Analysis of Multi-Pollutant Emissions Inventories for Key Industrial Sectors

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ABSTRACT

The National Emissions Inventory (NEI) is a central data repository of the U.S. Environmental Protection Agency (EPA) for air pollutant emissions data. The NEI includes data for criteria air pollutants (CAPs), CAP precursors, and hazardous air pollutants (HAPs). State, local, and Tribal governments provide most of the data in the NEI. The EPA also routinely develops greenhouse gas (GHG) inventories that estimate carbon dioxide (CO_2), methane (CH_4), nitrous oxides (N_2O), and fluorinated gases emissions from major source categories for the nation. This GHG inventory adheres to both (1) a comprehensive and detailed set of methodologies for estimating sources and sinks of anthropogenic greenhouse gases, and (2) a common and consistent mechanism that enables Parties to the United Nations Framework Convention on Climate Change (UNFCCC) to compare the relative contribution of different emission sources and greenhouse gases to climate change. The EPA recently proposed a GHG Reporting Rule that will require mandatory reporting of GHG gases above an appropriate threshold by facilities in all sectors of the economy.

This paper presents facility-specific GHG inventories developed by EPA for key industries including electric generating units, petroleum refining, Portland cement, iron and steel, and lime manufacturing, and compares these inventories to CAP and HAP data in the NEI. Multi-pollutant maps are presented for these key stationary source emissions along with key geographical information such as current Particulate Matter and Ozone National Ambient Air Quality Standard non-attainment areas and key ecosystem regions such as Class I areas.

INTRODUCTION

In order to determine if Clean Air Act programs are successful in reducing emissions and protecting human health and environmental risk, EPA compiles the NEI. The NEI currently contains source information and emissions of CAPs and their precursors (CO, NH_3, NO_x, PM, SO_2, and VOCs) and HAPs. The EPA compiles a comprehensive NEI every three years and has recently completed version 2 of the 2005 NEI. The NEI data are revised as revisions are received over time and new versions of a base year inventory are released. The NEI contains stationary (point and nonpoint area), mobile (onroad and nonroad), and biogenic source emissions for the entire U.S.[1] Point source data are available for individual units and processes within facilities. Airports and wildfires/prescribed burning sources are inventoried as point sources in the 2005 NEI. Offshore platforms were added for the first time in the 2005 NEI point source inventory. Nonpoint sources and mobile source categories of onroad vehicles, nonroad equipment, commercial marine vessels, and locomotives are inventoried in the NEI at the county level.

Primary data sources for the point sources NEI include:

1. State, local, and tribal agency emission inventories;

2. EPA's sector and Risk Technology and Review (RTR) Programs[2];
3. Department of Energy's (DOE) Energy Information Agency (EIA) and EPA's Clean Air Markets Division (CAMD) Emission Tracking System/Continuous Emissions Monitoring (ETS/CEM) data for electric generating utilities (EGUs);
4. EPA's Toxic Release Inventory (TRI); and
5. Data from other studies (e.g., trade associations, Minerals Management Services oil and natural gas platform data).

It is important to note that although most of the data in the NEI is submitted by state, local, and tribal air agencies, it is by no means complete and may contain under- and over-reported emissions data.

The EPA also prepares an annual GHG inventory called the "Inventory of U.S. Greenhouse Gas Emissions and Sinks" that estimates CO_2, CH_4, N_2O and fluorinated gases emissions. The national GHG inventory adheres to both (1) a comprehensive and detailed set of methodologies for estimating sources and sinks of anthropogenic greenhouse gases, and (2) a common and consistent mechanism that enables Parties to the United Nations Framework Convention on Climate Change (UNFCCC) to compare the relative contribution of different emission sources and greenhouse gases to climate change. The EPA recently proposed a GHG Reporting Rule that will require mandatory reporting of GHG gases above an appropriate threshold by facilities in all sectors of the economy.[3] The proposed rule would apply to fossil fuel suppliers, industrial gas suppliers, and to direct GHG emitters.

The National Academy of Science's report, "Air Quality Management in the United States", recommends that the EPA strive to take an integrated multi-pollutant approach to controlling emissions of pollutants posing the most significant risks.[4] To implement this recommendation, EPA has initiated multi-pollutant analyses to explore the development of multi-pollutant sector-based approaches for managing emissions and air quality. An integrated multi-pollutant emissions inventory is integral to conducting integrated sector assessments.

This paper presents facility-specific GHG inventories developed by EPA for key industries including electric utilities, petroleum refining, Portland cement manufacturing, iron and steel production, and lime manufacturing, and compares these inventories to CAP and HAP data. CAP and HAP data are compiled from the 2005 NEI, and GHG data are compiled from CAMD for electric utilities and from the proposed GHG reporting rule for other source categories. All of the CAP and HAP data and most of the GHG data are compiled at the emissions unit level. In this analysis, HAP emissions are presented as mass emissions and as toxicity-weighted for cancer risk and non-cancer effects using accepted methodology.[5] While the absolute magnitude of the pollutant-specific toxicity-weighted emissions is not meaningful, the relevant magnitude of toxicity-weighted emissions is useful in identifying the order of potential priority or pollutants of interest. The Clean Air Act contains individual HAPs and groups of HAPs. The NEI contains individual pollutants within HAPs groups. The emissions of the individual HAPs rather than HAP groups are used in this analysis.

RESULTS FOR INDIVIDUAL SOURCE CATEGORIES

Results are presented for 5 source categories in this section. The available pollutant data for each sector vary by facility. GHG emissions only include specific process and direct energy operations at facilities. GHG emissions associated with indirect energy (purchased electricity) are not included. When comparing facility level emissions for GHG, CAPs, and HAPs, GHG-emitting units are a subset of total facility operations. Pollutants emitted from units within individual facilities are not always consistent across the inventories, e.g., the NEI may show 3 boilers for HAPs and 2 boilers for CAPs and the GHG inventory may only show 1 boiler. Therefore, this analysis only compares pollutant at the facility level. In order to develop multi-pollutant sector-based approaches in the future, fully integrated multi-pollutant inventories at the unit level are needed.

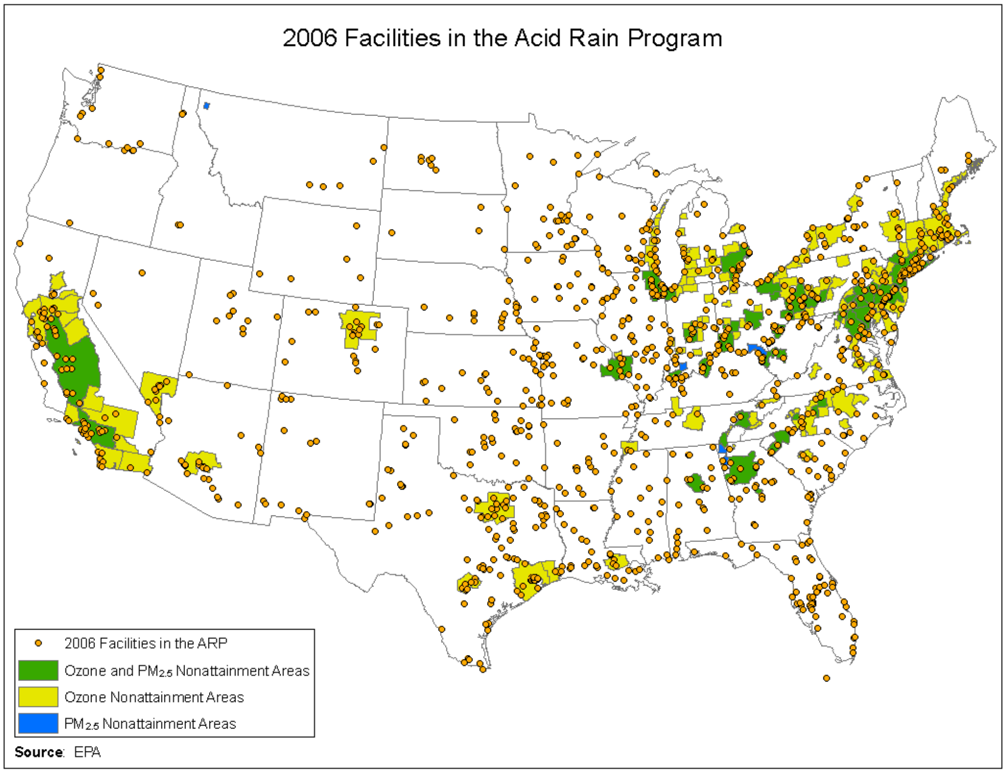
Electric Utilities

The source category with the greatest GHG, CAP and HAP emissions is electric utilities. The primary source of emissions at electric utilities is boilers. Electric utility GHG emission data are compiled from CAMD’s 2007 CAMD Acid Rain and 2004 EGRID databases. GHG, CAP, and HAP emissions data are available at the individual unit level within facilities. The CAMD Acid Rain database contains 1476 facilities, but not all facilities have GHG emissions. GHG emissions data are available for 1380 for the 1476 facilities. If 2007 Acid Rain data were not available, then 2004 EGRID GHG emissions data were used. Of the 1476 facilities, EGRID data were used for 154 facilities. Of the 1476 facilities, 105 facilities have processes in other major source categories, which may result in a potential of double-counting of emissions. Sectors for these facilities include the following.

- Aerospace – 2 facilities
- Biorefinery – 5 facilities
- Brewery – 1 facility
- Chemical Manufacturing – 27 facilities
- Iron and Steel Manufacturing – 10 facilities
- Iron Foundry – 1 facility
- Petroleum Refineries – 19 facilities
- Plywood Manufacturing – 2 facilities
- Portland Cement – 3 facilities
- Pulp and Paper Mills – 32 facilities
- Rubber Manufacture – 1 facility
- Textile – 1 facility
- Tire manufacture – 1 facility

Figure 1 depicts the locations of 1440 utilities in the dataset. Tables 1 and 2 present a summary of facility and emissions data for electric utilities. 1147 (80%) of the 1440 facilities have emissions of GHG, CAPs, and HAPs. 1194 (90%) of the 1328 facilities emitting CAPs have HAP emissions. Figures 2 – 5 present a correlation of GHG emissions to CAP and HAP emissions. High correlations exist between GHGs and HAPs and CAPs with the exception of VOC. NOx, SO_2, and GHG data are reported in the Acid Rain Program. Because utilities are the largest industrial emission source of GHGs, HAPs, NO_x, and SO_2, the absence of complete emissions data for 20% of facilities demonstrates the need for fully integrated multi-pollutant inventories.

Figure 1. Location of Acid Rain Electric Utility Facilities.



Source: EPA

Table 1. Electric Utility Facility Summary.

Parameter	Total	GHG	CAPs	HAPs
# Unique Facilities	1440	1380	1328	1194
# U.S. Counties	799	781	769	735
# Tribes	1	1	1	1
# U.S. States	49	49	49	48
# Facilities in Ozone Nonattainment areas (8 hr standard)	524	495	478	405
# Facilities in CO Nonattainment areas	10	10	9	5
# Facilities in $PM_{2.5}$ Nonattainment areas	365	340	332	302
2007 Acid Rain SO_2 Nonattainment areas	11	11	11	9
# HAPs (individual) reported	238			
HAPs with highest Cancer risk	arsenic, beryllium, cadmium, hexavalent chromium, nickel			
HAPs with highest Non-Cancer risk	acrolein, arsenic, HCl, HF, manganese nickel			
HAPs with highest emissions	acetaldehyde, hexane, HCl, HF, methanol			

Table 2. Electric Utility Emissions Summary.

