6. Biogenic Sources

6.1 Introduction

Biogenic emissions have been estimated for the 2011 Periodic Emissions Inventory for ozone precursors in Maricopa County (9,223 square miles) and the eight-hour ozone nonattainment area (NAA) (5,025 square miles). The Model of Emissions of Gases and Aerosols from Nature (MEGAN) has been used to estimate the biogenic emissions. MEGAN is a state-of-the-art biogenic emissions model developed by the National Center for Atmospheric Research (NCAR). Some important corrections and improvements were made in the latest version of MEGAN2.1 (Guenther et al, 2012; Jiang et al, 2011) compared to previous versions (Guenther, 2006a, 2006b, and 2007; Guenther et al, 2006). The most important change is that higher temporal and spatial resolution of land use and land cover data for MEGAN input has become available. MEGAN, with the vegetation data released in 2011, was applied to compute biogenic emissions in Maricopa County and the eight-hour ozone nonattainment area. Estimated emissions for volatile organic compounds (VOC), carbon monoxide (CO), and nitrogen oxides (NO_x) are included in this biogenic emissions inventory. The MEGAN runs were executed by the Maricopa Association of Governments. The contact person for the MEGAN emission estimates is Feng Liu (602-254-6300).

6.2 Modeling domain

As a numerical model, the MEGAN inputs and outputs are given in user-defined two-dimensional grid cells. To develop biogenic emissions for the 2011 Periodic Emissions Inventory for ozone precursors, the 4-km modeling domain that covers the entire area of Maricopa County were employed. The target area is the eight-hour ozone nonattainment area within the County. The definition of the domain in the Lambert Conformal Conic Projection (LCP) coordinate system is presented in Table 6.2–1. Since MEGAN estimates biogenic emissions for the entire modeling domain rather than specific areas, additional input files, masking areas covered by the eight-hour ozone nonattainment area and Maricopa County, were developed by applying Geographic Information Systems (GIS) to calculate emissions for those two target areas. In order to represent the target area, the masking file assigns 1.0 for the grid cells fully covered by the target area, a fractional value for grid cells partially covered by the target area, and 0.0 for grid cells outside the target area. As shown in Figure 6.3–1, biogenic emissions for the eight-hour ozone nonattainment area and Maricopa County were extracted from MEGAN runs for the masked grid cells in the 4-km modeling domain.

Table 6.2–1. Two modeling domains defined in the LCP coordinate system.

Grid Horizontal Resolution	Grid Size	LCP Range (km)	Target Area
4-km	65 by 65	(–131.4713, –129.4593) to (127.9845, 131.1945)	Eight-hour ozone NAA and Maricopa County

6.3 Input data

To calculate biogenic emissions using MEGAN, the following gridded input files for land cover and meteorological data were prepared:

1. EFMAP_LAI file: This file provides emission factors (EF) for 20 MEGAN species including NO_x, CO and VOC, and 8-day average leaf index (LAI) for year 2011in each grid cell.
2. PFTF file: This input file gives percentage of four plant function types (PFT) including broadleaf trees (BT), needle leaf trees (NT), grass and crops (HB) and shrubs (SB) for each model domain grid location.
3. METCRO2D file: This file contains meteorological parameters including temperature, short wave radiation, wind speed, humidity and soil moisture for each grid.

