National Emissions Inventory for Commercial Cooking

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Abstract

This paper describes the development of a National Emission Inventory (NEI) for commercial cooking processes. The U.S. Environmental Protection Agency (EPA) Emission Factor and Inventory Group (EFIG) produces the NEI for criteria and hazardous air pollutants (HAPs) and ammonia (NH_3). These data are needed by EPA and State agencies to evaluate emission trends and as a basis for various EPA modeling and regulatory analyses. Since the early 1990's, there have been several investigations and testing programs conducted to characterize emissions from commercial cooking activities. Commercial cooking activities were believed to be capable of producing significant amounts of criteria pollutants (especially fine particulate matter) and HAPs. This paper contains data and methods for quantifying emissions on a national level to determine the impact of commercial cooking activities on national air quality. The approach Pechan used for producing an emissions inventory (EI) of criteria pollutants and HAPs from commercial cooking for the calendar year 2002 are described. The most challenging aspect of the work was to identify appropriate activity data for the existing emission factors. This paper provides information on emission factors developed from recent test programs for commercial cooking followed by a discussion of the activity data that were used to construct the national inventory. Emissions summaries are presented to compare emission estimates for commercial cooking to other sources of fine particulate matter.

INTRODUCTION

Emissions from commercial cooking may contribute to exceedances of the Federal $PM_{2.5}$ air quality standards in certain regions. Commercial cooking processes are important contributors of secondary organic aerosols (SOA) and organic carbon (OC) and elemental carbon (EC). SOA is formed from the condensation of gaseous organic emissions at ambient temperatures, sometimes following photo-chemical processes. Estimated contributions of various source categories, including meat charbroiling, to carbonaceous PM in Pittsburgh, Pennsylvania are described by Cabada et al. (2002).

Based on previous tests conducted by EPA and State and local environmental agencies, the focus of the emissions inventory is commercial cooking of meat, which is the greatest source

of emissions. In particular, emissions of particulate matter (PM) and volatile organic compounds (VOCs) are the most significant from meat charbroiling.

Particulate matter is the general term used for a mixture of solid particles and liquid droplets suspended in air. EPA defines PM_{10} as particulate matter having a nominal aerodynamic diameter of 10 micrometer (µm) or less. $PM_{2.5}$ is defined as PM that is less than or equal to 2.5µm in aerodynamic diameter. The Federal Government has established emission standards for PM_{10}. In 1997, new standards for $PM_{2.5}$ were proposed by EPA due to the negative impact of $PM_{2.5}$ on human health and visibility in the United States.

VOCs contribute to the formation of ozone and SOA in some cases. Ozone is not directly emitted from stationary or mobile sources, but is formed through photo-chemical reactions in the atmosphere with other air pollutants (e.g., nitrogen oxides or NO_x). Commercial charbroiling processes also produce HAP emissions. Notable among these are emissions of polycyclic aromatic hydrocarbons (PAHs).

Pechan categorized the commercial cooking EI into five source categories based on equipment type. Source categories comprise emissions from cooking of meat and potatoes using a particular equipment type. The following types of meat are included: hamburger, steak, fish, pork, and chicken. The five equipment types have been adopted from work carried out by the South Coast Air Quality Management District (SCAQMD, 1997):

- Chain-driven (conveyorized) charbroilers,
- Under-fired charbroilers,
- Deep Fat Fryers,
- Griddles, and
- Clam Shell Griddles.

The studies reviewed by Pechan indicate that the type of fuel used by each cooking equipment category was not important in estimating emissions of PM or VOC. However, the testing programs were often designed to measure VOC, PM, and their components, and did not focus on other combustion products, such as NO_x, carbon monoxide (CO), or sulfur dioxide (SO_2), which may be more strongly associated with fuel combustion.

LITERATURE REVIEW

Emission Factors

Pechan reviewed an EPA report entitled "Emissions from Street Vendor Cooking Devices (Charcoal Grilling)" that was prepared by the Office of Air Quality Planning and Standards (OAQPS) (EPA, 1999). This report discusses tests that were conducted by EPA to quantify emissions due to charcoal grilling of meat by street vendors in Mexicali, Mexico. The emissions of interest included PM, VOC, semi-volatile compounds (SVOC), aldehydes, CO, carbon dioxide (CO_2), NO_x, total hydrocarbons (THC), and SO_2. Emissions were tested for charcoal grilling of both beef and chicken, including marinated and non-marinated meat. Test results and emissions factors are summarized in the technical memorandum prepared for U.S.

EPA "Methods for Developing a National Emission Inventory for Commercial Cooking Processes (Pechan, 2003).