Pollutant	Total (tpy)	Average Facility (tpy)	Facility Range (tpy)	Nonattainment Area Emissions (tpy)			
				Ozone	CO	SO_2	$PM_{2.5}$
GHG	2661336595	1928505	23-27231087	659127331	11896333	17755617	839535123
CO	924223	709	0.0001 - 69923	309179	2107	2839	288389
NH_3	27831	30	0.00000073 – 1624	8167	283	166	5390
NO_x	3887315	2970	0.00022-41743	820199	37096	19719	1226526
PM_{10}	687284	536	0.0000012 - 12143	188115	4262	12711	289407
$PM_{2.5}$	556963	434	0.0000012 - 9589	157008	3825	11442	242568
SO_2	10722071	8390	0.00000007 - 186470	2916877	43731	212311	5020729
VOC	127155	99	0.000007 - 11270	35380	277	108	33297
188 HAP	435666	365	0.000000006 - 8742	95265	4695	10528	151228

Figure 2. Correlation of GHG and HAP Electric Utility Facility Emissions.

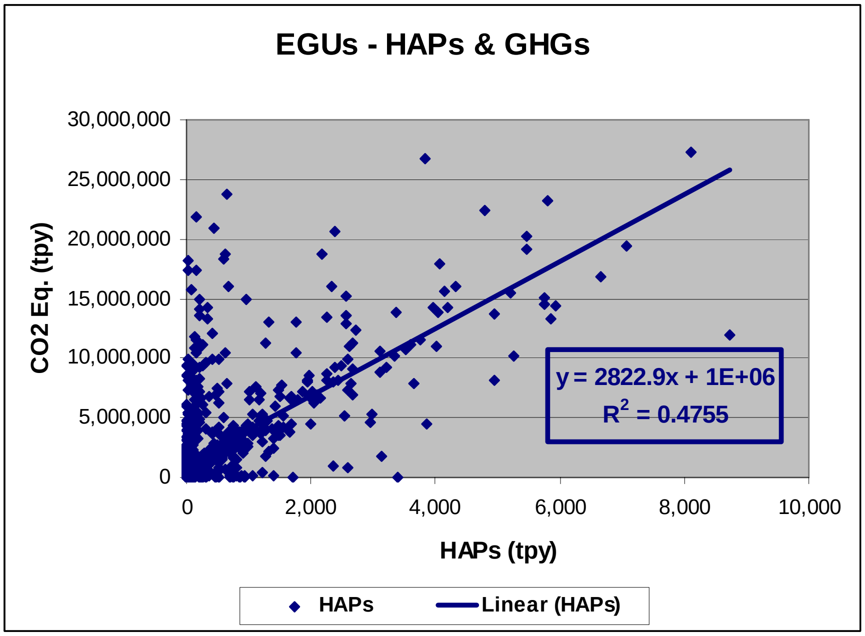


Figure 3. Correlation of GHG and SO_2 Electric Utility Facility Emissions.

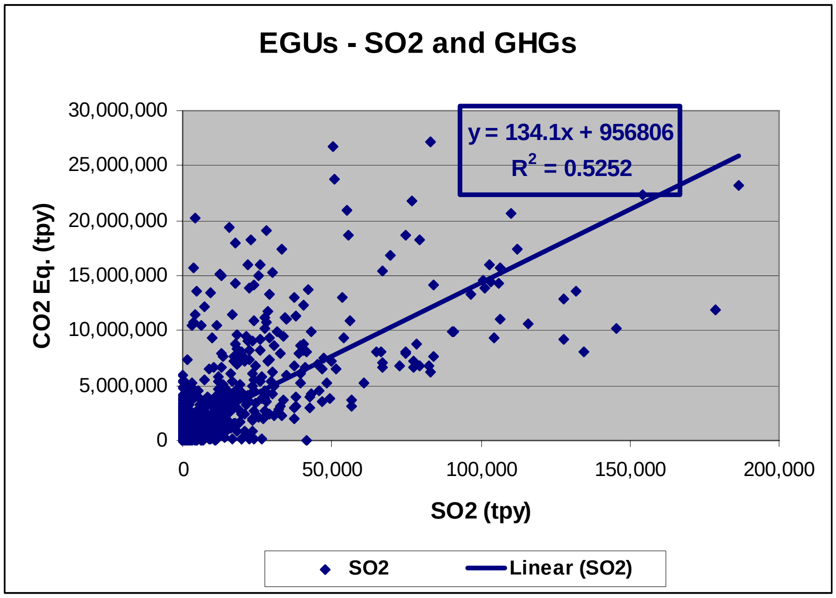


Figure 4. Correlation of GHG and NOx Electric Utility Facility Emissions.

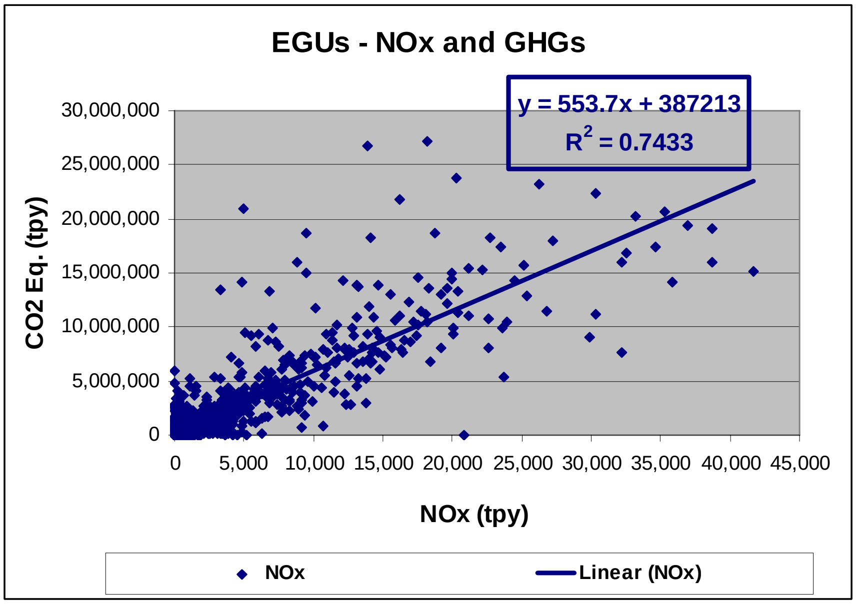
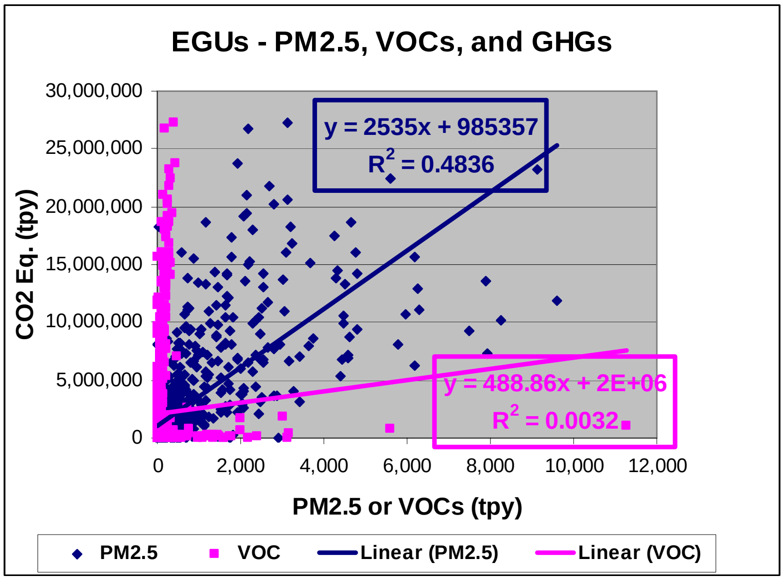


Figure 5. Correlation of GHG, $PM_{2.5}$ and VOC Electric Utility Facility Emissions.



Iron and Steel Industry

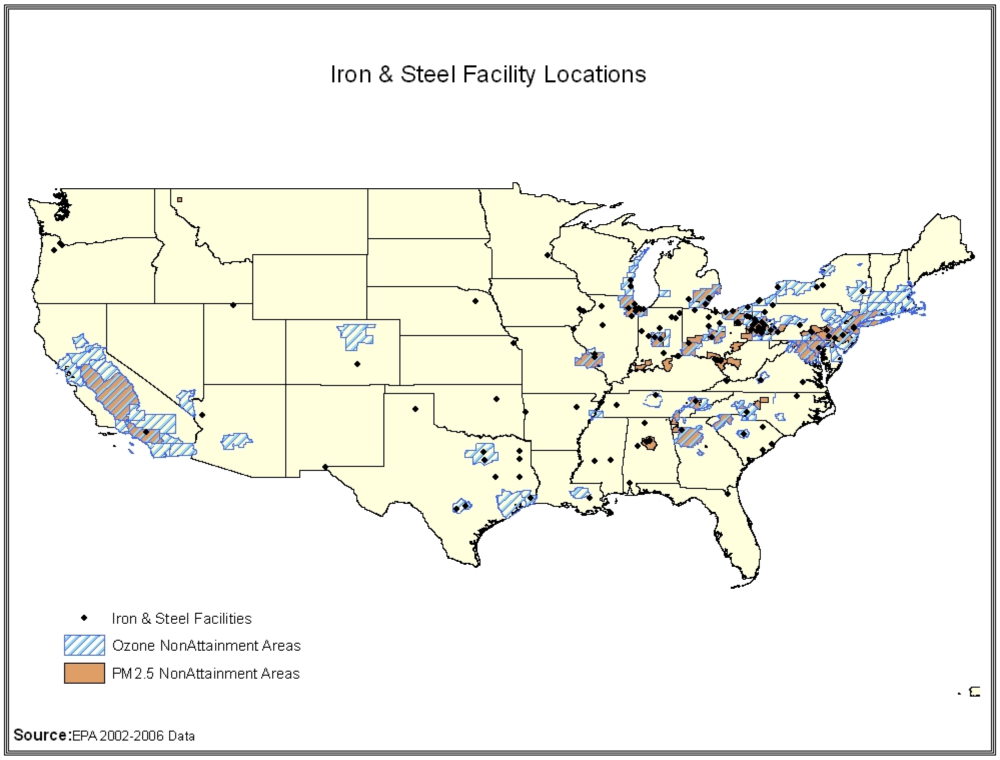
The iron and steel industry in the U.S., the third largest in the world, provides about 8 percent of the world's raw iron and steel production. The following types of facilities are included in this category.