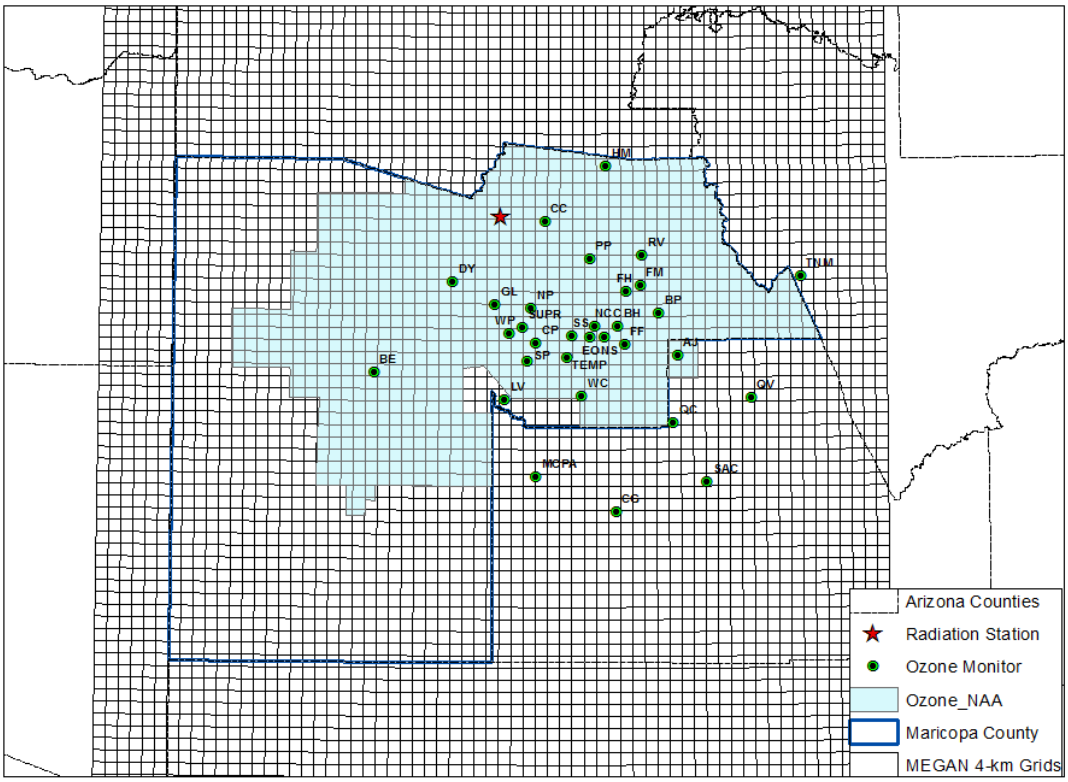

Figure 6.3–1. The masked grid cells in the 4-km modeling domain.

6.3.1 Land cover data

The land cover data, including the 8-day averaged LAI input files for North America for years 2003 to 2011 based on NASA MODIS data, monthly mean PFT, and EF, are provided by the EFMAP_LAI and PFTF files. These input data were derived from the MEGAN land cover database available at the resolution of 30 seconds latitude by 30 seconds longitude (1x1 km^2) in netCDF format (*http://acd.ucar.edu/~guenther/MEGAN/MEGAN.htm*).

6.3.2 Weather data

The weather data used by MEGAN are temperature, downward short wave radiation, wind speed, humidity and soil moisture. The Measurement and Instrumentation Data Center (MIDC) collects irradiance and meteorological data from nation-wide stations. One of those stations is located in northern Phoenix (33.83°N, 112.17°W, see red star in Figure 6.3–1) and is operated by the National Renewable Energy Laboratory (NREL). The archived hourly temperature, wind speed, humidity and radiation data from this site are available to the public. Monthly mean

diurnal cycles of the weather parameters were calculated based on hourly data for the year 2011, and a netCDF file representing 24-hour data for each month was prepared for MEGAN inputs. Biogenic emissions of VOC, NO_x, and CO are first governed by temperature and then highly dependent on downward short wave radiation. Figure 6.3–2 shows monthly mean (left panel) and annual mean diurnal cycle (right panel) of temperature. Figure 6.3–3 illustrates monthly averaged and annual mean diurnal cycle of short wave radiation. The maximum monthly temperature was recorded in August, while the highest radiation was observed in June. The maximum monthly temperature appeared two months later than the highest radiation. The peak hourly temperature was observed around 4:00 – 6:00 pm and lagged three hours behind the peak radiation. The delay is due to the fact that heating of the air occurs not from the sun's rays, but from heating of the earth and infrared radiation leaving the ground in the form of heat. As a result, maximum seasonal emission rates appear in the summer. The highest hourly emission rates take place in the afternoon because the emission rates are positively related to both temperature and short wave radiation (Guenther et al., 2006, 2012). The maximum monthly VOC, NO_x, and CO biogenic emission rates would be expected to occur in the same month as the maximum temperature.

