	550	550	550
Maryland	262	262	271	271	283	283	287	287
Massachusetts	721	721	743	743	775	775	783	783
Michigan	1,765	1,765	1,808	1,808	1,840	1,840	1,846	1,846
Minnesota	3,370	3,370	3,397	3,397	3,319	3,319	3,298	3,298
Mississippi	191	191	194	194	194	194	195	195
Missouri	923	923	947	947	949	949	949	949
Montana	177	177	183	183	192	192	194	194
Nebraska	270	270	276	276	278	278	278	278
Nevada	184	184	192	192	208	208	213	213
New Hampshire	409	409	421	421	432	432	434	434
New Jersey	592	592	610	610	634	634	640	640
New Mexico	199	199	206	206	215	215	218	218
New York	1,838	1,838	1,895	1,895	1,938	1,938	1,945	1,945
North Carolina	649	649	672	672	706	738	714	749
North Dakota	119	119	123	123	127	127	128	128
Ohio	1,505	1,505	1,540	1,540	1,555	1,555	1,557	1,557
Oklahoma	151	151	155	155	160	160	162	162
Oregon	668	668	668	668	668	668	668	668
Pennsylvania	2,072	2,072	2,136	2,136	2,181	2,181	2,188	2,188
Rhode Island	139	139	143	143	149	149	151	151
South Carolina	309	309	319	319	333	333	338	338
South Dakota	145	145	149	149	155	155	156	156
Tennessee	527	527	544	544	570	570	578	578
Texas	695	695	713	713	746	746	758	758

State	2014fd	2016fe	2016ff	2016fh	2023ff	2023fh	2028ff	2028fh
Utah	189	189	195	195	205	205	208	208
Vermont	815	815	849	863	868	963	869	989
Virginia	621	621	642	642	672	672	680	680
Washington	1,815	1,815	1,815	1,815	1,815	1,815	1,815	1,815
West Virginia	303	303	314	314	328	328	332	332
Wisconsin	1,081	1,081	1,104	1,104	1,112	1,112	1,113	1,113
Wyoming	83	83	85	85	90	90	91	91
Tribal Data	8	8	8	8	8	8	8	8

Table 9. Comparison of state total annual primary PM2.5 RWC emissions (tons/yr)

State	2014fd	2016fe	2016ff	2016fh	2023ff	2023fh	2028ff	2028fh
Alabama	2,726	2,726	2,736	2,736	2,652	2,652	2,635	2,635
Alaska	711	711	711	711	662	662	645	645
Arizona	3,184	3,184	3,170	3,170	2,987	2,987	2,948	2,948
Arkansas	1,266	1,266	1,273	1,273	1,233	1,233	1,225	1,225
California	6,825	6,825	6,825	6,825	6,825	6,825	6,825	6,825
Colorado	3,142	3,142	3,161	3,161	3,134	3,134	3,131	3,131
Connecticut	4,896	4,896	4,930	4,930	4,717	4,717	4,645	4,645
Delaware	501	501	505	505	495	495	493	493
District of Columbia	53	53	53	53	53	53	54	54
Florida	3,521	3,521	3,540	3,540	3,495	3,495	3,505	3,505
Georgia	4,194	4,194	4,210	4,210	4,107	4,107	4,094	4,094
Hawaii	505	505	507	507	499	499	499	499
Idaho	926	926	1,793	1,793	1,756	1,756	1,745	1,745
Illinois	11,227	11,227	11,227	11,227	9,969	9,969	9,589	9,589
Indiana	12,861	12,861	12,997	12,997	12,323	12,323	12,092	12,092
Iowa	6,066	6,066	6,082	6,082	5,582	5,582	5,424	5,424
Kansas	4,025	4,025	4,044	4,044	3,764	3,764	3,676	3,676
Kentucky	4,542	4,542	4,581	4,581	4,462	4,462	4,429	4,429
Louisiana	1,011	1,011	1,007	1,007	955	955	948	948
Maine	5,620	5,620	5,648	5,648	5,253	5,253	5,121	5,121
Maryland	2,404	2,404	2,422	2,422	2,375	2,375	2,368	2,368
Massachusetts	7,139	7,139	7,220	7,220	7,080	7,080	7,026	7,026
Michigan	19,611	19,611	19,806	19,806	19,020	19,020	18,749	18,749
Minnesota	49,166	49,166	49,756	49,756	47,730	47,731	47,038	47,038
Mississippi	1,815	1,815	1,816	1,816	1,745	1,745	1,729	1,729
Missouri	10,236	10,236	10,284	10,284	9,557	9,557	9,326	9,326
Montana	1,388	1,388	1,393	1,393	1,343	1,343	1,329	1,329
Nebraska	2,602	2,602	2,607	2,607	2,404	2,404	2,340	2,340
Nevada	1,316	1,316	1,328	1,328	1,330	1,330	1,340	1,340
New Hampshire	4,226	4,226	4,258	4,258	4,069	4,069	4,003	4,003
New Jersey	4,995	4,995	5,014	5,014	4,785	4,785	4,715	4,715
New Mexico	1,670	1,670	1,679	1,679	1,633	1,633	1,622	1,622
New York	17,916	17,916	17,988	17,988	16,860	16,860	16,495	16,495