- Integrated Iron and Steel facilities: make iron from iron ore and coke in a blast furnace (BF) and refine the molten iron (and some ferrous scrap) in a basic oxygen furnace (BOF) to make steel.
- Electric arc furnace (EAF) facilities: produce steel primarily from recycled ferrous scrap. Some EAFs are co-located at integrated iron and steel facilities.
- Taconite (iron ore) Processing facilities
- Coke-making facilities: produce coke in coke ovens for use in BFs; some of these facilities are co-located with integrated iron and steel facilities.
- Direct Reduced Iron-making (DRI) facilities – only one operating DRI plant that is located at an EAF steelmaking facility. [6]

Pollutants are emitted from both process and combustion units. 2005 GHG emissions for this category are compiled from the proposed GHG reporting. GHG, CAP and HAP emissions are available at the unit level. GHG pollutants include CO_2, N_2O, and CH_4 (CO_2 is emitted in the largest quantity). The major process units at iron and steel facilities where process units in combination with fuel combustion contribute to GHG emissions include: taconite indurating furnaces, nonrecovery coke oven battery combustion stacks, coke pushing, BOFs, EAFs, DRI furnaces, and sinter plants. The combustion units at iron and steel facilities where GHGs are formed solely from burning fuels include: byproduct recovery coke oven battery combustion stacks, BFs, boilers, process heaters, reheat furnaces, flame suppression systems, annealing furnaces, flares, ladle reheaters, and other miscellaneous combustion sources. [6]

Figure 6 shows the locations of 135 iron and steel facilities in the dataset. Table 3 lists the number of the types of facilities nationally.

Figure 6. Location of Iron and Steel Facilities.



Source: EPA 2002-2006 Data

Table 3. Integrated Iron and Steel Types of Facilities in the Dataset.

Type of Operations	**Number of Facilities**
Coke Oven	12
Coke Ovens and Integrated Iron and Steel	6
Integrated Iron and Steel	11
Integrated Iron and Steel and EAF	2
EAF	94
EAF and DRI	2
Taconite	8

Tables 4 and 5 present a summary of facility and emissions data for iron and steel mills. Process GHG emissions are estimated to be 55% of the total emissions, and combustion GHG emissions are estimated to be 45%. 112 (87 %) of the 135 facilities have emissions of GHG, CAPs, and HAPs. 119 (92%) of the 135 facilities emitting HAPs have CAP emissions. Tables 4 and 5 show that although one third of facilities are located in ozone nonattainment areas and less than one half of facilities are located in $PM_{2.5}$ nonattainment areas, more than 50% of GHG, CO, PM, SO_2 and VOC emissions are released by facilities in the nonattainment areas. This indicates a potential for using multi-pollutant sector-based approach to improve air quality in specific geographic areas. Figures 7 and 8 show that GHG emissions have good correlation with CAP emissions, but not with HAP emissions.

Table 4. Integrated Iron and Steel Facility Summary.

Parameter	Total	GHG	CAPs	HAPs
# Unique Facilities	135	128	119	135
# U.S. Counties	99	97	89	99
# Tribes	0	0	0	0
# U.S. States	32	32	30	32
# Facilities in Ozone Nonattainment areas (8 hr standard)	46	43	43	46
# Facilities in CO Nonattainment areas	0	0	0	0
# Facilities in $PM_{2.5}$ Nonattainment areas	61	56	53	61
2007 Acid Rain SO_2 Nonattainment areas	0	0	0	0
# HAPs individual reported	185			
HAPs with highest Cancer risk	arsenic, hexavalent chromium, coke oven emissions, nickel, POM			
HAPs with highest Non-Cancer effect	acrolein, arsenic, chlorine, manganese, nickel			
HAPs with highest emissions	benzene, coke oven emissions, chlorine, HCl, manganese			

Table 5. Integrated Iron and Steel Emissions Summary.

Pollutant	Total (tpy)	Average Facility (tpy)	Facility Range (tpy)	Nonattainment Area Emissions (tpy)			
				Ozone	CO	SO_2	$PM_{2.5}$
GHG	93862647	727617	2405 - 7132627	54075187			65228851
CO	554502	4699	1.6 - 131691	414523			449113
NO_x	111566	945	2.7 - 9660	49787			52190
PM_{10}	42039	362	0.46 - 4802	20771			25267
$PM_{2.5}$	27607	238	0.46 - 2605	14764			18697
SO_2	85551	731	0.037 - 18137	56220			58348
VOC	17548	147	0.86 - 24409	9275			11213
188 HAP	4410	33	.001 - 674	1400			2100

Figure 7. Correlation of GHG and CAP Iron and Steel Facility Emissions.

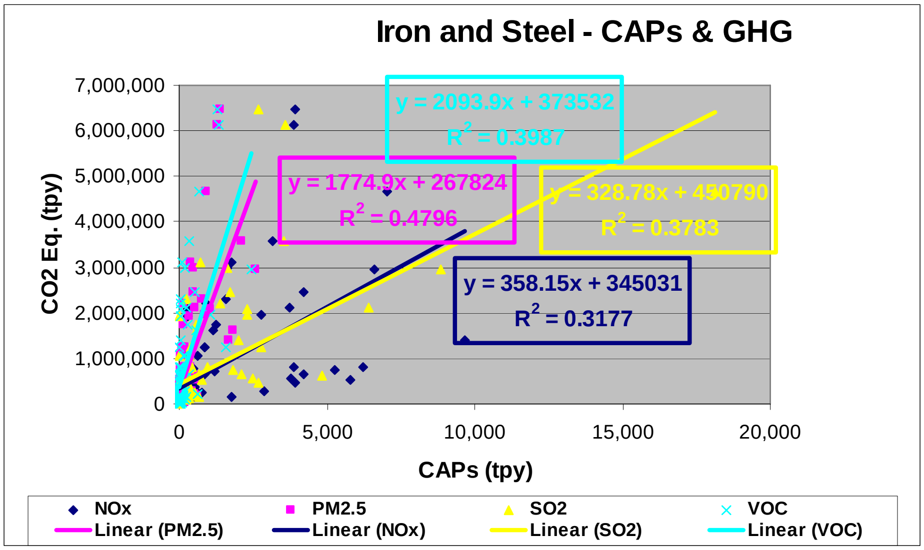
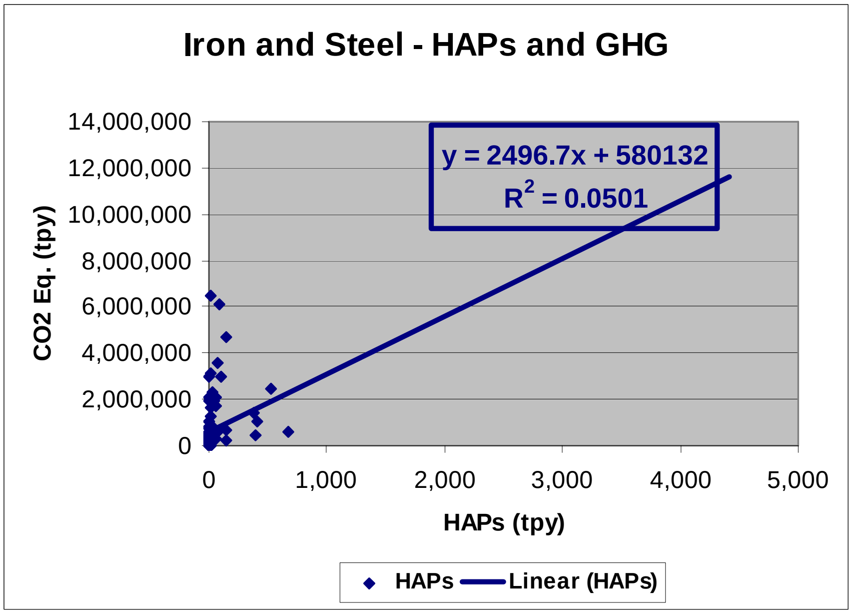


Figure 8. Correlation of GHG and HAP Iron and Steel Facility Emissions.



Lime Manufacturing

Lime manufacturing facilities produce four types of lime:

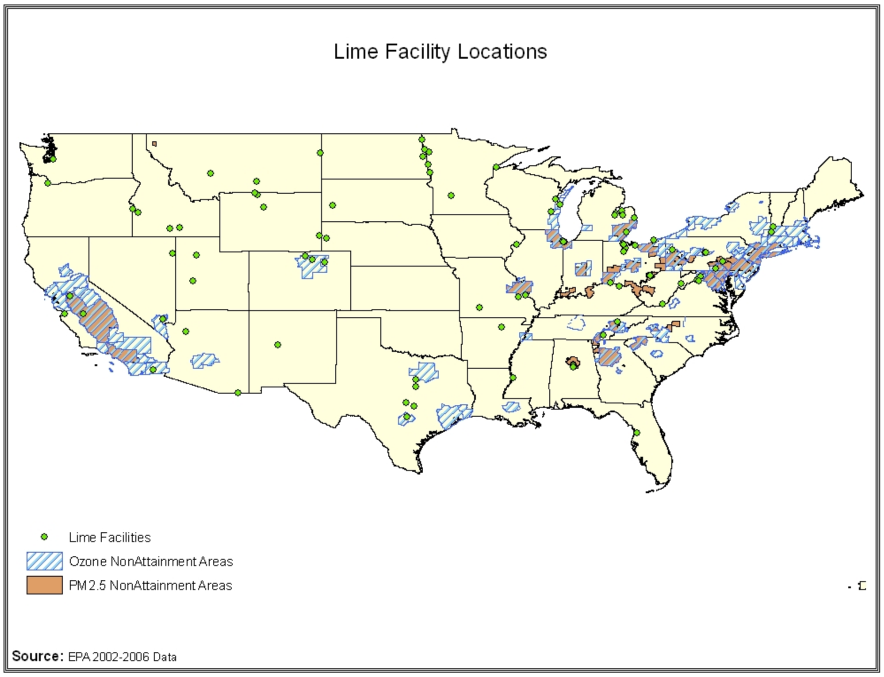
- high-calcium quick lime, calcium oxide (CaO),
- dolomitic quick lime, ([$CaO \bullet MgO$]),
- high-calcium hydrated lime, calcium hydroxide ($Ca(OH)_2$),
- dolomitic hydrated lime, dolomitichydrate ([$Ca(OH)_2 \bullet MgO$] or [$Ca(OH)_2 \bullet Mg(OH)_2$]), and
- dead-burned dolomitic lime.[7]

Lime production involves three main processes: stone preparation, calcination, and hydration. Lime facilities either have hydrators only, or lime kilns and hydrators. Lime kilns may be vertical, rotary or other types. GHGs are emitted from both process and combustion units. No GHG process emissions are released from hydrators. CO_2 process emissions are released from the production of high-calcium and dolomitic lime during calcination in kilns. At some facilities, lime reabsorbs CO_2 during use, e.g., sugar refineries use lime to remove impurities from the raw cane juice, and then remove excess lime through carbonation. CO_2, N_2O, and CH_4 are emitted from fossil fuel combustion which provides energy to kilns. Coal and natural gas are commonly burned in kilns although distillate and residual fuel oil are also burned.

GHG emissions for this category are compiled from the proposed GHG reporting rule and the CAP and HAP emissions are compiled from the 2005 NEI. 2004 GHG emissions are available at the facility level and split into process and combustion categories. Figure 9 identifies the locations of 94 lime manufacturing facilities in the dataset. Tables 6 and 7 present a summary of facility and emissions data for lime plants.