For the street vendor charcoal grilling test program, EPA (1999) noted that charcoal did not contribute significantly to total PM, VOC or SVOC emission levels. Marinated meat had higher VOC and total PM emissions than non-marinated meat. No significant differences were seen in emission rates between chicken and beef (chicken was whole chicken with skin). Emissions of CO and nitric oxide (NO) appeared to be primarily from the charcoal fire and not the cooking of meat. THC emissions were almost all from the initial burning of charcoal (e.g., first half hour), however there appears to be some contribution from meat cooking. Emission rates for SO_2 were not reported due to problems with the analyzer. The emission factors reported in the technical memorandum were developed as the average of two test results. When one test result was a non-detect, the emission factor from the detected result is reported as the emission factor. This was done since the report did not list the detection limits for each pollutant.

The University of California, Riverside Bourns College of Engineering - Center for Environmental Research and Technology (CE-CERT) conducted emission tests supporting rule development in the SCAQMD (CE-CERT; Norbeck 1997). These tests focused on PM and VOC. McDonald et al. (2003) used additional test data from CE-CERT to develop emission estimates for the Colorado Front Range Study. These data include emission factors for CO and some HAPs (mainly PAHs).

In constructing the national inventory, emission factors from Norbeck (1997) and McDonald et al. (2003) were generally favored since they are based on common commercial cooking operations. The EPA (1999) study was performed to characterize emissions from street vendors in Mexico (e.g., using charcoal-fired charbroilers and marinated meat). Several HAP emission factors from the EPA study were used where these factors were not available from the other studies and where the emissions do not appear to be mainly from the burning of charcoal.

Activity Data

The emission factors for meat require the amount of meat cooked by meat type and cooking device. Therefore, Pechan performed a literature search for activity data including the amount of meat cooked at various types of commercial facilities and number of restaurants/other commercial cooking facilities that perform these activities.

U.S. Census Data

In the Statistical Abstract of the United States, the U.S. Census Bureau presents per capita expenditures on food consumed both at home and away from home (BOC, 2002). At-home food expenditures are broken down into categories, such as meat, and subcategories, such as, beef, pork, other meats, poultry, fish and seafood, and eggs. However, expenditures on food consumed away from home is not tracked by food category.

Pechan also examined the U.S. Census Bureau sector report on food wholesaling. According to the sector report on wholesaling, food service outlets buy over 20% of wholesale

grocery and related products. The food service industry includes a broad range of business types. Data specific to commercial cooking facilities such as restaurants and cafeterias were not available.

The U.S. Census Bureau provides basic data on "eating and drinking places" including sales, earnings, number of establishments, number of employees, and payroll. The sales data are broken down into various types of eating and drinking places. These data are also provided by the National Restaurant Association (NRA, 2002).

U.S. Department of Agriculture

Pechan contacted the U.S. Department of Agriculture (USDA) regarding food consumption data. The USDA does not track food away from home consumption or sales data which are specific to meat or meat cuts. Panel and individual survey data on food consumption was available which contains the amount of food consumed away from home. However, these data may not specify the meat cut or how the meat was cooked. The surveys were generally conducted for 2 week periods.

Scientific and Industry Literature

Pechan researched the scientific and industry literature to obtain information on the consumption and expenditures of meat products in the "away from home" market and sales of meat to restaurants and other food service facilities. The business, hospitality, and agriculture literature was reviewed. Several reports were obtained for expenditures in the "away from home" market and sales of meat, however, no information was obtained that was usable as activity data. The available agriculture data focused on the cost and sales of meat at the wholesale level, which as stated previously, does not distinguish between different types of food service suppliers, such as restaurants versus grocery stores. The hospitality literature focused on total sales of food by restaurant type and trends in the food and type of restaurants such as fast-food and national chains. The business literature focused on sales information by type of restaurant. There was limited information on sales at specific franchises and regional/national chains and types of meat such as hamburger.

Pechan reviewed one article which mentioned estimating emissions from meat cooking (Cabada, et al., 2002). The work was part of an effort to estimate atmospheric carbonaceous PM for a number of source categories in the Pittsburgh metropolitan area. The emissions estimate for meat cooking was developed using the population of the Pittsburgh area and the annual per capita consumption of meat in the United States from the U.S. Census Bureau State and Metropolitan Data Book. The estimate assumed that 90% of the meat consumed was fried and 10% was charbroiled. Meat cooking operations were assumed to remain constant during the year. In addition, no distinction was made between in home consumption and "away from home" consumption.

Meat and Food Service Industry Associations

Pechan contacted a variety of industry groups, including the National Restaurant Association and the American Meat Institute, to request information on the sales, consumption and expenditures of meat products in restaurants and the food service industry. None of the associations or institutions reported having data available on sales, consumption or expenditures of meat at restaurants or other commercial cooking facilities. The data are generally provided at a higher level than that desired for activity data.

Dun & Bradstreet

The Dun & Bradstreet Marketplace data provide facility counts by county and 8-digit SIC code (Dun & Bradstreet, 2002). These data also include facility counts by revenue class, which may be useful in future inventory development (e.g., at regional/local levels, if relationships are established between revenue and the amount of meat processed).

Environmental Agency Reports

EPA's Emission Inventory Improvement Program (EIIP) Area Source Method Abstract on charbroiling provides an average ground beef throughput per restaurant with a charbroiler of 1,160 pounds (lbs) cooked per week (EPA, 2000). This estimate was based on Whopper® and hamburger sales as posted on the Burger King® website (www.burgerking.com), and assumes an average hamburger weight of 0.25 lb.

