Community Green House Gas Emissions Based on Vehicle Miles Traveled Estimates of the 2010 Base Year Model

Technical Report

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Catalyst for Regional Progress

pvpc

PREPARED UNDER THE DIRECTION OF THE PIONEER VALLEY MPO BY: PIONEER VALLEY PLANNING COMMISSION

Prepared in cooperation with the Massachusetts Department of Transportation and the U.S. Department of Transportation. The views and opinions of the Pioneer Valley Planning Commission expressed herein do not necessarily state or reflect those of the Massachusetts Department of Transportation or the U.S. Department of Transportation.

This report calculates the Green House Gas Emissions based on the estimated Vehicles Miles Traveled as modeled by the regional Travel Demand model for each of the 43 communities in the Pioneer Valley. This task was identified as part of the 2021 Unified Planning Work Program.

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Table of Contents

Table of Figures

List of Tables

A. Introduction

The Regional Travel Demand Model provides estimates of traffic flows along major roadways within the Pioneer Valley. This estimate is used to calculate Vehicle Miles Traveled (VMT). The Pioneer Valley Planning Commission (PVPC) often receives requests from its member communities for VMT values based on the most recent model year scenario. During the review period of the 2020 update of the Regional Transportation Plan (RTP), PVPC received a recommendation to calculate GHG emissions based on Total VMT for each of the member communities within the Pioneer Valley Region. Subsequently, PVPC agreed to include this recommendation as a task in the FFY2021 Unified Planning Work Program (UPWP). This technical memo explains the methodology and assumptions made in the process of calculating community-level GHG emissions based on VMT estimates. The final document of the 2020 update to the Regional Transportation Plan for the Pioneer Valley Metropolitan Planning Organization (RTP) can be viewed at this link: http://www.pvpc.org/content/2020-regional-transportation-plan-rtp

B. Vehicle Miles Traveled

The average daily traffic (ADT) volume estimates were obtained from the base year 2010 of the Pioneer Valley's regional travel demand model (Figure 1). This traffic volume estimate for each modeled link was multiplied by the length of that link to calculate the number of Vehicle Miles Traveled (VMT) for that particular roadway link. The sum of VMT across all links in a community provided the total VMT for that community.

C. Green House Gas Emissions

This report uses the average weekday vehicle miles traveled along major roadways included in the 2010 base-year of the regional transportation model for this analysis. The regional model is a macro-level simulation of traffic volumes that does not include local roads. Therefore, several broad sweeping assumptions were made while calculating GHG emissions for a community based on the regional travel demand model output.