Process GHG emissions are estimated to be 52% of total emissions, and combustion GHG emissions are estimated to be 48%. 67 (71 %) of the 94 facilities have emissions of GHG, CAPs, and HAPs. 69 (82 %) of the 84 facilities emitting HAPs have CAP emissions. Table 7 and Table 8 show that a low number of lime facilities and emissions are present in nonattainment areas. Figures 10 and 11 indicate that lime manufacturing GHG emissions do not have high correlation with CAP and HAP emissions. One possible reason for the low correlation is that lime manufacturing data have not received as much review as the other categories because the category is not currently part of RTR. In order to develop a multi-pollutant sector-based approach for this category, an integrated multi-pollutant emissions inventory is first needed.

Figure 9. Location of Lime Manufacturing Facilities.



Source: EPA 2002-2006 Data

Table 6. Lime Facility Summary.

Parameter	Total	GHG	CAPs	HAPs
# Unique Facilities	94	89	78	84
# U.S. Counties	81	77	69	73
# Tribes	0	0	0	0
# U.S. States	34	32	32	32
# Facilities in Ozone Nonattainment areas (8 hr standard)	15	14	15	12
# Facilities in CO Nonattainment areas	1	1	1	1
# Facilities in $PM_{2.5}$ Nonattainment areas	18	16	15	16
2007 Acid Rain SO_2 Nonattainment areas	2	2	2	2
# HAPs individual reported	138			
HAPs with highest Cancer risk	acetaldehyde, arsenic, cadmium, hexavalent chromium, nickel			
HAPs with highest Non-Cancer effect	acrolein, arsenic, HCl, manganese, nickel			
HAPs with highest emissions	acetaldehyde, HCl, HF, methanol			

Table 7. Lime Emissions Summary.

Pollutant	Total (tpy)	Average Facility (tpy)	Facility Range (tpy)	Nonattainment Area Emissions (tpy)			
				Ozone	CO	SO_2	$PM_{2.5}$
GHG	28020714	298093	6614 - 1901484	5179753	417775	116845	8475660
CO	38638	544	0.1 - 13486	2693	814	227	3041
NO_x	53151	759	0.26 - 5433	5974	1566	75	10270
PM_{10}	15165	194	0.02 - 3198	751	233	108	912
$PM_{2.5}$	9013	116	0.01 - 2310	396	180	64	381
SO_2	51526	726	0.01 - 10834	2727	228	132	6689
VOC	3125	46	0.006 - 976	91	39	7	259
188 HAP	2204	26	0.00002 - 691	276	13	39	483

Figure 10. Correlation of GHG and NOx, $PM_{2.5}$, and SO_2 Lime Facility Emissions.

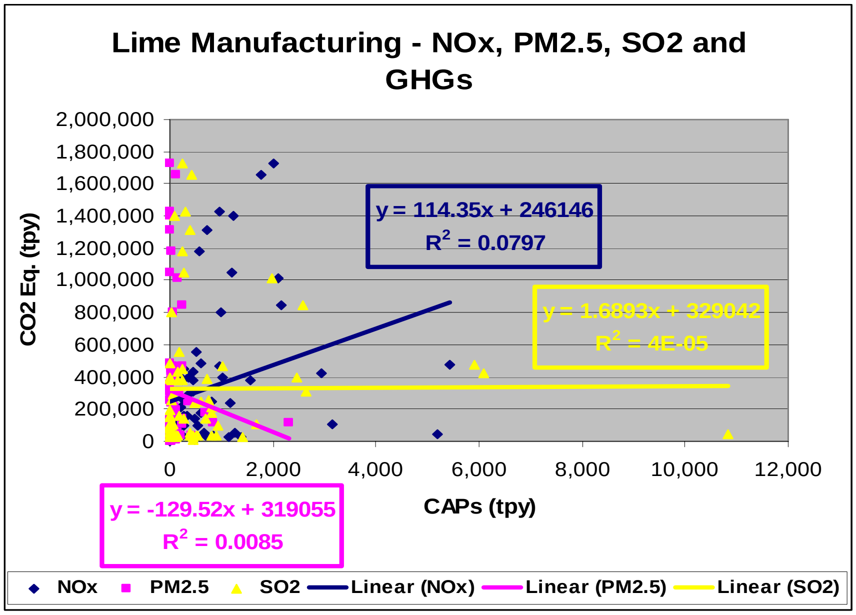
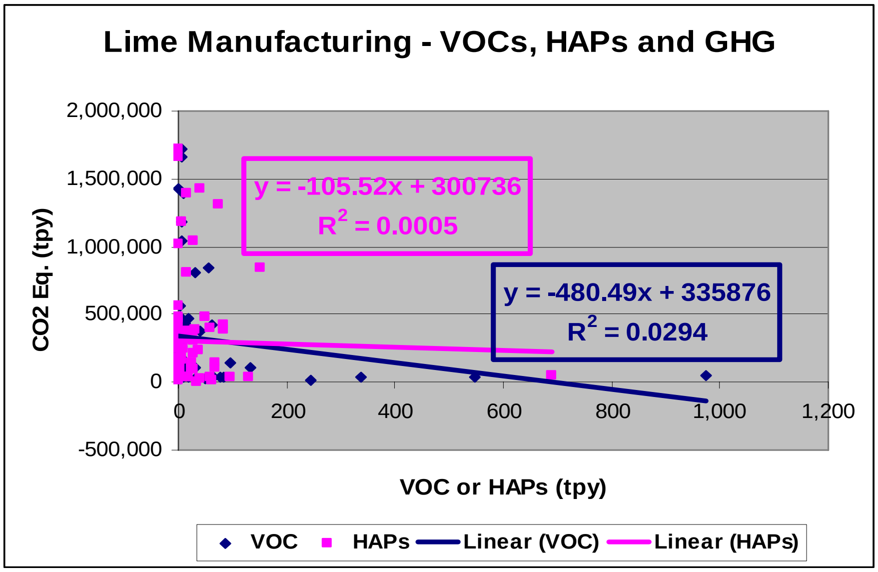


Figure 11. Correlation of GHG and HAP and VOC Lime Facility Emissions.

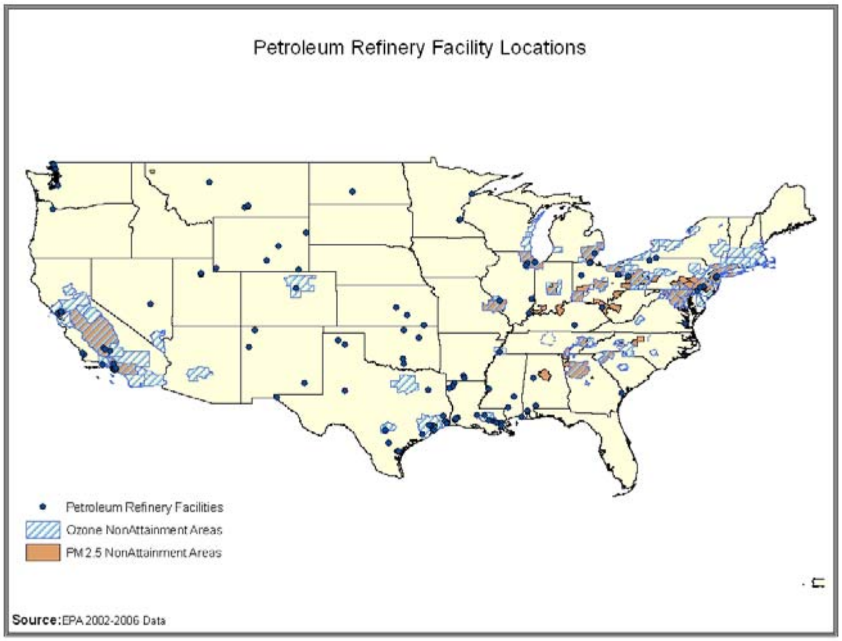


Petroleum Refineries

There are three basic types of refineries in the United States: topping, hydroskimming, and upgrading (also referred to as conversion or complex). Topping refineries have a crude distillation column and produce naphtha and other intermediate products, but not gasoline. A few topping refineries are located in the U.S., mainly in Alaska. Hydroskimming refineries have hydrotreating units and/or reforming units that produce finished gasoline products, but they do not upgrade heavier components of the crude oil that exit near the bottom of the crude distillation column. Most U.S. refineries are upgrading refineries. Upgrading refineries have cracking or coking operations that convert heavy distillates (long chain high molecular weight hydrocarbons) into smaller hydrocarbons which are used to produce gasoline product (light distillates) and petrochemical feedstocks.[8] Figure 12 shows the 152 refineries in the U.S., eight of which are asphalt plants located at topping and hydroskimming refineries.

2004 GHG emissions for this category are compiled from the proposed GHG reporting rule. GHG, CAP, and HAP emissions are available at the unit level. CO_2, CH_4 and N_2O are emitted from both process and combustion units at refineries. Process units emitting GHGs include fluid catalytic cracking units (FCCU), hydrogen production units, sulfur recovery plants, flares, and other sources such as equipment leaks, crude oil storage tanks, asphalt blowing, delayed coking units and system blow down. Combustion sources, including process heaters and boilers, emit CO_2 in large quantities and CH_4 and N_2O in smaller quantities. 68% of GHGs are emitted from combustion units. The remaining 32% of GHG emissions are emitted from the following processes: FCCUs (25%), hydrogen production units (2.7%), sulfur recovery units (1.9%), flares (1.6%), and other sources (0.8%). CO_2 emissions account for 99% of total GHG emissions.

Figure 12. Location of Petroleum Refineries.



Tables 8 and 9 present a summary of facility and emissions data for refineries. 135 (89 %) of the 152 facilities have emissions of GHG, CAPs, and HAPs. 136 (90%) of the 151 facilities emitting HAPs have CAP emissions. Figures 13 and 14 present a correlation of GHGs to CAPs and HAPs. When comparing the emissions of facilities emitting pollutants, good agreement exists between GHG and HAP emitting facilities. It is believed that this agreement exists because of the recent RTR proposed rule-making for refineries. However, 10 refineries are missing CAP data, which is a deficiency in the NEI.

Table 8. Petroleum Refinery Facility Summary.

Parameter	Total	GHG	CAPs	HAPs
# Unique Facilities	152	151	137	151
# U.S. Counties	99	99	87	98
# Tribes		0	0	0
# U.S. States and Territories	35	35	30	34
# Facilities in Ozone Nonattainment areas (8 hr standard)	53	53	51	53
# Facilities in CO Nonattainment areas	0	0	0	0
# Facilities in $PM_{2.5}$ Nonattainment areas	31	31	31	31
2007 Acid Rain SO_2 Nonattainment areas	5	5	5	5
# HAPs individual reported	149			
HAPs with highest Cancer risk	benzene, 1,3-butadiene, hexavalent chromium, naphthalene, POM			
HAPs with highest Non-Cancer effect	acrolein, 1,3-butadiene, chlorine, manganese, nickel			
HAPs with highest emissions	benzene, hexane, methanol, toluene, xylenes			

Table 9. Petroleum Refinery Emissions Summary.