Pechan contacted the Massachusetts Department of Environmental Protection (MADEP) to gather underlying information for their emission estimates for this source category (Santal, 2003). MADEP estimated VOC emissions from commercial charbroilers and commercial deep fat fryers using emission factors obtained from a 1992 EPA report (EPA, 1992). The EPA report provided equipment fractions and VOC emission factors to apply to facility counts.

Pechan reviewed documents pertaining to the SCAQMD Rule 1138 development process. This includes a staff report for the proposed Rule 1138 (SCAQMD, 1997) and a survey of commercial cooking operations in the SCAQMD conducted by PES (1999). In the staff report on the proposed rule, the average daily amount of hamburger cooked on a chain-driven charbroiler was estimated to be 233 lb. This value was based on confidential data provided by affected restaurants. No other meat types were discussed in the report. For comparison, Pechan calculated a value of 154 lb/day based on information provided on Burger King's web-site (Burger King, 2003). This estimate assumes one chain-driven charbroiler per facility, each hamburger patty weighs 0.25 lb prior to cooking, and 365 days of operation per year.

The study conducted by PES was to obtain accurate estimates of the total number of restaurants in the SCAQMD, to classify restaurants using a scheme that is relevant to meat cooking operations, and to obtain the distribution in the SCAQMD of the following:

- Types of cooking equipment;
- Types and amount of meats cooked for each equipment;
- Fuels used by cooking equipment;
- Fat content of hamburger cooked;

- Days per year of operation;
- Ventilation hoods and stacks; and
- Percentage of small businesses.

The total number of restaurants was obtained by reviewing lists of facilities regulated by the county health departments in the District. This total was adjusted to account for restaurants that had gone out of business. The remaining information was obtained by a detailed survey of restaurants.

CARB began work on estimating emissions from charbroiling activities at restaurants in the State of California. A detailed survey of restaurants was conducted by the Public Research Institute of San Francisco State University (PRI) (PRI, 2001). Pechan contacted CARB regarding further development of an emission inventory from charbroiling activity but was told that there were no plans for developing an inventory.

The PRI survey was similar to the PES survey, with a few key differences. First, PRI surveyed restaurants using computer-assisted telephone interviews instead of a self-administered (mail-out) questionnaire. Second, PRI used a more detailed restaurant classification scheme, and not all restaurant categories were surveyed. PRI surveyed a subset of restaurants most likely to employ charbroilers. Third, PRI surveyed fewer types of cooking devices.

In 2002, the San Joaquin Valley Unified Air Pollution Control District promulgated a rule regarding commercial charbroiling (SJVUAPCD, 2002). The Final Draft of the Staff report for Rule 4692 utilized the average pounds of meat cooked per day that SCAQMD utilized in its staff report for the proposed Rule 1138 (SCAQMD, 1997). The number of restaurants was determined from health department records on permitted restaurants.

METHODOLOGY

After reviewing the literature, Pechan developed activity data based on data provided by the PRI survey (PRI, 2001). From the 4,518 surveys sent to restaurants in the SCAQMD, PES obtained 543 usable responses. The PRI survey included a slightly larger sample, with 655 completed interviews. The PRI survey sample included restaurants from all over the State of California. Although the sample size of the PRI survey was only slightly larger than the PES survey, the PRI survey covered the entire State of California. This broader geographic coverage makes for a better fit with the national scope of this project.

PES categorized restaurants into 9 different types using a 6-digit SIC categorization approach. This type of approach does not fully resolve the types of restaurants that are thought to contribute the most emissions. For example, fast food chains were associated with a more generic group of establishments called “restaurants” rather than breaking out the type of restaurant into “limited service”and “full-service” restaurants

The CARB study conducted by PRI did not survey all types of restaurants. Instead, this study focused on a subset of restaurants most likely to employ charbroilers. These restaurant categories were classified using a system developed by Dun & Bradstreet (a 2-digit extension of

the 4-digit SIC code). Survey data from this study can be directly applied to national, county-level facility counts available from Dun & Bradstreet.

Table 1 provides the recommended source categories for the commercial cooking and charbroiling inventory. The following sources/pollutants were not included in the inventory: residential or special-event cooking; cooking processes at institutional facilities; cooking processes at facilities that do not fall within the surveyed categories. Criteria pollutant emissions associated with fuel combustion in cooking equipment are included in the commercial fuel combustion emissions sector of the NEI.

The technical memorandum (Pechan, 2003) presents data from the PRI survey that were used to construct the activity data for each source category (i.e., pounds of meat/year). There are no emission factors for pork; therefore, Pechan used emission factors for chicken to estimate emissions from the cooking of pork. Pechan used steak emission factors for the "other" category; which includes lamb, veal, and venison.