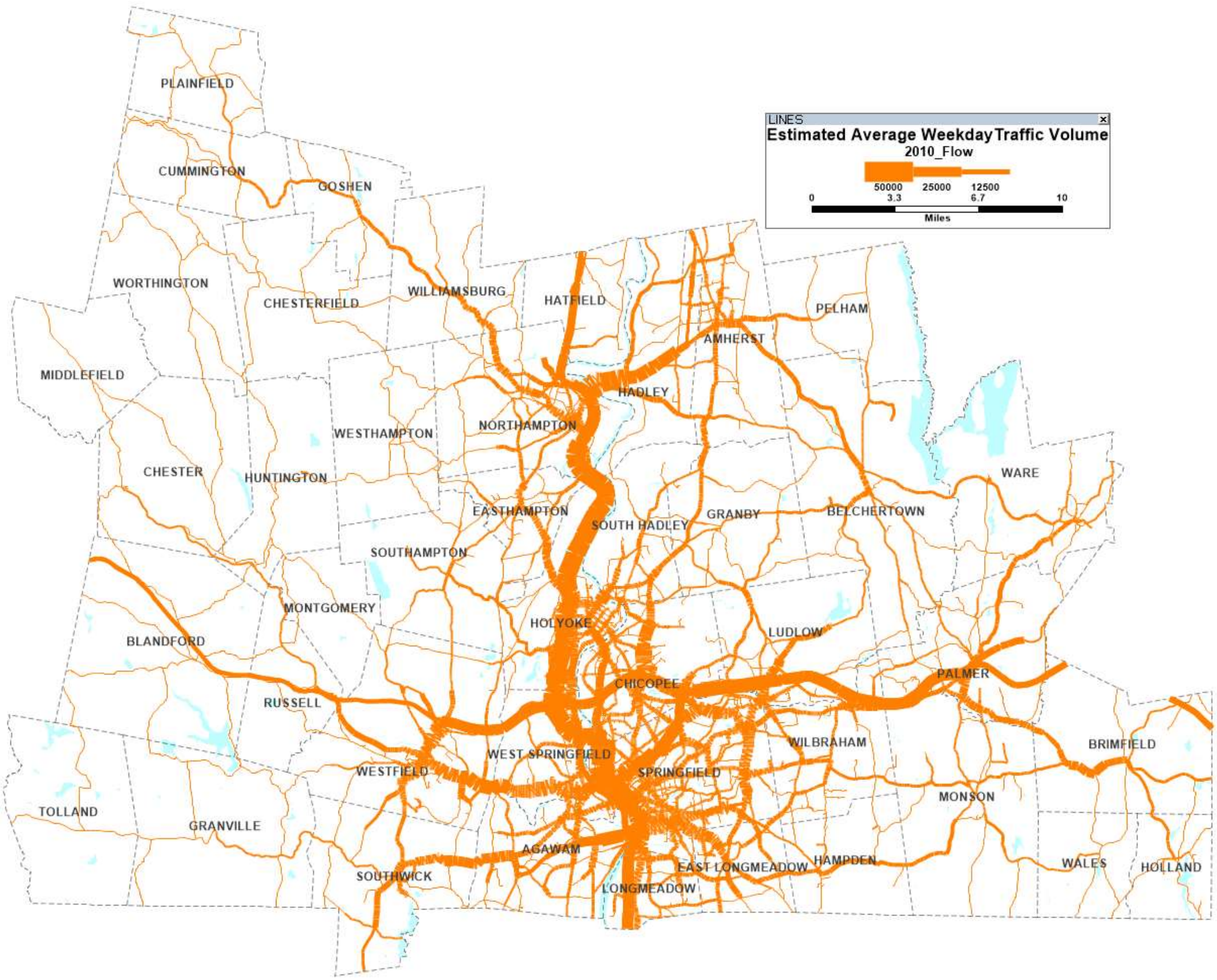
Assumptions:

1. Total Community VMT equals the sum of the VMT on all major roadway links in that community.
2. Vehicle travel speeds are based on the actual posted speed limit for the link.
3. The emission factors applied in this report were derived from the CMAQ analysis spreadsheets provided by the Massachusetts Department of Transportation (MassDOT) for analyzing GHG emissions in Western Massachusetts
4. GHG emissions factors used are based on the July summer weekday factors in grams per mile per pollutant type for moving commuter vehicles. These factors vary by vehicle speed and are based on software runs of MOVES2014a conducted in 2015 for Middlesex County (MA) for an Urban Unrestricted Roadway.
5. The vehicle mix in the Pioneer Valley is consistent with the assumptions used to develop

MassDOT's GHG emissions factors.

6. Emission factors used were for 25 mph to 65 mph speeds per 1 Mile stretch of a roadway assuming zero grade, and each vehicle fuel source is Gasoline.

Figure 1 – 2010 Estimated Average Weekday Traffic Volume.



The estimated vehicle GHG emissions on major roadways within a community were added together to calculate the total GHG emissions for a community. Emission factors of 7 pollutants by gasoline vehicles moving at the posted mph speed were multiplied by the VMT 2010 model estimate for each major roadway link to calculate the level of pollutants. The resulting values in grams were then converted to kilograms for an average weekday (Table 1). The Average Weekday GHG emissions were next multiplied by 250 as the number of commuter days in a year. This resulting values represent the Average Annual Weekday Emissions shown in Table 2. The following section explains in detail various air pollutants from transportation sources and their impact on environment and health.