State	2014fd	2016fe	2016ff	2016fh	2023ff	2023fh	2028ff	2028fh
North Carolina	5,401	5,401	5,428	5,428	5,265	5,316	5,219	5,276
North Dakota	1,200	1,200	1,212	1,212	1,174	1,174	1,161	1,161
Ohio	16,738	16,738	16,875	16,875	15,953	15,953	15,649	15,649
Oklahoma	1,290	1,290	1,295	1,295	1,255	1,255	1,249	1,249
Oregon	6,350	6,350	6,350	6,350	6,350	6,350	6,350	6,350
Pennsylvania	21,332	21,332	21,459	21,459	20,186	20,186	19,762	19,762
Rhode Island	1,254	1,254	1,263	1,263	1,217	1,217	1,201	1,201
South Carolina	2,530	2,530	2,539	2,539	2,473	2,473	2,462	2,462
South Dakota	1,473	1,473	1,487	1,487	1,442	1,442	1,427	1,427
Tennessee	4,733	4,733	4,766	4,766	4,652	4,652	4,628	4,628
Texas	5,380	5,380	5,416	5,416	5,366	5,366	5,379	5,379
Utah	1,405	1,405	1,415	1,415	1,393	1,393	1,388	1,388
Vermont	7,415	7,415	7,410	7,546	6,453	7,736	6,138	7,789
Virginia	5,725	5,725	5,766	5,766	5,635	5,635	5,606	5,606
Washington	14,924	14,924	14,924	14,924	14,924	14,924	14,924	14,924
West Virginia	2,855	2,855	2,877	2,877	2,804	2,804	2,784	2,784
Wisconsin	12,233	12,233	12,335	12,335	11,730	11,730	11,526	11,526
Wyoming	637	637	639	639	617	617	610	610
Tribal Data	73	73	73	73	68	68	67	67