Pollutant	Total (tpy)	Average Facility (tpy)	Facility Range (tpy)	Nonattainment Area Emissions (tpy)			
				Ozone	CO	SO_2	$PM_{2.5}$
GHG	233117905	1532211	10257 - 7749238	122535731		3624657	55265072
CO	134050	986	1.11 – 2337	62082		1856	27509
NO_x	149426	1132	4 – 9511	67750		1230	38277
PM_{10}	34842	254	0.07 – 2607	15098		681	6766
$PM_{2.5}$	30566	223	0.04 – 2063	13886		483	6108
SO_2	242175	1781	0.06 – 26403	121961		9069	96141
VOC	101823	749	0.13 – 6990	37158		3472	15133
188 HAP	10423	69	0.00009 - 1093	4000		256	1162

Figure 13. Correlation of GHG and CAPs Petroleum Refinery Facility Emissions.

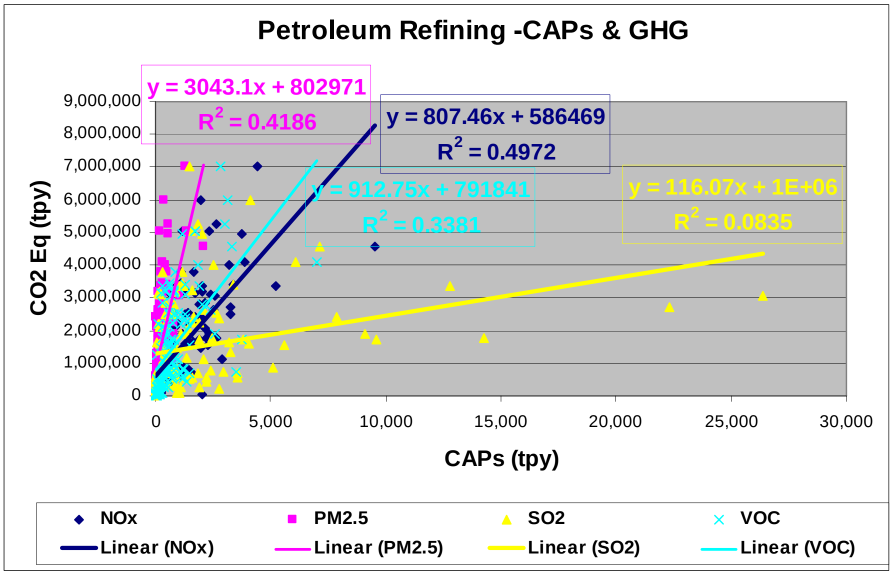
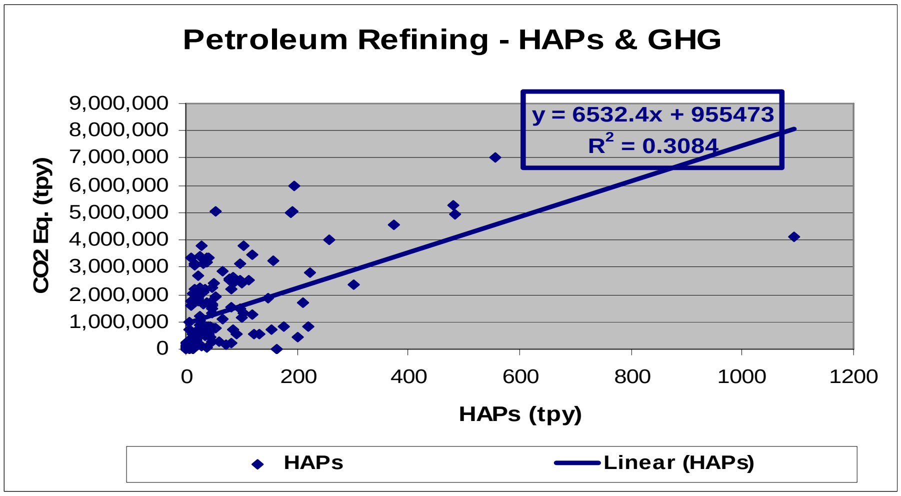


Figure 14. Correlation of GHG and HAPs Petroleum Refinery Facility Emissions.



Portland Cement Production

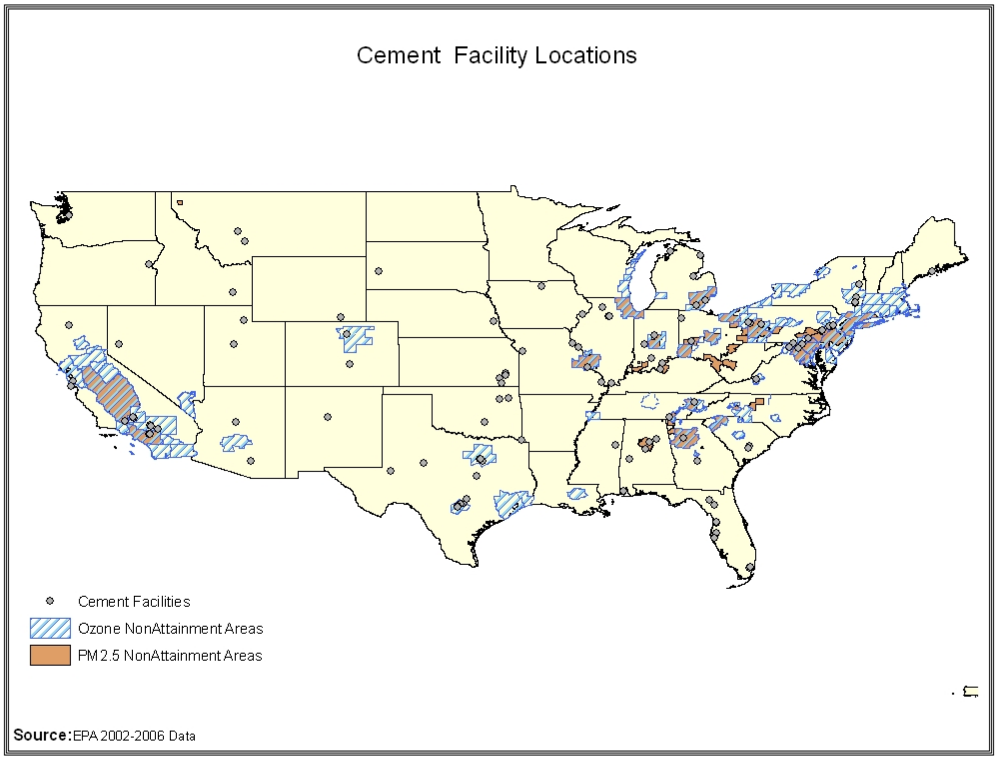
Cement plants are either integrated plants or fine grinding-only plants. The majority of plants are integrated plants that have both kilns for producing clinker and mills for grinding cement from clinker. Grinding-only plants only have grinding mills for producing cement from purchased clinker and other additives.

During clinker production, calcination occurs when calcium carbonate ($CaCO_3$) (limestone and chalk), and sometimes very small amounts of other carbonates, are heated in kilns to form lime (CaO). The lime then reacts with raw materials (silica-containing materials, iron oxide and alumina) that are fed to the kiln to produce clinker. The clinker is cooled and mixed with a small amount of gypsum, and other materials, such as slag. In the grinding mill, the clinker is finely ground with gypsum and other materials to produce Portland cement. During clinker production, some of the clinker precursor materials form cement kiln dust (CKD), which is either recycled back to the kiln or disposed of on-site or off-site. The three primary types of kilns used in the U.S. are wet kilns, simple dry kilns, and dry kilns equipped with a preheater and precalciner. Most kilns burn coal, but some kilns burn wastes, including solvents, oils and tires. Some kilns also burn hazardous waste.[9]

Portland cement facilities emit GHGs from clinker production and combustion units. There are no GHG emissions from the finish grinding. Clinker production emits CO_2 from calcination of carbonates and formation of CKD. Additional process-related CO_2 are emitted from the calcination of other carbonates and non-carbonate organic carbon contained in the raw materials. Kilns, the primary combustion sources at cement plants, emit CO_2 in large quantities and CH_4 and N_2O in smaller quantities. Other combustion sources include transportation equipment used to mine and transport raw and finished materials.

2005 GHG emissions for this category are compiled from the proposed GHG reporting rule. GHG, CAP and HAP emissions are available at the unit level. Figure 15 identifies the locations of 113 facilities in the dataset. Tables 10 and 11 present a summary of facility and emissions data for Portland cement plants. Process GHG emissions are estimated to be 53 % of total emissions and combustion GHG emissions are estimated to be 47 %. 109 (96 %) of the 113 facilities have emissions of GHG, CAPs, and HAPs. 109 (99 %) of the 110 facilities emitting HAPs have CAP emissions. Tables 10 and 11 show that a low number of facilities and their emissions are present in nonattainment areas compared to total number of facilities and emissions. Figures 15 and 16 show that Portland cement GHG emissions have good correlation to emissions of HAPs and CAPs, except NOx and VOC.

Figure 15. Location of Portland Cement Facilities.



Source: EPA 2002-2006 Data

Table 10. Portland Cement Facility Summary.

Parameter	Total	GHG	CAPs	HAPs
# Unique Facilities	113	113	110	110
# U.S. Counties	38	38	36	36
# Tribes	0	0	0	0
# U.S. States	37	37	36	36
# Facilities in Ozone Nonattainment areas (8 hr standard)	24	24	24	24
# Facilities in CO Nonattainment areas	0	0	0	0
# Facilities in $PM_{2.5}$ Nonattainment areas	28	28	28	28
2007 Acid Rain SO_2 Nonattainment areas	0	0	0	0
# HAPs individual reported	194			
HAPs with highest Cancer risk	benzene, beryllium, hexavalent chromium, POM			
HAPs with highest Non-Cancer effects	acrolein, chlorine, HCl, manganese			
HAPs with highest emissions	benzene, chlorine, formaldehyde, HCl, toluene			

Table 11. Portland Cement Emissions Summary.

Pollutant	Total (tpy)	Average Facility (tpy)	Facility Range (tpy)	Nonattainment Area Emissions (tpy)			
				Ozone	CO	SO_2	$PM_{2.5}$
GHG	101412500	881848	7385 - 3381445	27337283			26014511
CO	154375	1470	0.4 - 34087	19093			16488
NO_x	217681	2073	2 - 9705	51678			52668
PM_{10}	38009	346	14 - 1970	10079			12748
$PM_{2.5}$	16804	153	6 - 707	4416			5374
SO_2	155917	1485	0.003 - 16587	41955			23623
VOC	8830	84	0.007 - 1750	2963			2576
188 HAP	6167	56	0.0006 - 687	1052			911

Figure 15. Correlation of GHG and CAPs Portland Cement Facility Emissions.