Table 1 – Average Daily Weekday Emissions by Community in Kilograms

Town	CO	NOx	SO2	VOC	CO2	PM10	PM2.5
Agawam	1,645	295	2	40	336,858	10	9
Amherst	943	169	1	24	193,283	6	5
Belchertown	834	150	1	21	171,551	5	5
Blandford	517	88	1	10	95,693	3	2
Brimfield	729	128	1	17	143,902	4	4
Chester	84	15	0	2	17,443	1	0
Chesterfield	89	16	0	2	18,098	1	0
Chicopee	3,144	563	5	73	633,381	18	17
Cummington	140	26	0	3	29,102	1	1
East Longmeadow	778	138	1	20	158,867	5	4
Easthampton	626	110	1	15	125,458	4	3
Goshen	131	24	0	3	27,427	1	1
Granby	454	81	1	12	92,673	3	2
Granville	126	22	0	3	25,716	1	1
Hadley	1,040	186	2	26	213,172	6	6
Hampden	255	45	0	7	52,187	2	1
Hatfield	429	73	1	8	80,081	2	2
Holland	93	17	0	2	19,007	1	1
Holyoke	3,614	627	5	76	693,441	19	18
Huntington	107	19	0	3	21,984	1	1
Longmeadow	1,029	184	2	24	208,568	6	5
Ludlow	1,694	293	2	36	325,591	9	8
Middlefield	14	2	0	0	2,769	0	0
Monson	500	89	1	13	102,149	3	3
Montgomery	32	6	0	1	6,352	0	0
Northampton	2,347	413	3	54	463,651	13	12
Palmer	1,843	320	3	41	357,958	10	9
Pelham	155	28	0	4	31,724	1	1
Plainfield	64	11	0	2	12,977	0	0
Russell	350	61	0	7	67,389	2	2
South Hadley	524	94	1	13	107,456	3	3
Southampton	299	53	0	8	61,171	2	2
Southwick	628	112	1	16	129,019	4	3
Springfield	6,244	1,131	9	154	1,287,470	38	35
Tolland	46	8	0	1	9,299	0	0
Wales	72	13	0	2	14,782	0	0
Ware	390	70	1	10	80,432	2	2
West Springfield	2,868	505	4	64	566,397	16	15
Westfield	2,203	393	3	53	444,972	13	12
Westhampton	101	18	0	3	20,698	1	1
Wilbraham	908	160	1	22	182,329	5	5
Williamsburg	257	47	0	6	53,380	2	1
Worthington	40	7	0	1	8,160	0	0
Pioneer Valley	38,386	6,811	56	900	7,694,019	223	203