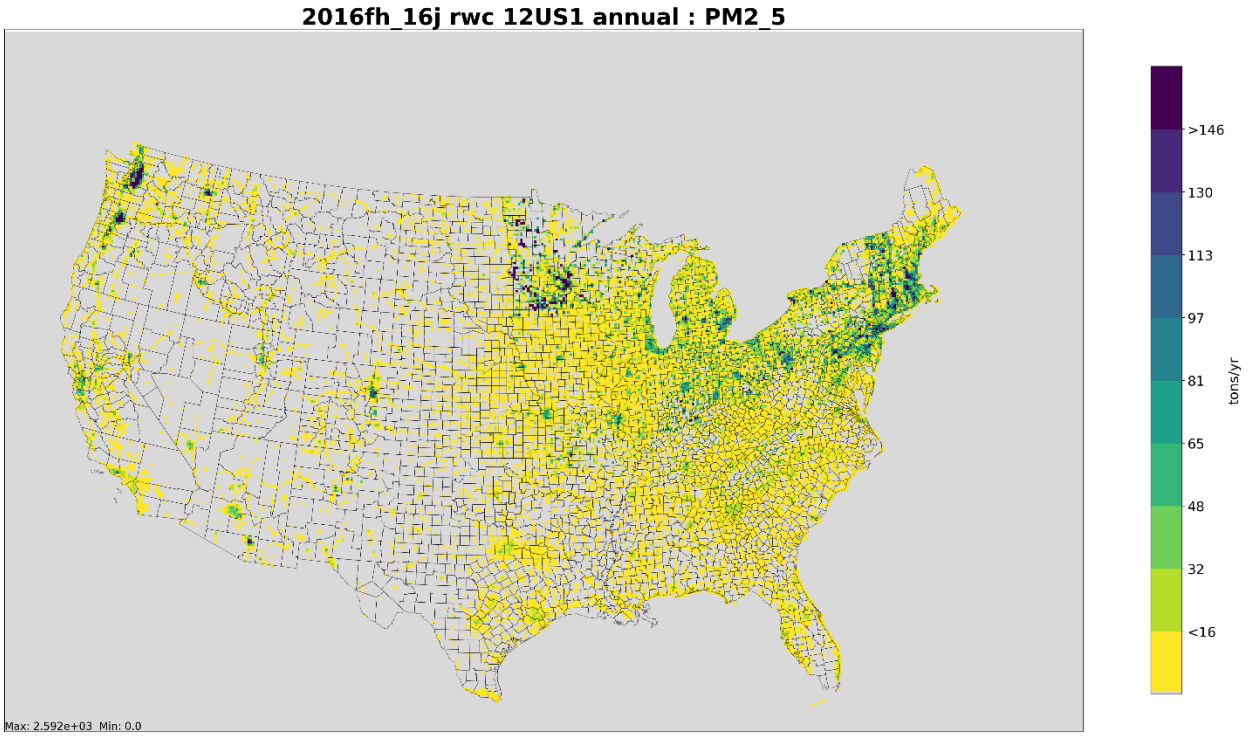

Figure 7. Annual gridded RWD $PM_{2.5}$ emissions

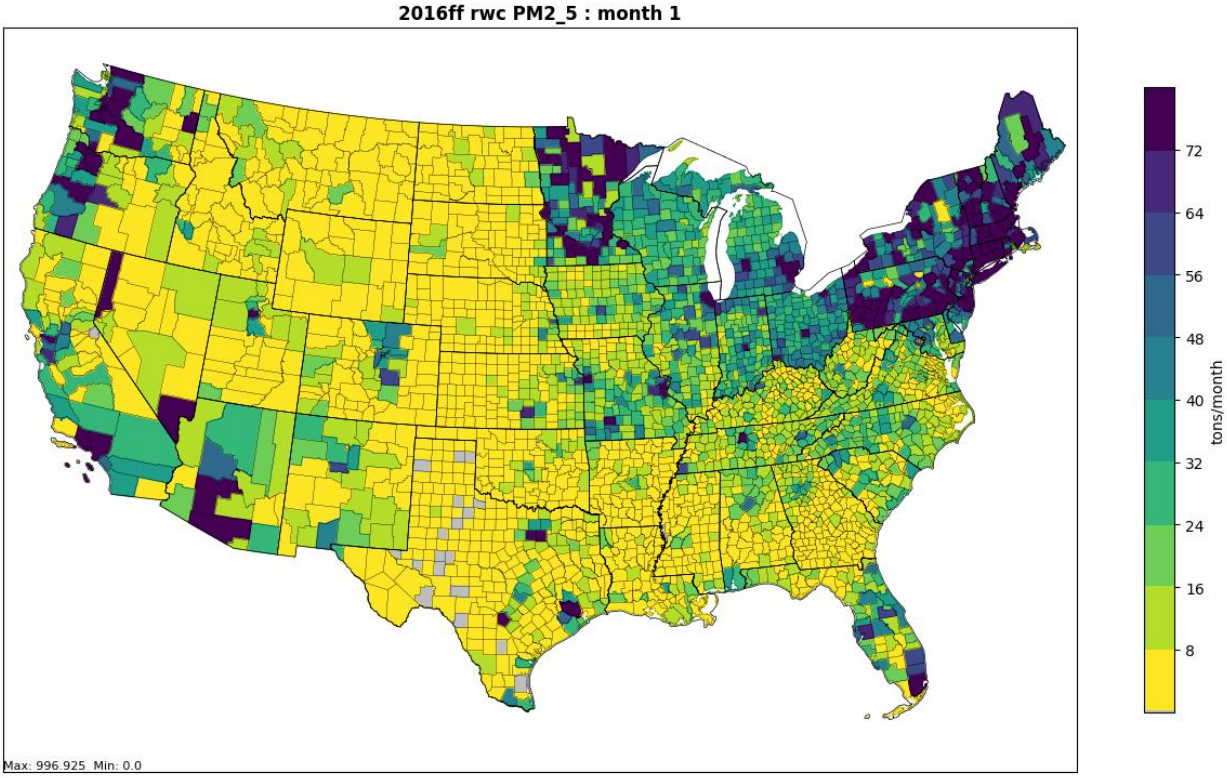