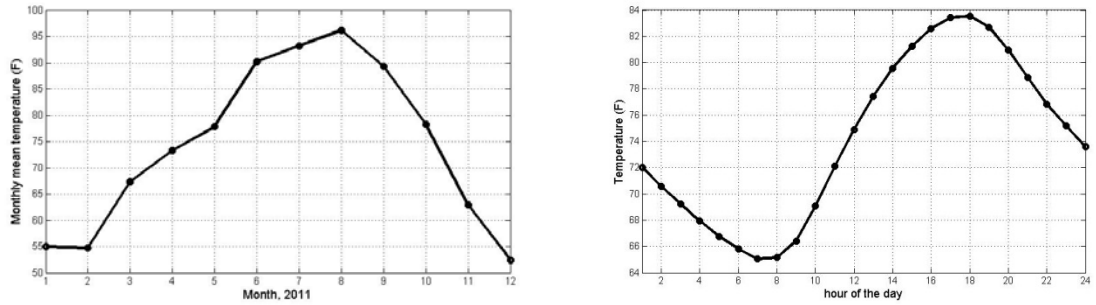

Figure 6.3–2. Monthly averaged temperature (left panel) and annual mean diurnal cycle of temperature (right panel) in 2011.

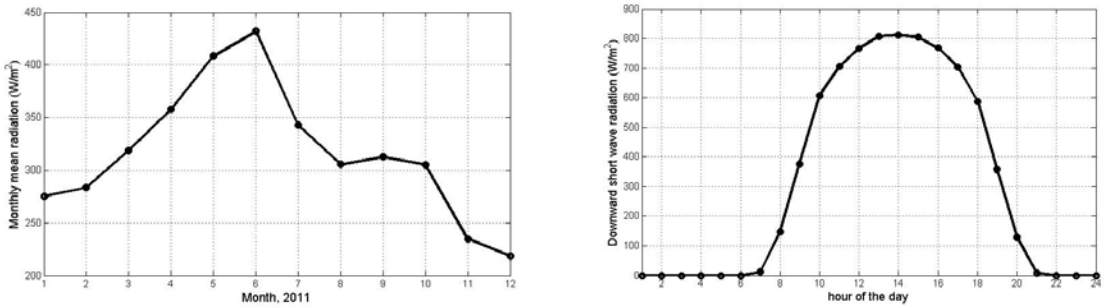

Figure 6.3–3. Monthly averaged radiation (left panel) and annual mean diurnal cycle of radiation (right panel) in 2011.

6.4 Emission estimation

MEGAN runs for the modeling domain provide hourly emission outputs for the year 2011. Figure 6.4–1 illustrates isoprene (ISOP), a major contributor to VOCs, and NO_x emission rates simulated by MEGAN at 17:00 MST in August, 2011. The high ISOP emissions occur in northeastern portion. The high NO_x emissions appear at the central part of Maricopa County and southeastern portion. Daily mean emissions for each month in 2011 are derived by using the hourly outputs for each month. In addition, monthly total emissions were obtained by multiplying the daily mean emissions for each month by the number of days in the month. The

daily mean emissions for the 12 months in 2011 are shown in Tables 6.4–1 and 6.4–2 for the eight-hour ozone nonattainment area and Maricopa County, respectively.