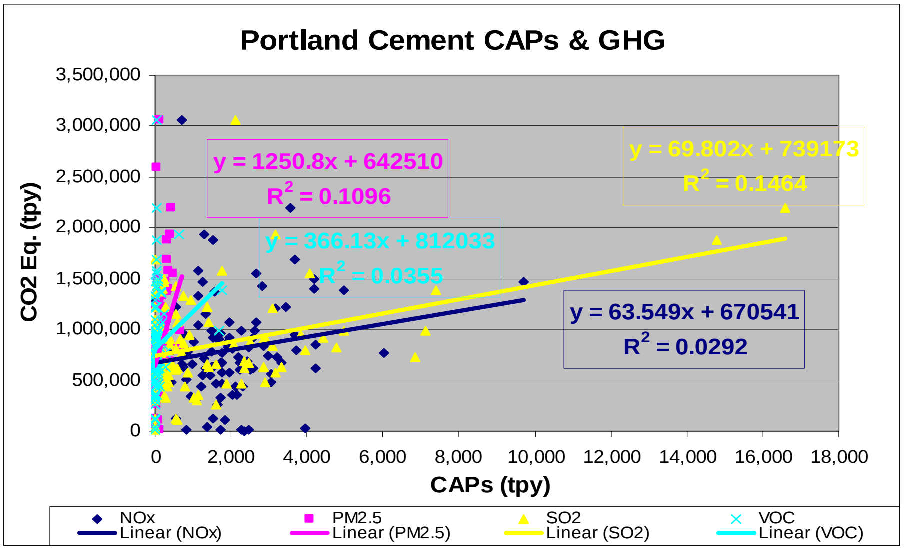
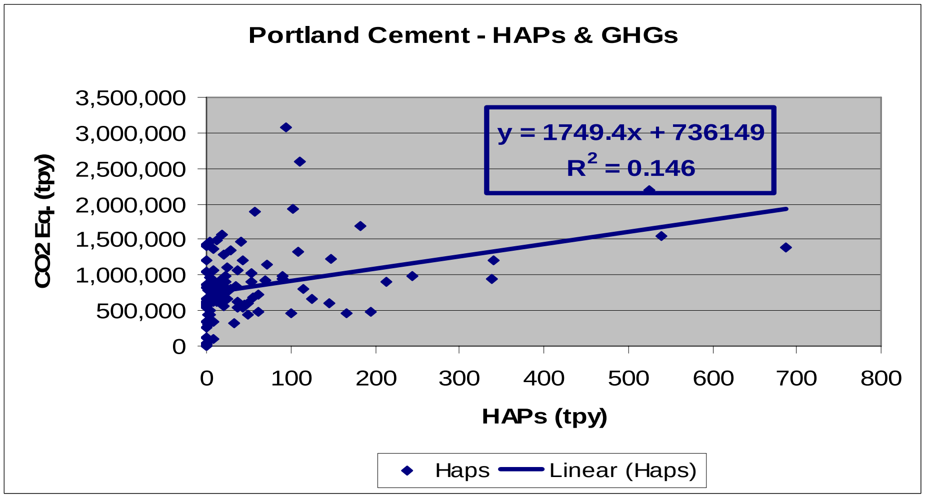


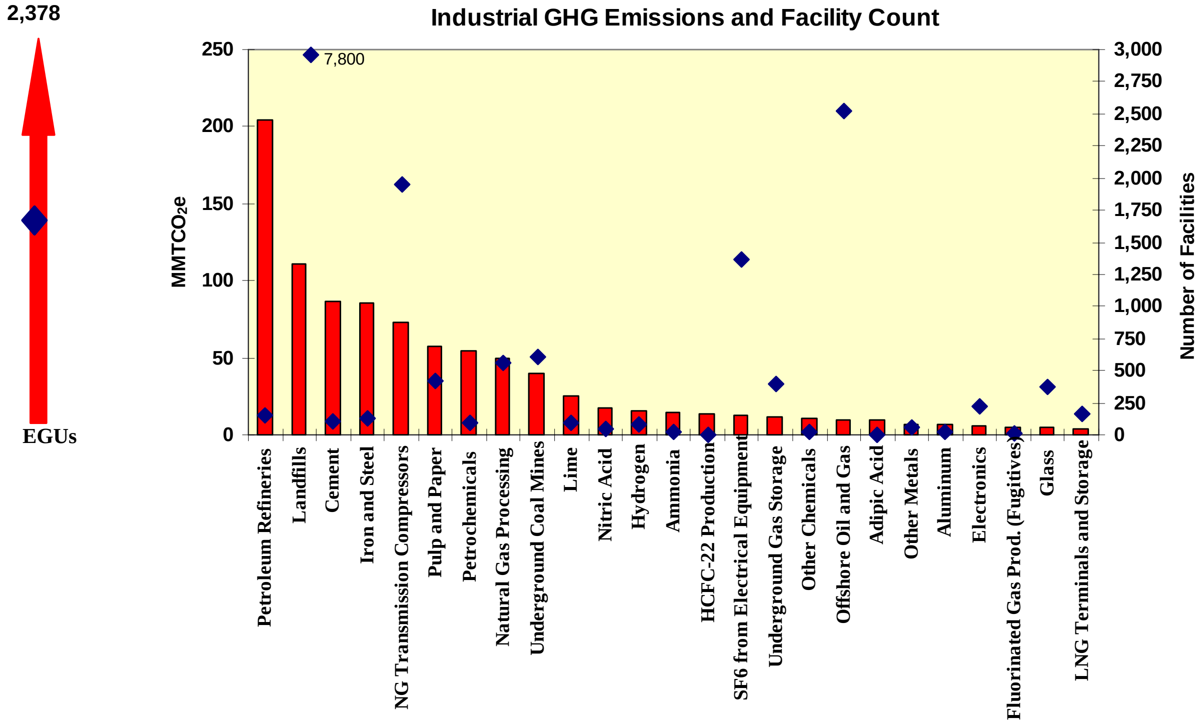
Figure 16. Correlation of GHG and HAPs Portland Cement Facility Emissions.



RANKING OF SOURCE CATEGORIES

Multi-pollutant emissions from source categories can be compared on a national, regional and local basis to develop multi-pollutant sector-based approaches for managing emissions and air quality. Source category contributions vary by individual pollutants. Figures 17 – 23 show source category emissions by pollutant for stationary sources, excluding wildfires and prescribed burning, open burning categories, and paved and unpaved road dust.

Figure 17. Stationary Source GHG Emissions.



Source: Based on EIA Manufacturing Energy Consumption Survey and EPA Inventory of Greenhouse Gas Emissions and Sinks 1990-2005.

Figure 18. Stationary Source CO Emissions.

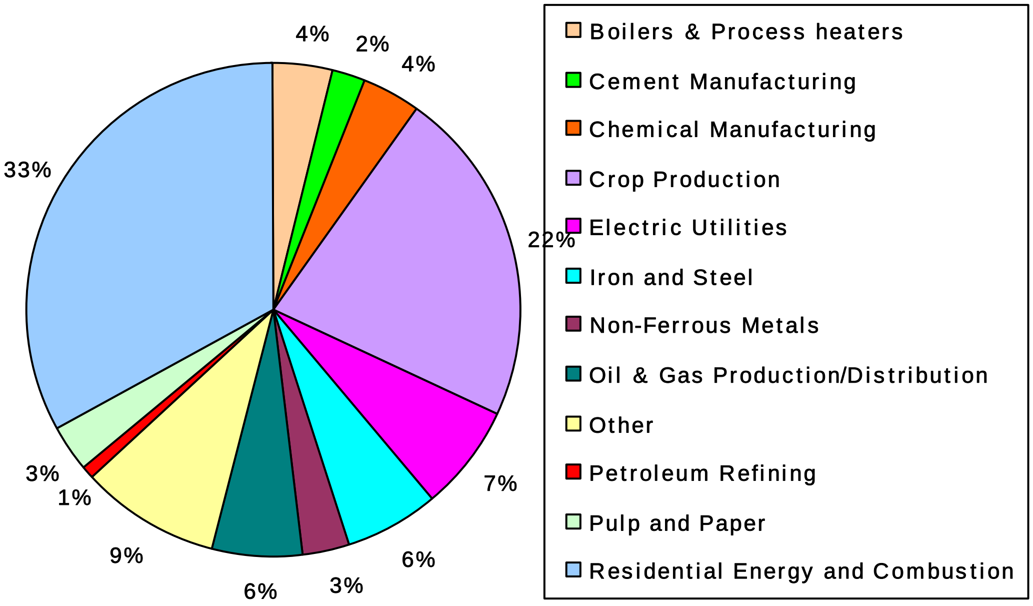


Figure 19. Stationary Source NOx Emissions.

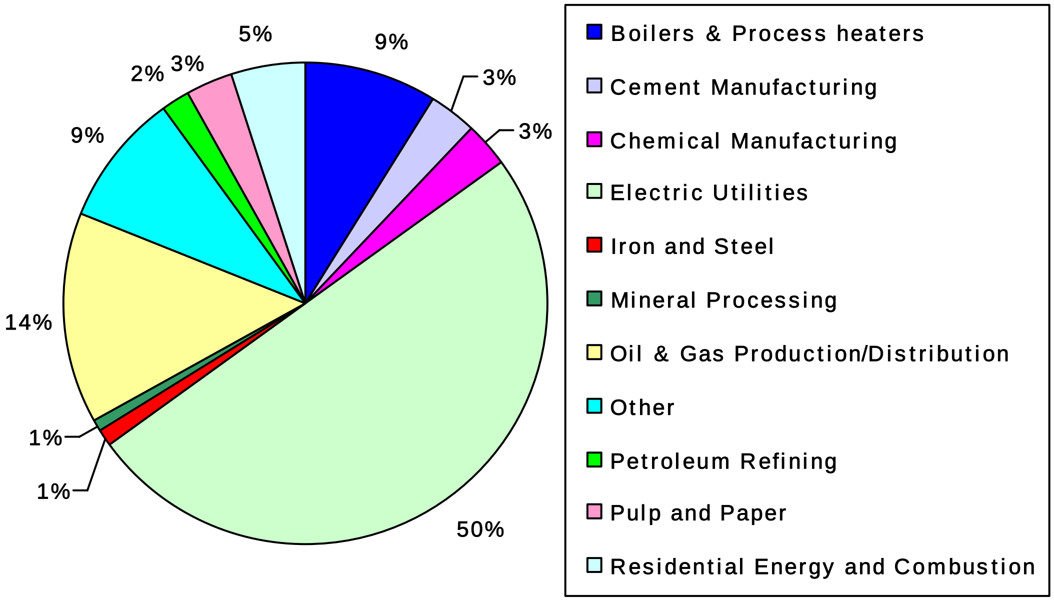


Figure 20. Stationary Source PM2.5 and PM10 Emissions.