Pechan also estimated emissions from deep fat frying of french fries. The mass of frozen potatoes sold by food services in 2001 (6,736,530 lbs) was obtained from American Frozen Food Institute (USDA, 2001). French fries sold by fast food restaurants account for 91 percent (6,130,242 lbs) of frozen potatoes sold (Lucier, 2003). Also from this USDA source, 9,338 lbs of french fries was estimated to be sold by the other restaurant types. The national mass of french fries was allocated to the county level based on the number of deep fat fryers estimated for each county (from the survey and D&B data).

The only known area with controls in place with regards to commercial charbroiling is SCAQMD. Controls consistent with the requirements of Rule 1138 currently only affect chain-driven charbroilers (SCAQMD, 1997). Pechan applied an 86% control efficiency (CE) for VOC and an 83% CE for PM to uncontrolled chain-driven charbroiler emissions in the SCAQMD counties. For uncontrolled HAP emissions in SCAQMD, Pechan applied either the CE that was used to estimate controlled VOC emissions or the CE used to estimate controlled PM emissions depending on whether the HAP was in the particulate or gaseous form. Rule effectiveness for these four counties was set to 100%. Los Angeles and Orange counties are assumed to have 100% rule penetration. San Bernardino and Riverside counties were assumed to have 80% rule penetration, since about 80% of the population of these counties resides within the SCAQMD.

RESULTS

2002 National criteria pollutant and hazardous air pollutant (HAP) emissions are summarized in Table 2 by SCC and pollutant type. Emissions are expressed in tons per year.

Pechan reviewed the percent contribution of $PM_{2.5}$ emissions by source category to the total $PM_{2.5}$ commercial cooking emissions. The percentages are summarized in Figure 1. The total $PM_{2.5}$ commercial cooking emissions were also compared to various source category $PM_{2.5}$ emissions obtained from EPA's 2001 NEI (EPA, 2003a). Percent contributions, by source category, to the total 2001 area source NEI $PM_{2.5}$ emissions are summarized in Figure 2.

Pechan reviewed the percent contribution of total polycyclic aromatic hydrocarbon (PAH) emissions by source category to the total PAH commercial cooking emissions. The percentages are summarized in Figure 3. The total PAH commercial cooking emissions were compared to various source category PAH emissions obtained from EPA's 1999 NEI (EPA, 2003b). In the NEI, PAH emissions are expressed as either total PAH, 16-PAH, 7-PAH, or by PAH species. For the comparison, Pechan used all available PAH emissions from the NEI. Percent contributions, by source category, to the total 1999 area source NEI PAH emissions are summarized in Figure 4. Figures 5 and 6 show emission density plots of $PM_{2.5}$ emissions for the contiguous States and Alaska/Hawaii, respectively.

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Key Words

Emission Inventories
Commercial Cooking
PM
VOC

Table 1. Recommended source categories for commercial cooking.

SCC	Descriptor 1	Descriptor 2	Descriptor 3	Descriptor 4
2302002000	Industrial Processes	Food and Kindred Spirits: SIC 20	Commercial Cooking - Charbroiling	Charbroiling Total
2302002100	Industrial Processes	Food and Kindred Spirits: SIC 20	Commercial Cooking - Charbroiling	Conveyorized Charbroiling
2302002200	Industrial Processes	Food and Kindred Spirits: SIC 20	Commercial Cooking - Charbroiling	Under-fired Charbroiling
2302003000	Industrial Processes	Food and Kindred Spirits: SIC 20	Commercial Cooking - Frying	Deep Fat Frying
2302003100	Industrial Processes	Food and Kindred Spirits: SIC 20	Commercial Cooking - Frying	Flat Griddle Frying
2302003200	Industrial Processes	Food and Kindred Spirits: SIC 20	Commercial Cooking - Frying	Clamshell Griddle Frying

Table 2. 2002 national criteria and hazardous air pollutant emissions for commercial cooking.