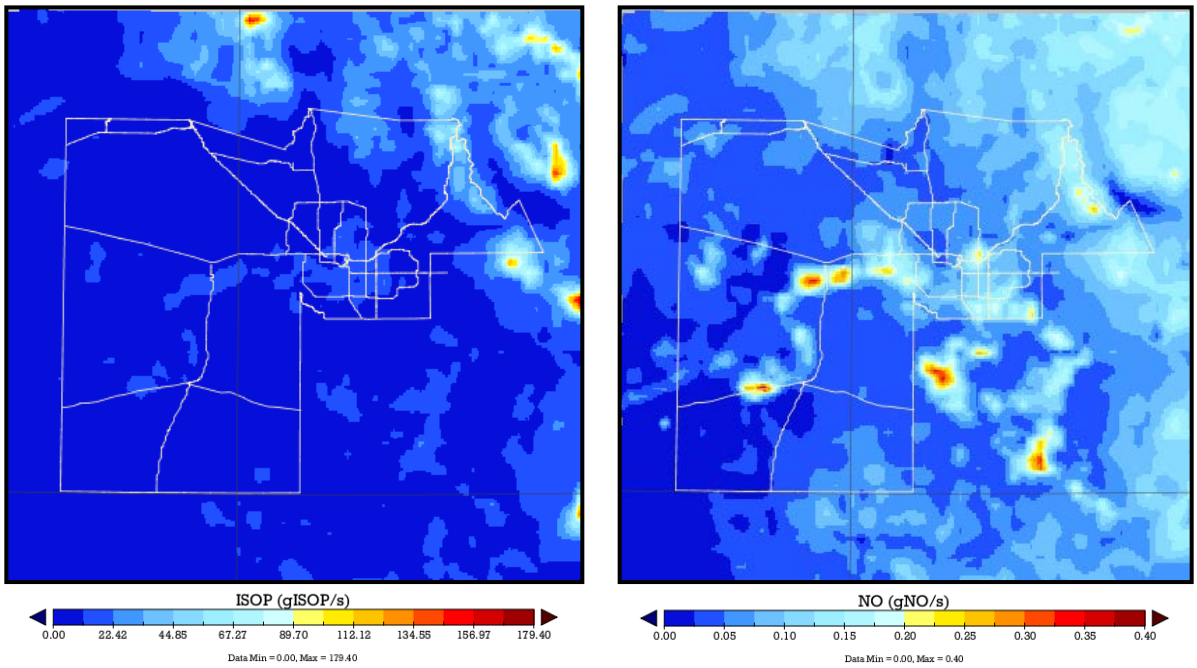

Figure 6.4–1. Estimated emission rates of ISOP (left panel) and NO_x (right panel) at 17:00 MST, August 2011 by MEGAN model.

Table 6.4–1. Daily mean biogenic emissions for each month in the eight-hour ozone NAA.

	VOC		NO_x		CO	
Month	**kg/day**	**lbs/day**	**kg/day**	**lbs/day**	**kg/day**	**lbs/day**
January	15,264.7	33,652.9	210.5	464.1	2,950.2	6,504.1
February	35,341.7	77,915.0	351.6	775.1	5,262.4	11,601.6
March	73,407.4	161,835.4	796.7	1,756.4	10,665.2	23,512.7
April	97,461.1	214,864.7	910.5	2,007.3	11,966.6	26,381.8
May	139,906.1	308,439.8	1,113.0	2,453.7	14,937.6	32,931.7
June	313,026.5	690,104.5	2,308.4	5,089.1	27,998.8	61,726.7
July	314,669.0	693,725.6	2,855.0	6,294.2	29,982.6	66,100.2
August	326,736.8	720,330.5	3,415.3	7,529.4	32,557.0	71,775.8
September	208,257.6	459,128.9	2,209.6	4,871.3	22,623.7	49,876.7
October	86,989.6	191,779.0	994.4	2,192.3	11,389.6	25,109.7
November	20,395.5	44,964.3	309.9	683.2	3,687.5	8,129.5
December	11,230.4	24,758.8	171.8	378.8	2,295.1	5,059.8

Table 6.4–2. Daily mean biogenic emissions for each month in Maricopa County.

	VOC		NO_x		CO	
Month	**kg/day**	**lbs/day**	**kg/day**	**lbs/day**	**kg/day**	**lbs/day**
January	23,123.3	50,978.1	316.3	697.3	5,654.4	12,465.8
February	53,015.2	116,878.4	524.0	1,155.2	9,971.5	21,983.4
March	104,165.5	229,645.3	1,152.6	2,541.0	19,383.1	42,732.4
April	139,181.0	306,841.2	1,330.8	2,933.9	22,591.4	49,805.5
May	200,913.3	442,937.5	1,641.2	3,618.2	28,869.2	63,645.6
June	451,990.3	996,466.9	3,432.5	7,567.4	55,292.2	121,898.3
July	451,204.3	994,734.0	4,207.9	9,276.8	58,566.5	129,116.9
August	467,398.8	1,030,436.7	5,031.7	11,093.0	63,445.8	139,873.9
September	300,464.1	662,409.2	3,278.2	7,227.2	44,256.1	97,567.9
October	129,711.0	285,963.5	1,506.4	3,321.0	23,713.3	52,278.8
November	30,063.3	66,278.2	462.5	1,019.6	7,101.2	15,655.4
December	16,413.2	36,184.9	252.8	557.3	4,255.2	9,381.1

Monthly mean emissions for Maricopa County and the eight-hour ozone nonattainment area are illustrated in Figure 6.4–2. Monthly emission values for the eight-hour ozone nonattainment area and Maricopa County are presented in Tables 6.4–3 and 6.4–4, respectively. It can be seen that the maximum monthly VOC, NO_x, and CO emissions took place in August, because monthly mean temperatures reached the maximum levels in this month.