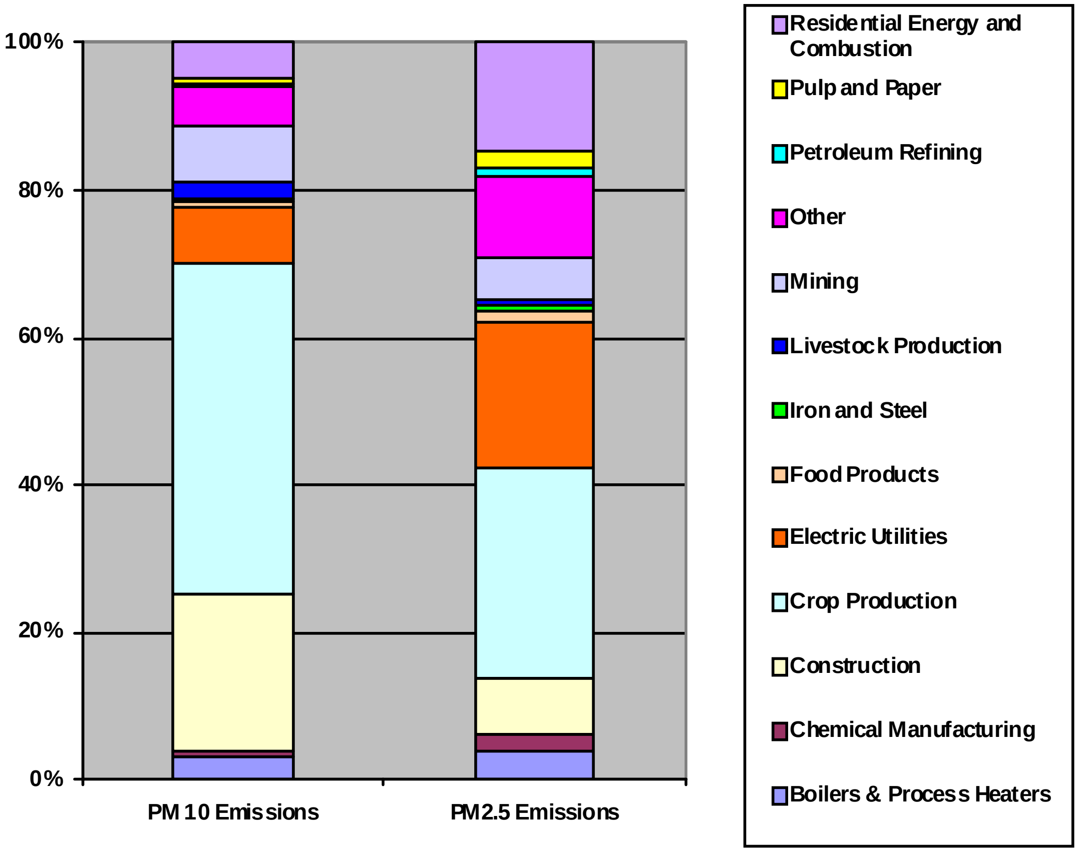


Figure 21. Stationary Source SO_2 Emissions.

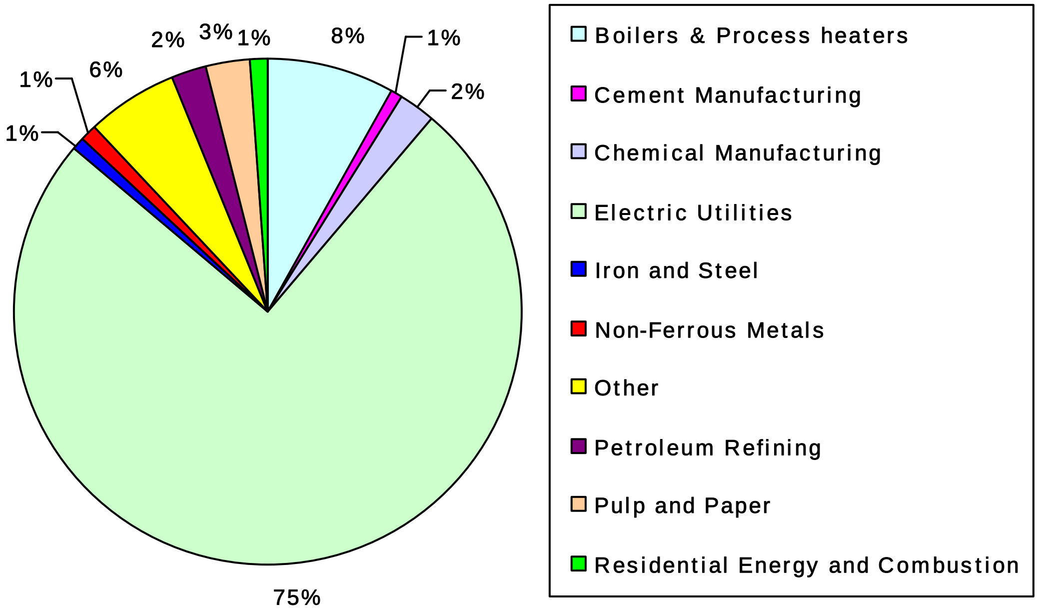


Figure 22. Stationary Source VOC Emissions.

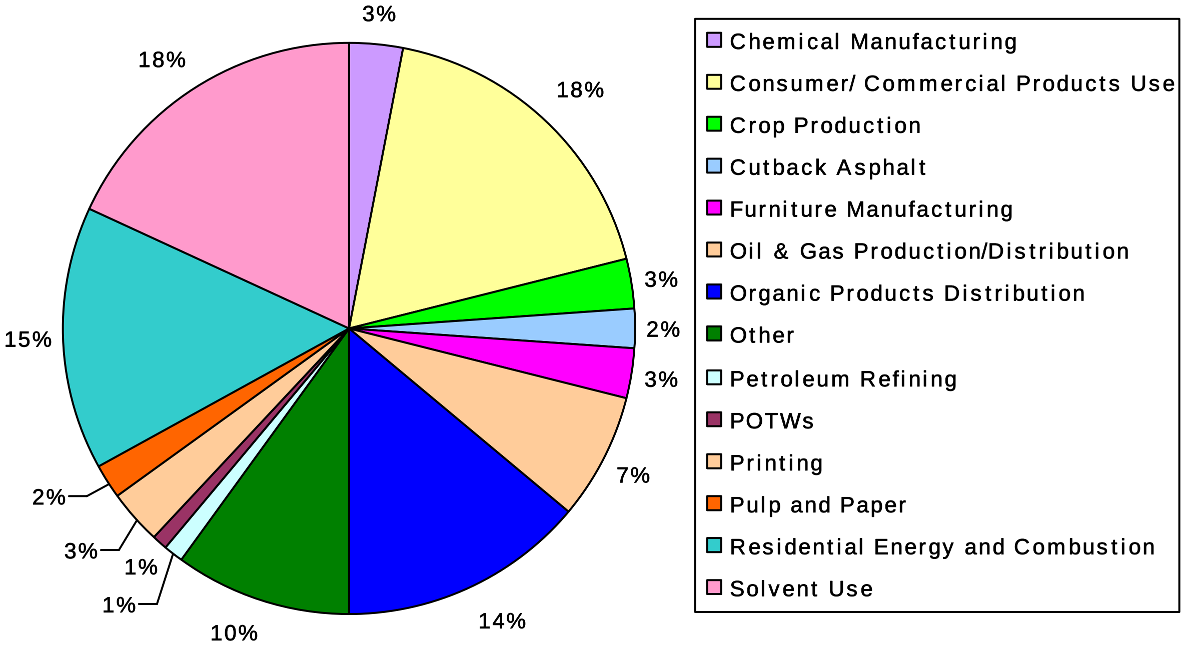


Figure 23. Stationary Source HAP Emissions.

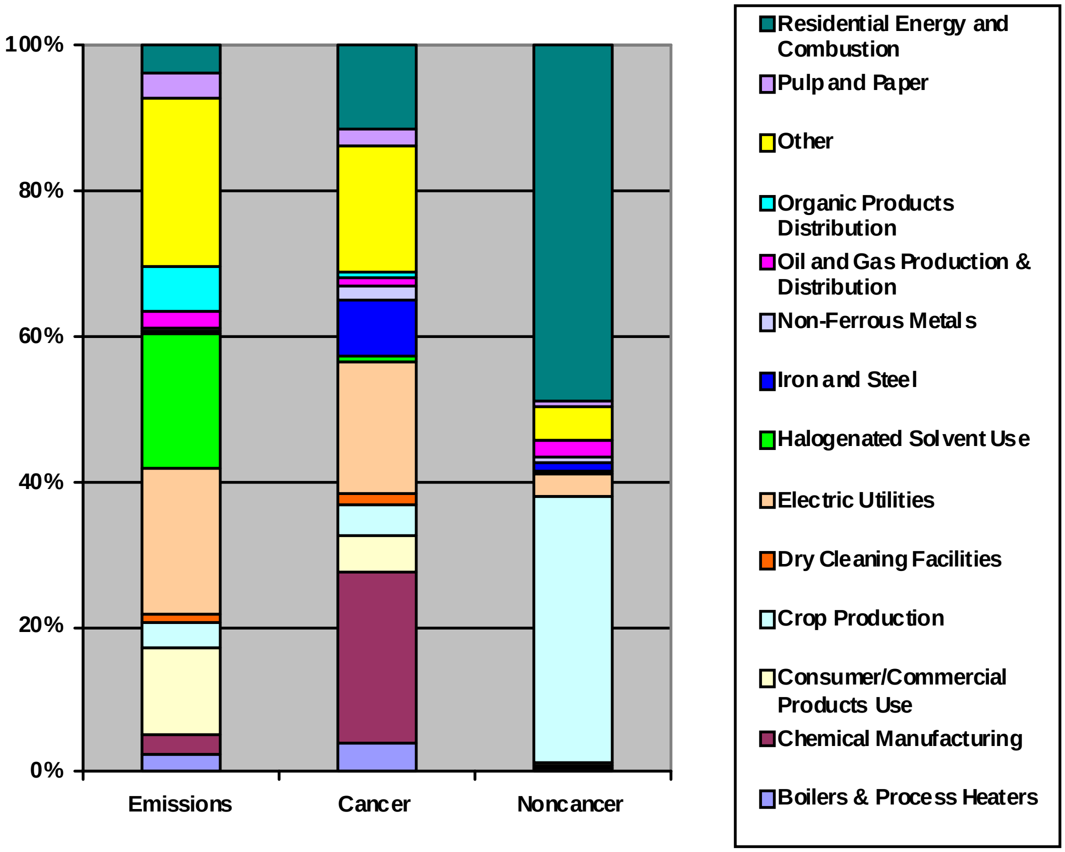


Table 12 compares the relative ranking of the top 10 GHG source categories by emissions of CAPs and HAPs. Fires, open burning, and road dust were excluded from the ranking. 75 source categories were ranked in this analysis. All of the categories in Table 12 except mining are subject to CAP and HAP regulations. A rank of “1” is the highest (most emissions). The GHG ranking of mineral processing in the top 10 categories is due to lime manufacturing being included in mineral processing.

Table 13 compares the GHG emissions to CAP and HAP emissions correlation coefficients for 5 of the top 10 source categories in Table 12. In general, emissions of NOx, PM and SO_2 are highly correlated with GHG emissions, with correlation coefficients exceeding 0.50 for most sectors. An exception is Portland cement, which only has a correlation coefficient above 0.50 for NOx. HAPs appear to be highly correlated to GHGs for electric utilities and petroleum refineries. VOC are high related for iron and steel mills and petroleum refineries. Lime manufacturing has low correlations between individual CAPs and HAPs with GHGs. Lime manufacturing data have not received as much review as the other categories because it is not yet part of RTR. This may suggest that lime manufacturing data need further review. As shown in Table 12, VOC emissions ranked in the top 20 categories only for petroleum refineries. This may be a reason for the low correlation of VOC and GHGs for the other categories. The HAP emissions data for petroleum refineries, Portland cement, and iron and steel mills have been reviewed as part of RTR rule-making efforts. However, version 2, 2005 NEI has not been updated with RTR data for refineries and Portland cement. An analysis is needed to determine if the type of units (combustion or process) that emit GHGs within a sector impacts the correlation of GHGs to CAPs and HAPs. For example, process emissions of GHGs are the largest for petroleum refineries (68%) and the lowest for electric utilities (0%). Another analysis is needed to determine how the non-GHG emitting units that emit HAPs and CAPs affect facility correlations shown in Table 13. For example, HAP and CAP emissions are present in the NEI for storage and handling operations and grinding mills at Portland cement facilities.