Pollutants	Emissions by Source Classification Code (SCC) in tons per year					
	2302002000	2302002100	2302002200	2302003100	2302003200	2302003000
VOC	11,499	2,113	7,234	940	39	1,173
CO	33,004	7,401	23,662	1,941		
PM	85,515	8,460	60,304	15,679	1,073	
PM_{10}	85,515	8,460	60,304	15,679	1,073	
$PM_{2.5}$	79,320	8,201	58,295	11,916	909	
NAPHTHALENE	80.9	18.1	42.0	20.8		
BENZO[A]PYRENE	0.57	0.15	0.34	0.08		
ACENAPHTHYLENE	14.9	3.93	10.2	0.72		
FLUORENE	5.05	0.95	3.13	0.96		
PHENANTHRENE	27.7	4.35	13.8	9.61		
FLUORANTHENE	8.94	0.99	4.22	3.73		
PYRENE	12.00	1.33	5.70	4.97		
BENZ[A]ANTHRACENE	1.49	0.25	0.81	0.42		
INDENO[1,2,3-C,D]PYRENE	0.30	0.09	0.21			
ACENAPHTHENE	0.77	0.22	0.40	0.15		
ANTHRACENE	5.14	0.88	2.99	1.27		
BENZO[G,H,I,]PERYLENE	0.50	0.14	0.36			
PAH, TOTAL	205.6	42.9	121.9	40.8		
BIPHENYL	6.44	1.92	4.12	0.40		
BENZENE	1,237	154.3	1,083			
TOLUENE	489.7	61.2	428.5			
ETHYL BENZENE	94.4	12.2	82.2			
O-XYLENE	79.0	10.1	68.9			
XYLENES	69.6	8.57	61.1			
STYRENE	468.7	58.2	410.6			
FORMALDEHYDE	987.8	120.3	867.5			
ACETALDEHYDE	715.6	86.3	629.3			
PROPIONALDEHYDE	193.1	23.3	169.9			
ETHYLENE DICHLORIDE	38.9	4.28	34.6			
PHENOL	55.1	7.04	48.0			
ACETOPHENONE	5.92	0.74	5.18			
O-CRESOL	3.84	0.51	3.32			
P-CRESOL	7.75	1.05	6.70			
DIBUTYL PHTHALATE	4.37	0.59	3.78			
4-NITROPHENOL	12.4	2.02	10.4			

Figure 1. $PM_{2.5}$ emissions by commercial cooking source category.

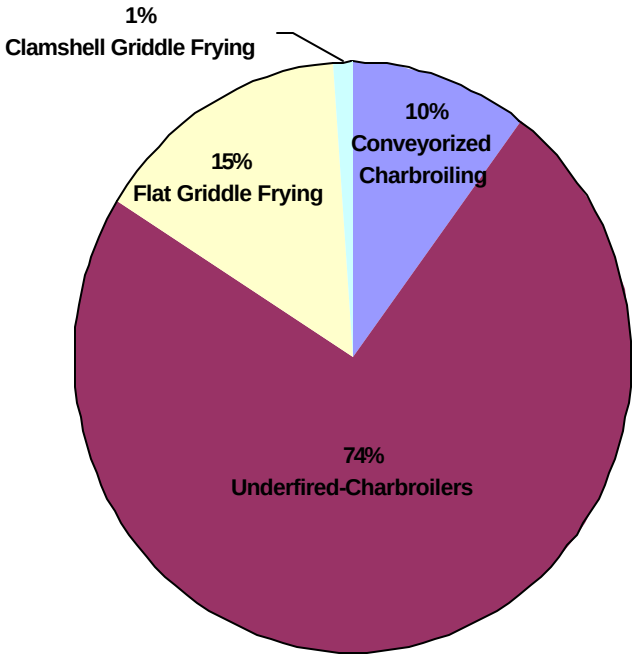
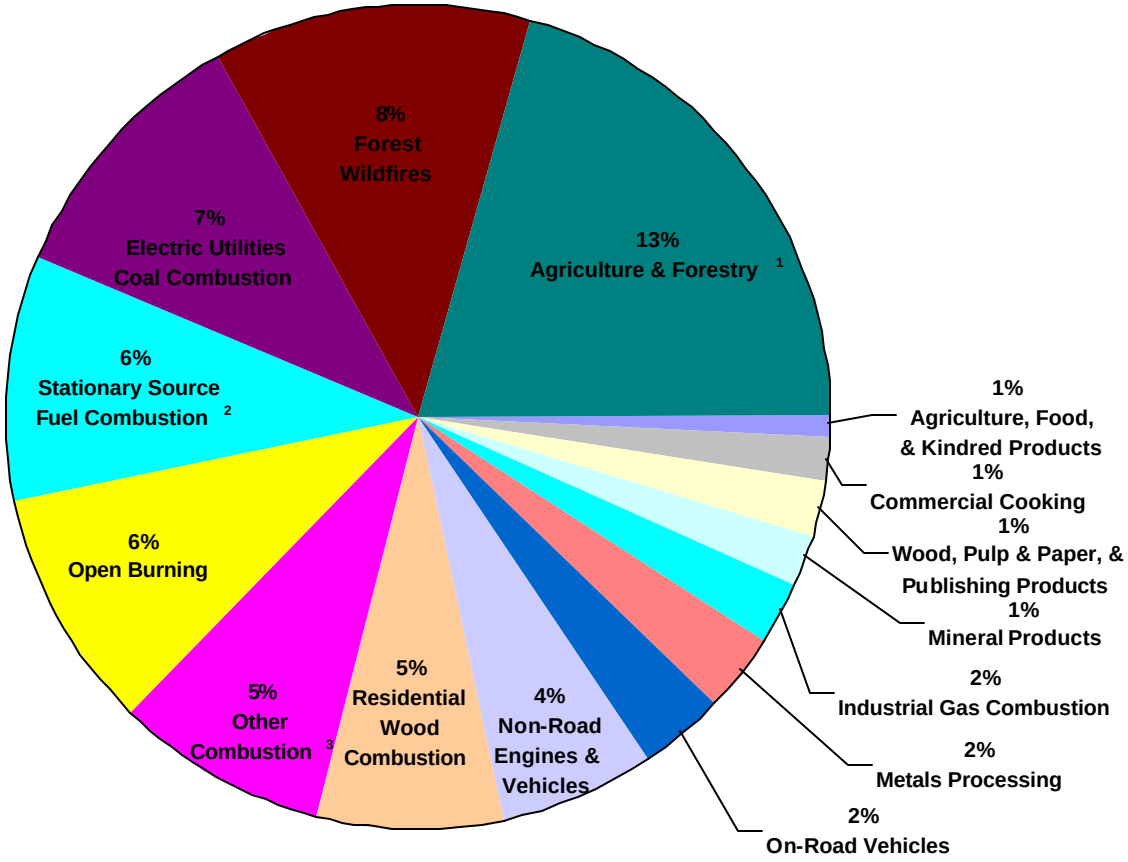