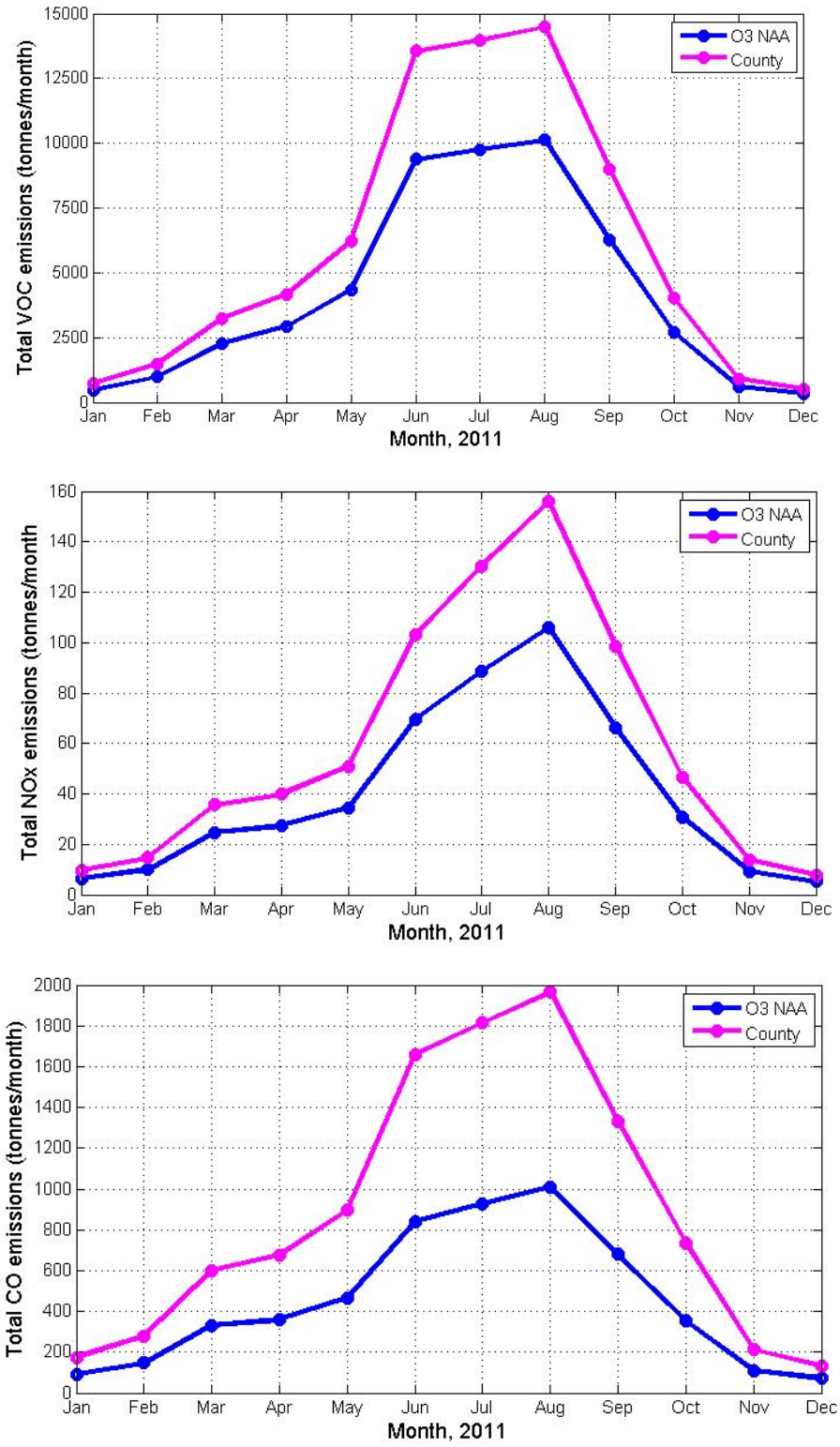

Figure 6.4–2. Monthly emissions of VOC (top), NO_x (middle) and CO (bottom) in Maricopa County (pink solid line, abbreviated as "County") and the eight-hour ozone NAA (blue solid line, abbreviated as "O3 NAA").