Table 2 – Average Annual Weekday Emissions by Community in Kilograms

Town	CO	NOx	SO2	VOC	CO2	PM10	PM2.5
Agawam	411,209	73,863	618	10,044	84,214,585	2,441	2,225
Amherst	235,805	42,141	355	5,931	48,320,648	1,415	1,291
Belchertown	208,493	37,460	315	5,187	42,887,751	1,253	1,142
Blandford	129,303	21,937	175	2,481	23,923,316	641	584
Brimfield	182,239	31,999	264	4,128	35,975,488	1,019	928
Chester	20,956	3,832	32	501	4,360,817	126	115
Chesterfield	22,150	3,936	33	565	4,524,403	133	121
Chicopee	785,934	140,631	1,162	18,239	158,345,331	4,619	4,210
Cummington	35,014	6,391	53	839	7,275,595	210	191
East Longmeadow	194,397	34,553	292	4,961	39,716,825	1,169	1,067
Easthampton	156,597	27,581	230	3,780	31,364,589	906	826
Goshen	32,828	6,040	50	771	6,856,659	197	179
Granby	113,424	20,156	170	2,894	23,168,204	682	622
Granville	31,474	5,593	47	803	6,428,959	189	173
Hadley	259,897	46,579	391	6,444	53,293,013	1,551	1,415
Hampden	63,872	11,350	96	1,630	13,046,666	384	350
Hatfield	107,292	18,279	146	2,113	20,020,225	542	493
Holland	23,262	4,134	35	593	4,751,629	140	128
Holyoke	903,529	156,753	1,270	18,946	173,360,338	4,864	4,429
Huntington	26,688	4,804	40	661	5,496,063	160	146
Longmeadow	257,340	46,064	382	6,032	52,142,022	1,483	1,353
Ludlow	423,610	73,166	596	9,112	81,397,828	2,270	2,068
Middlefield	3,389	602	5	86	692,329	20	19
Monson	125,023	22,217	188	3,190	25,537,351	751	685
Montgomery	7,930	1,396	12	192	1,588,093	46	42
Northampton	586,792	103,230	851	13,450	115,912,819	3,368	3,069
Palmer	460,758	80,041	656	10,177	89,489,451	2,518	2,295
Pelham	38,814	6,901	58	989	7,931,097	233	213
Plainfield	15,883	2,822	24	405	3,244,250	95	87
Russell	87,387	15,251	123	1,786	16,847,216	462	421
South Hadley	131,017	23,400	197	3,323	26,864,103	791	722
Southampton	74,869	13,304	112	1,910	15,292,826	450	410
Southwick	156,984	28,121	237	3,944	32,254,674	944	861
Springfield	1,561,102	282,760	2,364	38,580	321,867,469	9,621	8,773
Tolland	11,381	2,022	17	290	2,324,768	68	62
Wales	18,092	3,215	27	462	3,695,453	109	99
Ware	97,618	17,561	148	2,432	20,107,875	588	536
West Springfield	716,883	126,368	1,038	16,042	141,599,161	4,032	3,674
Westfield	550,736	98,252	817	13,227	111,243,028	3,300	3,008
Westhampton	25,332	4,502	38	646	5,174,517	152	139
Wilbraham	226,918	40,113	334	5,445	45,582,307	1,315	1,199
Williamsburg	64,215	11,716	98	1,542	13,345,089	386	351
Worthington	9,987	1,775	15	255	2,040,031	60	55
Pioneer Valley	9,596,425	1,702,808	14,113	225,029	1,923,504,861	55,705	50,775

The CO2 burden per registered vehicle varied between communities within the Pioneer Valley (Table 3). The highest rate of CO2 emissions per registered vehicle was in the Town of Blandford. This attributed to the added emissions from vehicular traffic along I-90 that runs through this community.

Table 3 – Average Annual Weekday CO2 Emissions per Registerd Vehicle in a Community

Town	CO2 (Kilograms / Year)	Registered Vehicles 2015	CO2 Burden per Registered Vehicle (Kilograms/Vehicle)
Agawam	84,214,585	27,220	3,094
Amherst	48,320,648	14,478	3,338
Belchertown	42,887,751	14,925	2,874
Blandford	23,923,316	1,388	17,236
Brimfield	35,975,488	4,094	8,787
Chester	4,360,817	1,429	3,052
Chesterfield	4,524,403	1,391	3,253
Chicopee	158,345,331	44,789	3,535
Cummington	7,275,595	988	7,364
East Longmeadow	39,716,825	15,199	2,613
Easthampton	31,364,589	14,941	2,099
Goshen	6,856,659	1,187	5,776
Granby	23,168,204	6,700	3,458
Granville	6,428,959	1,896	3,391
Hadley	53,293,013	5,347	9,967
Hampden	13,046,666	5,683	2,296
Hatfield	20,020,225	4,111	4,870
Holland	4,751,629	2,719	1,748
Holyoke	173,360,338	24,275	7,142
Huntington	5,496,063	2,299	2,391
Longmeadow	52,142,022	13,481	3,868
Ludlow	81,397,828	19,700	4,132
Middlefield	692,329	541	1,280
Monson	25,537,351	9,154	2,790
Montgomery	1,588,093	1,029	1,543
Northampton	115,912,819	21,848	5,305
Palmer	89,489,451	12,347	7,248
Pelham	7,931,097	1,266	6,265
Plainfield	3,244,250	748	4,337
Russell	16,847,216	1,770	9,518
South Hadley	26,864,103	14,784	1,817
Southampton	15,292,826	6,782	2,255
Southwick	32,254,674	10,207	3,160
Springfield	321,867,469	90,493	3,557
Tolland	2,324,768	610	3,811
Wales	3,695,453	1,961	1,884
Ware	20,107,875	8,906	2,258
West Springfield	141,599,161	24,325	5,821
Westfield	111,243,028	34,901	3,187
Westhampton	5,174,517	1,883	2,748
Wilbraham	45,582,307	14,156	3,220
Williamsburg	13,345,089	2,641	5,053
Worthington	2,040,031	1,407	1,450
Pioneer Valley	**1,923,504,861**	**489,999**	**3,926**