Figure 2. Comparison of commercial cooking $PM_{2.5}$ emissions to NEI 2001 $PM_{2.5}$ emissions.



1. Agriculture & Forestry consists of agricultural crops and agricultural livestock.
2. Stationary Source Fuel Combustion consists of electric utilities oil, gas, other, and internal combustion; industrial coal, oil, other, and internal combustion; commercial/institutional coal, oil, and gas combustion; miscellaneous fuel combustion (except residential), and residential other fuel combustion.
3. Other Combustion consists of structural fires, agricultural fires, slash/prescribed burning, and other miscellaneous area source combustion.

Figure 3. Total polycyclic aromatic hydrocarbon (PAH) emissions by commercial cooking source category.

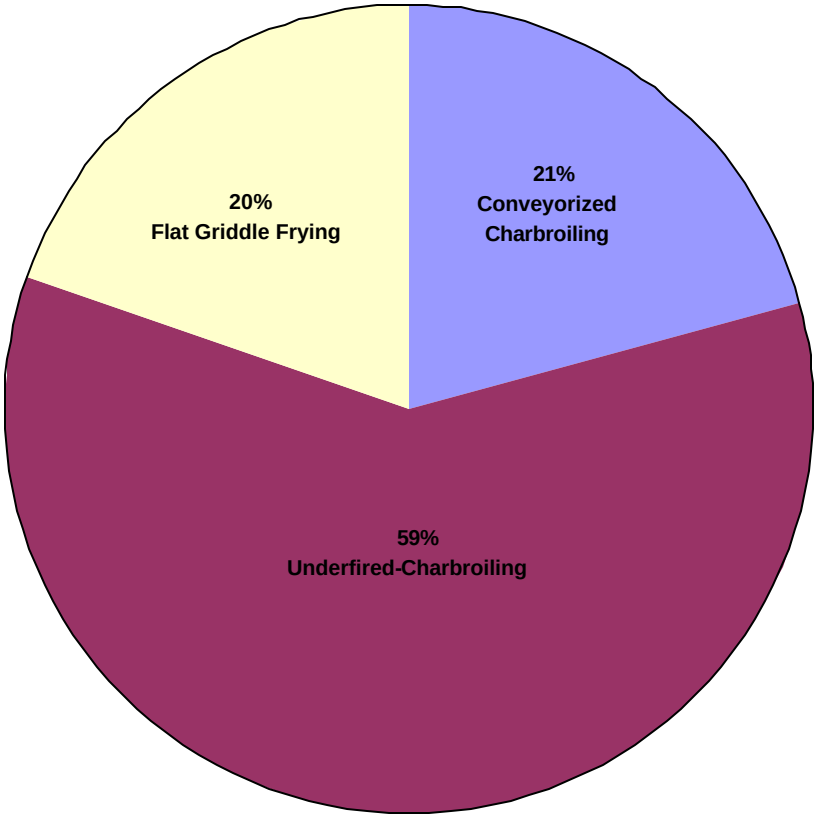
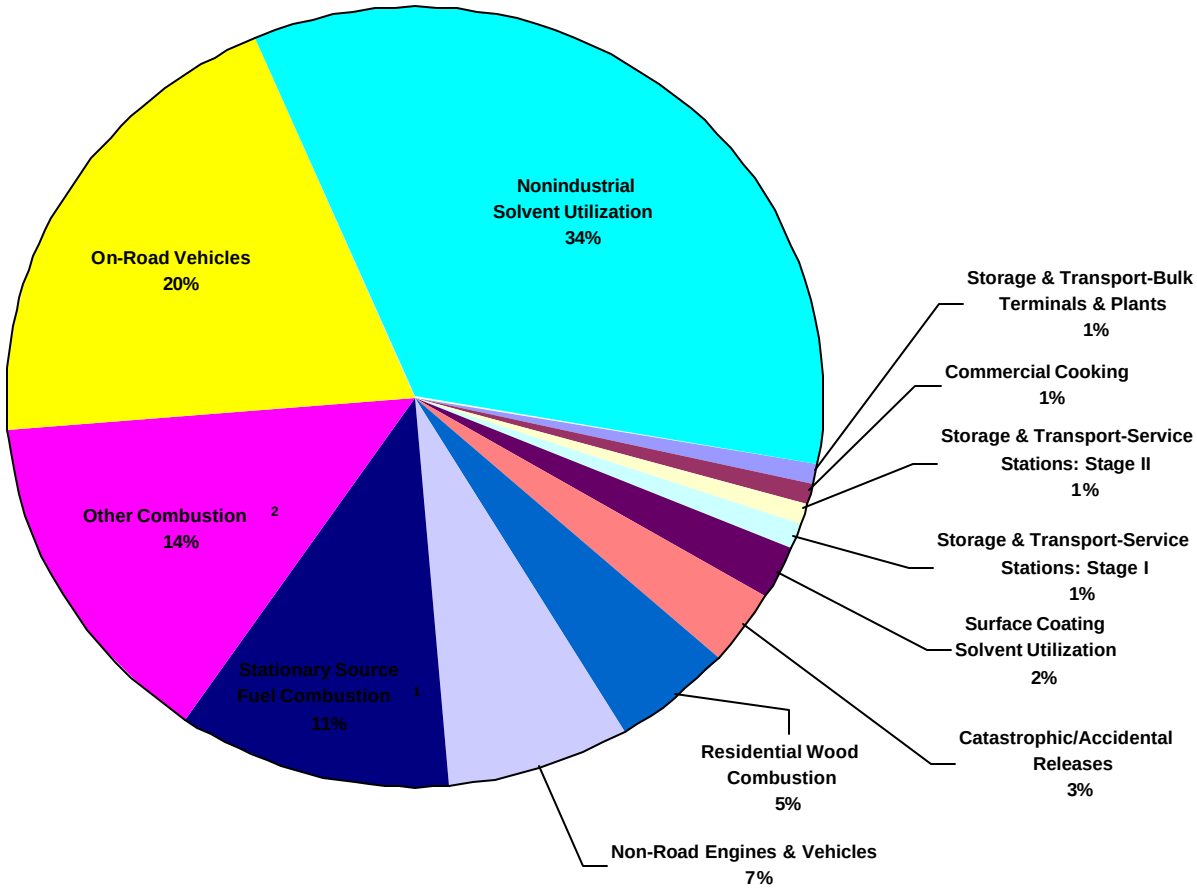