Figure 8. January 2016 county total RWC $PM_{2.5}$ emissions

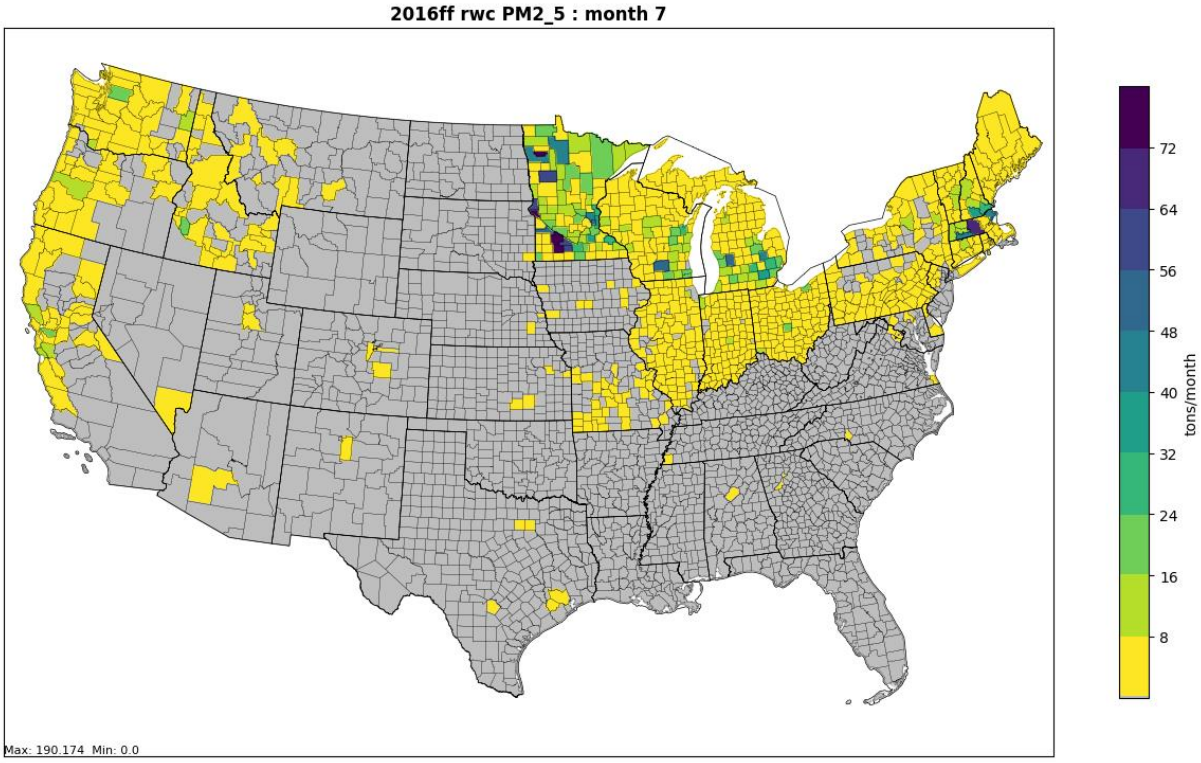

Figure 9. July 2016 county total RWC $PM_{2.5}$ emissions