Table 6.4–3. Monthly biogenic emissions in the eight-hour ozone NAA.

	VOC		NO_x		CO	
Month	**Metric tons**	**Short tons**	**Metric tons**	**Short tons**	**Metric tons**	**Short tons**
January	473.21	521.62	6.53	7.19	91.46	100.81
February	989.57	1,090.81	9.84	10.85	147.35	162.42
March	2,275.63	2,508.45	24.70	27.22	330.62	364.45
April	2,923.83	3,222.97	27.32	30.11	359.00	395.73
May	4,337.09	4,780.82	34.50	38.03	463.07	510.44
June	9,390.80	10,351.57	69.25	76.34	839.96	925.90
July	9,754.74	10,752.75	88.51	97.56	929.46	1,024.55
August	10,128.84	11,165.12	105.87	116.71	1,009.27	1,112.53
September	6,247.73	6,886.93	66.29	73.07	678.71	748.15
October	2,696.68	2,972.57	30.83	33.98	353.08	389.20
November	611.87	674.46	9.30	10.25	110.63	121.94
December	348.14	383.76	5.33	5.87	71.15	78.43

Table 6.4–4. Monthly biogenic emissions in Maricopa County.

	VOC		NO_x		CO	
Month	**Metric tons**	**Short tons**	**Metric tons**	**Short tons**	**Metric tons**	**Short tons**
January	716.82	790.16	9.81	10.81	175.29	193.22
February	1,484.43	1,636.30	14.67	16.17	279.20	307.77
March	3,229.13	3,559.50	35.73	39.39	600.88	662.35
April	4,175.43	4,602.62	39.92	44.01	677.74	747.08
May	6,228.31	6,865.53	50.88	56.08	894.95	986.51
June	13,559.71	14,947.00	102.98	113.51	1,658.77	1,828.47
July	13,987.33	15,418.38	130.44	143.79	1,815.56	2,001.31
August	14,489.36	15,971.77	155.98	171.94	1,966.82	2,168.05
September	9,013.92	9,936.14	98.35	108.41	1,327.68	1,463.52
October	4,021.04	4,432.43	46.70	51.48	735.11	810.32
November	901.90	994.17	13.88	15.29	213.04	234.83
December	508.81	560.87	7.84	8.64	131.91	145.41

6.5 Summary of biogenic source emissions

Ozone season daily emissions for Maricopa County and the eight-hour ozone nonattainment area in 2011 are shown in Table 6.5–1. Annual emissions for Maricopa County and the eight-hour ozone nonattainment area in 2011 are summarized in Table 6.5–2. Emissions of VOC, NO_x, and CO all decreased in 2011 compared to MEGAN results for PEI 2008. Due to the incorporation of land cover data that are more characteristic of plants located in the desert southwest, as well as improvements to the MEGAN model, the 2011 data shown in Tables 6.5–1 and 6.5–2 represent a substantial improvement over previous biogenic emission estimates for Maricopa County and the eight-hour ozone NAA.

Table 6.5–1. Season-day biogenic emissions.

	VOC		NO_x		CO	
Area	**kg/day**	**lbs/day**	**kg/day**	**lbs/day**	**kg/day**	**lbs/day**
Maricopa County	406,355.7	895,860.0	4,172.6	9,199.0	55,422.8	122,186.2
8-hr ozone NAA	283,221.1	624,395.0	2,826.6	6,231.7	28,387.8	62,584.2

Table 6.5–2. Annual biogenic emissions.

	VOC		NO_x		CO	
Area	**tonnes*/yr**	**tons*/yr**	**tonnes/yr**	**tons/yr**	**tonnes/yr**	**tons/yr**
Maricopa County	72,316.20	79,714.87	707.17	779.52	10,476.94	11,548.84
8-hr ozone NAA	50,178.11	55,311.84	478.25	527.18	5,383.74	5,934.55

* "Tonne" denotes metric ton, and "ton" denotes short (or English) ton

6.6 References

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