Table 12. Comparison of Source Category Rankings for GHGs, CAPs, and HAPs.

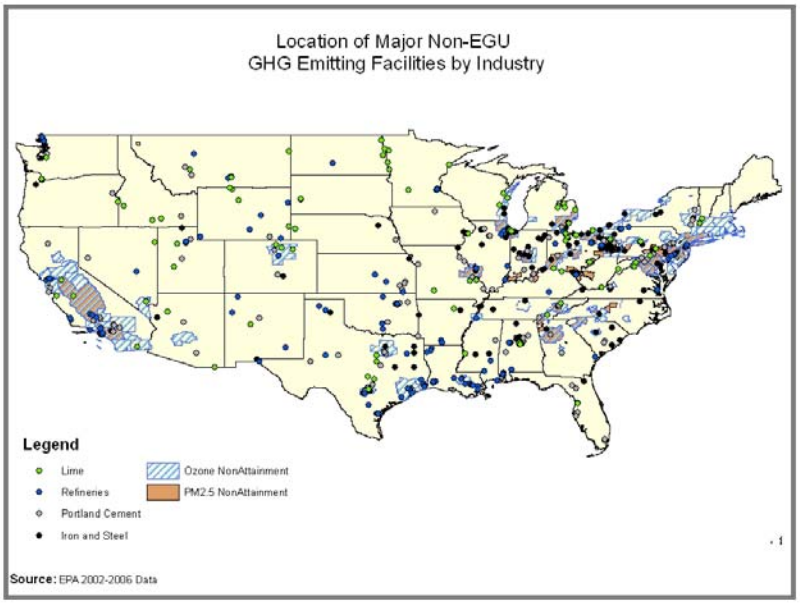
Source Category	Rank GHG Emiss	Rank CO Emiss	Rank NOx Emiss	Rank PM10 Emiss	Rank PM25 Emiss	Rank SO2 Emiss	Rank VOC Emiss	Rank 188 Emissions	Rank Cancer Tox Wt	Rank Non Cancer Tox Wt Emiss
Electric Utilities	1	3	1	4	2	1	26	1	1	2
Petroleum Refining	2	12	9	15	11	4	15	30	27	30
Solid Waste Landfills	3	20	20	23	27	35	24	15	19	25
Cement Manufacturing	4	10	7	13	17	8	49	44	33	31
Iron and Steel	5	4	11	14	12	9	38	37	3	4
Oil and Gas Production & Distribution	6	5	3	25	19	12	5	14	20	12
Pulp and Paper	7	7	6	9	8	3	12	5	12	7
Chemical Manufacturing	8	9	8	10	9	6	9	8	8	10
Mining	9	26	15	3	5	26	53	58	42	33
Mineral Processing	10	16	10	11	14	13	51	50	21	27

Table 13. Correlation Matrix of HAPs & CAPs with CO_2 Equivalent.

Industry	CO	NOx	PM_{10}	$PM_{2.5}$	SO_2	VOC	188 HAPs	CO_2 Equivalent
Electric Utilities	0.23756	0.86216	0.72212	0.69542	0.72468	0.05621	0.68956	1
Petroleum refining	0.26306	0.70512	0.60240	0.64697	0.28890	0.58144	0.55532	1
Portland Cement	0.09715	0.59179	0.28805	0.33109	0.38260	0.18841	0.38206	1
Iron and Steel	0.72917	0.56366	0.64417	0.69255	0.615043	0.63146	0.22380	1
Lime Manufacturing	0.07782	0.28233	-0.02984	-0.05832	0.00668	-0.17158	-0.02134	1

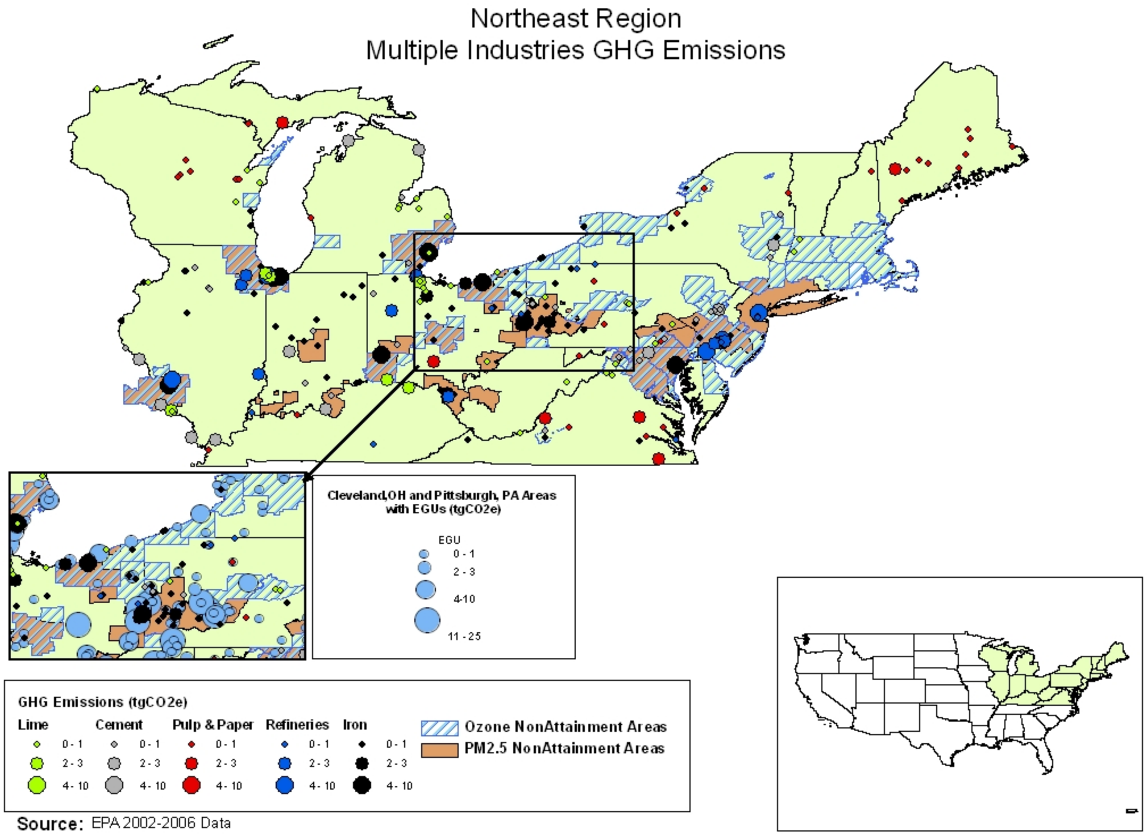
Figure 17, which shows the locations of facilities for four of the categories in Table 12, indicates that many high GHG emitting facilities are located in $PM_{2.5}$ and ozone nonattainment areas. These areas also have high risks in the 2002 NATA. Figure 18, which shows the Northeast Region in more detail, indicates that utilities, iron and steel mills, and refineries having high GHG emissions are also located in non-attainment areas. A sector-based multi-pollutant approach in specific geographic areas could reduce multi-pollutant emissions and allow agencies to target sources with that have the greatest public health issues in specific locales.

Figure 17. Location of Non-Electric Utility GHG Facilities in the U.S.



Source: EPA 2002-2006 Data

Figure 18. . Location of GHG Facilities in the Northeast



Source: EPA 2002-2006 Data

Table 12 and Figures 17 and 18 illustrate that the potential for development of multi-pollutant strategies exists for the 5 categories highlighted in this paper. Many of these source sectors are subject to separate regulations for CAPs and HAPs. As an example, petroleum refineries are subject to more than 20 MACT standards, NSPS, CTGs, ACTs, and NESHAPs, including but not limited to the following standards.

• Boilers:	NSPS Db, J, and Ja and boiler MACT
• Process heaters:	NSPS Ja, and boiler MACT
• Fuel gas combustion	NSPS J and Ja
• FCCU	NSPS J and Ja; and MACT UUU
• Catalytic Reformer	MACT UUU
• SRP	NSPS J and Ja; and MACT UUU
• Fluid Coker	NSPS J and Ja
• Flares	NSPS Ja and Subpart CC
• Wastewater	Benzene Waste Rule; MACT CC; Part 61 FF; NSPS QQQ
• Process Vents	MACT CC
• Cooling Towers	Lead Detection and Repair; Cooling Tower MACT
• Storage	NSPS Ka and Kb; MACT CC; Group1 Tank Controls CTG
• Loading	MACT CC, References Subpart R
• Equipment Leaks	NSPS GGG, W, GGa; MACT CC, UU, T; NESHAP V

Implementing control measures for specific pollutants emitted from refineries may increase or decrease emissions of other pollutants. For example, increasing energy efficiency will likely reduce GHG, CAP, and HAP emissions from boilers and process heaters in refineries. However, adding air preheaters on process heaters and boilers may increase NOx levels slightly while reducing emissions of GHG, other CAPS, and HAPs. An example of co-control benefits occurs for HAPs in refineries when storage tank VOC controls are put in place. Increased cost savings could occur if multi-pollutant approaches are undertaken. The following refinery example presents a scenario where costs are increased as a result of not looking at controls in a multi-pollutant strategy - wastewater control requirements for NSPS QQQ stop at the end of the separator tank, and control requirements for benzene waste rule continue through the biological treatment unit. Owners and operators that install separators and open channels into uncontrolled dissolved air float units to meet NSPS would have to upgrade controls through the biological treatment unit to meet benzene waste rule requirements, resulting in stranded control expenditures.

The first step in the development of multi-pollutant control strategies is the development of an integrated pollutant inventory. Currently, inventories are not fully integrated across pollutants at the unit level. Revisions are not made in the NEI across pollutants. For example, as part of separate RTR and NSPS evaluations, agencies, industry and the public only review individual units and processes for separate pollutants. HAP emissions from units subject to MACT were updated for RTR through FR review, but revisions were not received for CAPs.

CONCLUSIONS

EPA has initiated multi-pollutant analyses in order to explore the development of multi-pollutant sector-based approaches for managing emissions and air quality. An integrated multi-pollutant emissions inventory is key to conducting integrated sector assessments. An analysis of GHG, CAP and HAP emission inventory data identifies source sectors that have the greatest potential for emission reductions. After identifying source sectors, EPA can then perform comprehensive analysis on controls and their benefits across pollutants. Integrated multi-pollutant sector-based approaches can result in the following benefits.

- Development of innovative multi-pollutant sector strategies to reduce emissions associated with greatest public health
- Optimization of resources for data collection and analysis, e.g. consolidated monitoring and reporting of emissions
- Improvement in inventories and analysis tools
- Maximization of capital and operating environmental expenditures by industry

This paper discussed the need for integrated multi-pollutant emission inventory data to support development of multi-pollutant sector-based strategies. Multi-pollutant reporting of emissions across GHGs, CAPs, and HAPs would be more efficient for agencies, industry and EPA. Inventory partners are encouraged to improve consistency in reporting integrated multi-pollutant inventory data to EPA to support sector approaches in the future.

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NEI
greenhouse gas inventories
multi-pollutant inventory

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