Another way to look at variations in emission impacts by community is to calculate the density of an emission (Table 4). Springfield experienced the highest CO2 emissions per acre due to high volume of traffic from several highways that run through this community such as I-91, I-291, Route 20 and Route 5.

Table 4 – Average Annual Weekday CO2 Emissions Density by Community

Town	CO2 (Kilograms/Year)	Total Area (Acres)	CO2 Density (Kilograms/Acre)
Agawam	84,214,585	15,593	5,401
Amherst	48,320,648	17,765	2,720
Belchertown	42,887,751	35,402	1,211
Blandford	23,923,316	34,228	699
Brimfield	35,975,488	22,564	1,594
Chester	4,360,817	23,769	183
Chesterfield	4,524,403	20,004	226
Chicopee	158,345,331	15,286	10,359
Cummington	7,275,595	14,764	493
East Longmeadow	39,716,825	8,311	4,779
Easthampton	31,364,589	8,707	3,602
Goshen	6,856,659	11,350	604
Granby	23,168,204	17,983	1,288
Granville	6,428,959	27,563	233
Hadley	53,293,013	15,791	3,375
Hampden	13,046,666	12,593	1,036
Hatfield	20,020,225	10,766	1,860
Holland	4,751,629	8,354	569
Holyoke	173,360,338	14,584	11,887
Huntington	5,496,063	17,159	320
Longmeadow	52,142,022	6,144	8,487
Ludlow	81,397,828	18,134	4,489
Middlefield	692,329	15,459	45
Monson	25,537,351	28,637	892
Montgomery	1,588,093	9,628	165
Northampton	115,912,819	22,848	5,073
Palmer	89,489,451	20,481	4,369
Pelham	7,931,097	16,961	468
Plainfield	3,244,250	13,623	238
Russell	16,847,216	11,457	1,470
South Hadley	26,864,103	11,816	2,273
Southampton	15,292,826	18,524	826
Southwick	32,254,674	20,236	1,594
Springfield	321,867,469	21,174	15,201
Tolland	2,324,768	20,985	111
Wales	3,695,453	10,227	361
Ware	20,107,875	25,577	786
West Springfield	141,599,161	11,197	12,646
Westfield	111,243,028	30,295	3,672
Westhampton	5,174,517	17,478	296
Wilbraham	45,582,307	14,244	3,200
Williamsburg	13,345,089	16,425	812
Worthington	2,040,031	20,560	99
Pioneer Valley	**1,923,504,861**	**754,646**	**2,549**

D. Air Pollutants from Transportation Emission Sources

Greenhouse gases trap heat and make the planet warmer. Human activities are responsible for almost all of the increase in greenhouse gases in the atmosphere over the last 150 years. The largest source of greenhouse gas emissions from human activities in the United States is from burning fossil fuels for electricity, heat, and transportation. In addition, several vehicular emission pollutants also impact health and environment. The following is a description of these pollutants identified by the Environmental Protection Agency for monitoring, Information provided in this section of the report was garnered from the EPA website: https://www.epa.gov/report-environment/outdoor-air-quality

Commonly Measured Pollutants and Green House Gases:

Pollutants common in outdoor air that can harm human health and the environment include carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter of different size fractions, and sulfur dioxide. These six air pollutants are referred to as “criteria pollutants” because EPA regulates them by developing human health-based or environmentally based criteria for setting permissible levels. The Clean Air Act requires EPA to set National Ambient Air Quality Standards (NAAQS) for these pollutants. In addition to the list of Criteria Pollutants mentioned, two other pollutant precursors are of interest when estimating GHG emissions. These are Carbon Dioxide and Volatile Organic Compounds. Source:

List of Air Pollutants:

CO	Carbon Monoxide
NOx	Nitrogen Oxides
SO2	Sulphur Dioxide
VOC	Volatile Organic Compounds
CO2	Carbon Dioxide
PM 10	Particulate Matter Size ≤ 10 Micrometers
PM 2.5	Particulate Matter Size ≤ 2.5 Micrometers

Exposure to Outdoor Air Pollution

Human exposure to outdoor air pollution is a function of the composition and magnitude of air pollution, combined with human activity patterns. Whether people are harmed by poor air quality depends on the level and mixture of pollutants in the air, exposure doses and durations, individuals' susceptibilities to diseases, and other factors. Similarly, air pollutants' interactions with ecosystems determine whether air pollution causes harmful environmental effects.

For a complete understanding of a given air pollution issue, information is typically sought on emissions sources, ambient air concentrations, exposures, and effects on exposed populations. The question on Diseases and Conditions in Human Exposure and Health presents several indicators of diseases and conditions for which outdoor air is a risk factor, including Cancer, Asthma, Cardiovascular Disease, and Chronic Obstructive Pulmonary Disease. However, since there are many other risk factors for these diseases, the contribution of outdoor air to these trends cannot be determined. The following is a description of transportation related emission pollutants and their environment and health impacts:

Carbon Monoxide CO: CO is a colorless, odorless gas that can be harmful when inhaled in large amounts. CO is released when something is burned. The greatest sources of CO to outdoor air are cars, trucks and other vehicles or machinery that burn fossil fuels. Breathing air with a high concentration of CO reduces the amount of oxygen that can be transported in the blood stream to critical organs like the heart and brain. Very high levels of CO are not likely to occur outdoors. However, when CO levels are elevated outdoors, they can be of particular concern for people with some types of heart disease. These people already have a reduced ability for getting oxygenated blood to their hearts in situations where the heart needs more oxygen than usual. They are especially vulnerable to the effects of CO when exercising or under increased stress. In these situations, short-term exposure to elevated CO may result in reduced oxygen to the heart accompanied by chest pain also known as angina. https://www.epa.gov/co-pollution/basic-information-about-carbon-monoxide-co-outdoor-air-pollution#What%20is%20CO

Nitrogen Oxides NOx: NO2 is of greater concern. Nitrogen Dioxide (NO2) is one of a group of highly reactive gases known as oxides of nitrogen or nitrogen oxides (NOx). Other nitrogen oxides include nitrous acid and nitric acid. NO2 is used as the indicator for the larger group of nitrogen oxides. All of these gases are harmful to human health and the environment. NO2 primarily gets in the air from the burning of fuel. NO2 forms from emissions from cars, trucks and buses, power plants, and off-road equipment. NO2 along with other NOx reacts with other chemicals in the air to form both particulate matter and ozone. Both of these are also harmful when inhaled due to effects on the respiratory system.

Health effects: Breathing air with a high concentration of NO2 can irritate airways in the human respiratory system. Such exposures over short periods can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions and visits to emergency rooms. Longer exposures to elevated concentrations of NO2 may contribute to the development of asthma and potentially increase susceptibility to respiratory infections. People with asthma, as well as children and the elderly are generally at greater risk for the health effects of NO2.

Environmental effects: NO2 and other NOx interact with water, oxygen and other chemicals in the atmosphere to form acid rain. Acid rain harms sensitive ecosystems such as lakes and forests. The nitrate particles that result from NOx make the air hazy and difficult to see though. This affects the many national parks that we visit for the view. NOx in the atmosphere contributes to nutrient pollution in coastal waters. https://www.epa.gov/no2-pollution/basic-information-about-no2#What%20is%20NO2

Sulphur Dioxide SO2: Emissions that lead to high concentrations of SO2 generally also lead to the formation of other SOx. The largest sources of SO2 emissions are from fossil fuel combustion at power plants and other industrial facilities. Smaller sources of SO2 emissions include: industrial processes such as extracting metal from ore; natural sources such as volcanoes; and locomotives, ships and other vehicles and heavy equipment that burn fuel with a high sulfur content.

Health effects: Short-term exposures to SO2 can harm the human respiratory system and make breathing difficult. People with asthma, particularly children, are sensitive to these effects of SO2. SO2 emissions that lead to high concentrations of SO2 in the air generally also lead to the formation of other sulfur oxides (SOx). SOx can react with other compounds in the atmosphere to form small particles. These particles contribute to particulate matter (PM) pollution. Small particles may penetrate deeply into the lungs and in sufficient quantity can contribute to health problems.

Environment effects: At high concentrations, gaseous SOx can harm trees and plants by damaging foliage and decreasing growth. SO_2 and other sulfur oxides can contribute to acid rain which can harm sensitive ecosystems.

Visibility effects: SO2 and other sulfur oxides can react with other compounds in the atmosphere to form fine particles that reduce visibility (haze) in parts of the United States, including many of our treasured national parks and wilderness areas. Deposition of particles can also stain and damage stone and other materials, including culturally important objects such as statues and monuments.
https://www.epa.gov/so2-pollution/sulfur-dioxide-basics#what%20is%20so2

Volatile Organic Compounds VOC: Volatile organic compounds (VOCs) are a large group of organic chemicals that include any compound of carbon (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate). VOCs are of interest in part because they participate in atmospheric photochemical reactions that contribute to ozone formation. Ozone (the Ozone Concentrations indicator) is formed from chemical reactions involving airborne VOCs, airborne nitrogen oxides, and sunlight. VOCs are also of interest because they play a role in formation of secondary organic aerosols, which are found in airborne particulate matter (the Particulate Matter Concentrations indicator). Finally, VOCs are of interest because many individual VOCs are known to be harmful to human health (the Air Toxics Concentrations indicator; the Air Toxics Emissions indicator). Health effects vary by pollutant. VOCs are emitted from a variety of sources, including motor vehicles
https://cfpub.epa.gov/roe/indicator.cfm?i=23#2

Carbon Dioxide CO2: Carbon dioxide (CO2) is the primary greenhouse gas emitted through human activities. In 2018, CO2 accounted for about 81.3 percent of all U.S. greenhouse gas emissions from human activities. The main human activity that emits CO2 is the combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation. The combustion of fossil fuels such as gasoline and diesel to transport people and goods was the largest source of CO2 emissions in 2018, accounting for about 33.6 percent of total U.S. CO2 emissions and 27.3 percent of total U.S. greenhouse gas emissions. This category includes transportation sources such as highway and passenger vehicles, air travel, marine transportation, and rail. Carbon dioxide is removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle. https://www.epa.gov/ghgemissions/overview-greenhouse-gases

Particulate Matter (PM10, PM2.5): PM stands for particulate matter (also called particle pollution): the term for a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Others are so small they can only be detected using an electron microscope. Particle pollution are measured for two size categories. PM10 are inhalable particles, with diameters that are generally 10 micrometers and smaller. Whereas, PM2.5 are fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller.

Sources of PM: These particles come in many sizes and shapes and can be made up of hundreds of different chemicals. Some are emitted directly from a source, such as construction sites, unpaved roads, fields, smokestacks or fires. Most particles form in the atmosphere as a result of complex reactions of chemicals such as sulfur dioxide and nitrogen oxides, which are pollutants emitted from power plants, industries and automobiles.

Health effects: Particulate matter contains microscopic solids or liquid droplets that are so small that they can be inhaled and cause serious health problems. Some particles less than 10 micrometers in diameter can get deep into your lungs and some may even get into your bloodstream. Of these, particles less than 2.5 micrometers in diameter, also known as fine particles or PM2.5, pose the greatest risk to health.

Visibility effects: Fine particles are also the main cause of reduced visibility (haze) in parts of the United States, including many of our treasured national parks and wilderness areas. https://www.epa.gov/pm-pollution/particulate-matter-pm-basics#PM