Figure 4. Comparison of commercial cooking PAH emissions to NEI 1999 PAH emissions.



1. Stationary Source Fuel Combustion consists of electric utilities oil, gas, other, and internal combustion; industrial coal, oil, other, and internal combustion; commercial/institutional coal, oil, and gas combustion, and miscellaneous fuel combustion (except residential).

2. Other Combustion consists of structural fires, agricultural fires, slash/prescribed burning, and other miscellaneous area source combustion.

Figure 5. 2002 NEI PM2.5 Emissions Density for the 48 Contiguous States (tons/year/mi^2)

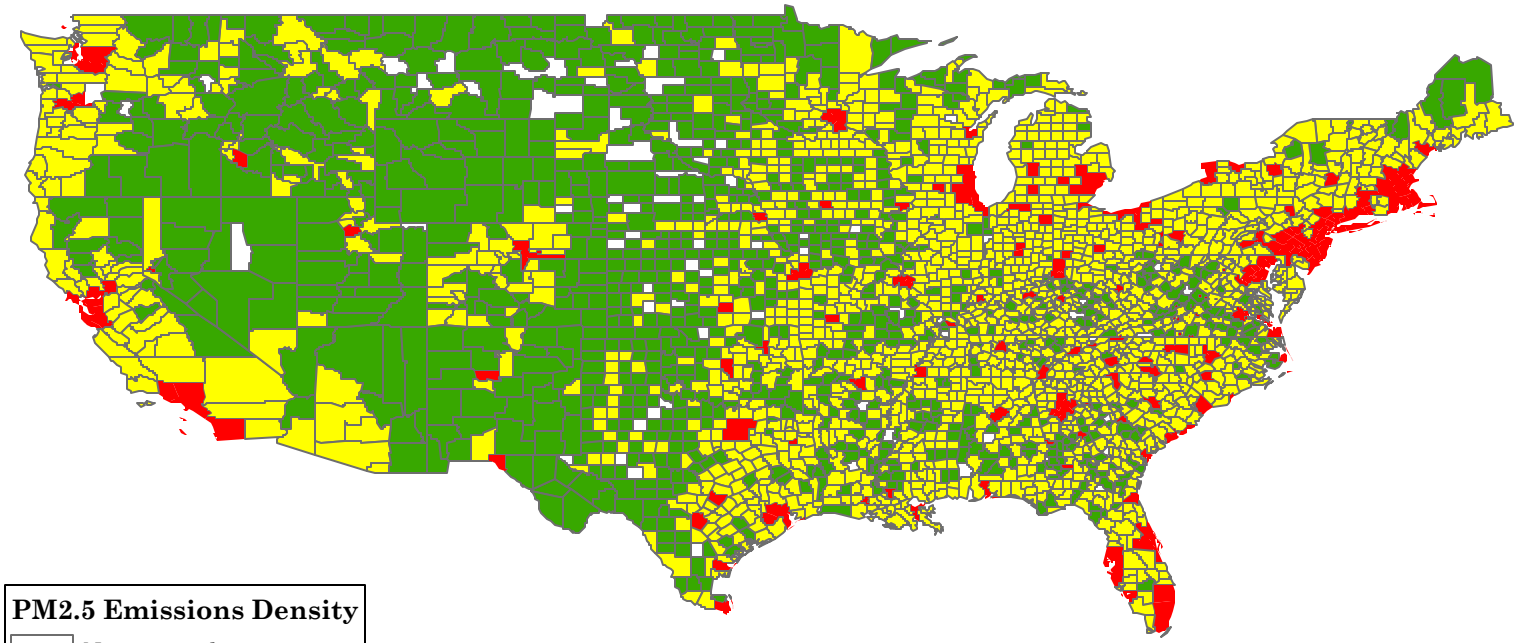


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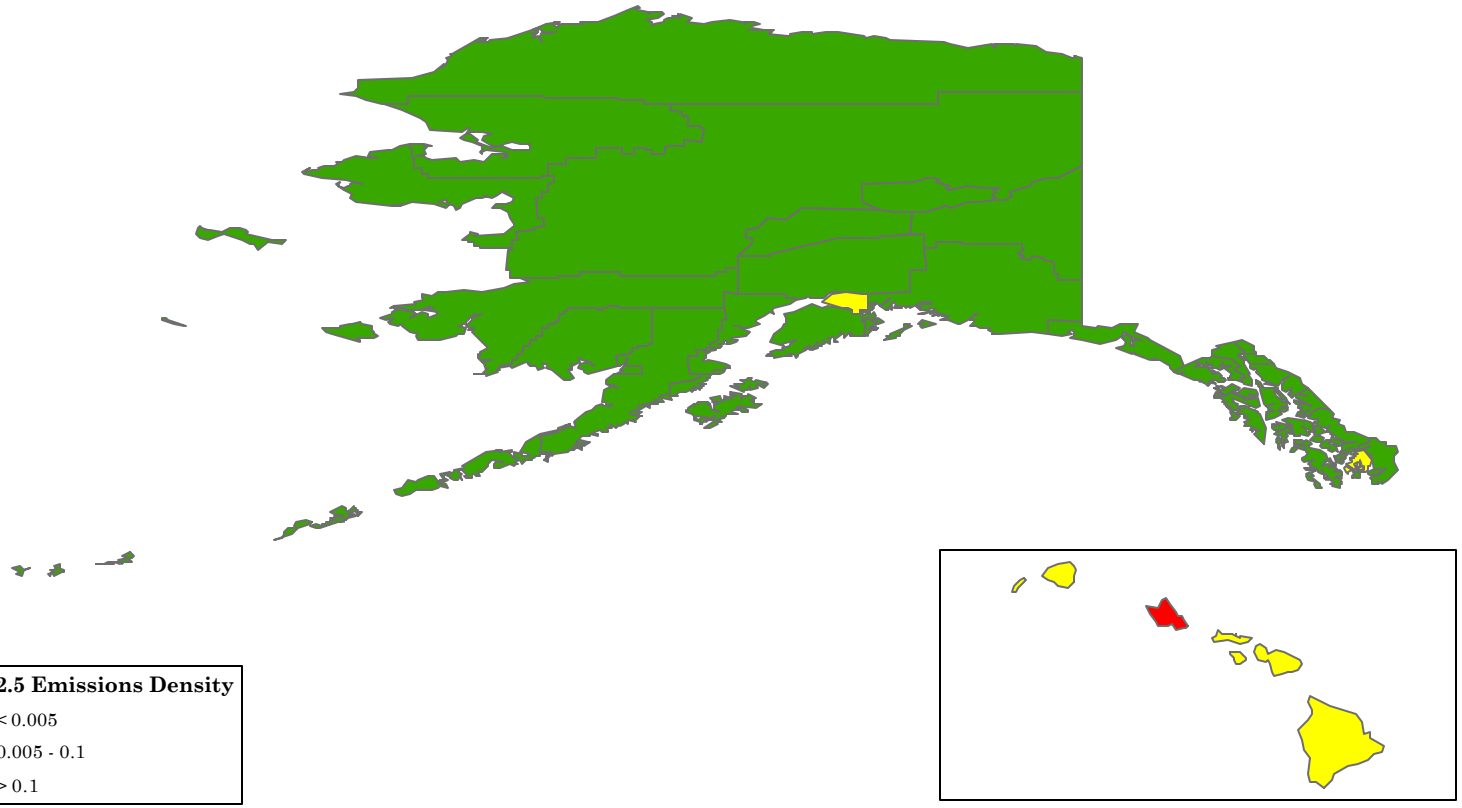
Figure 6. 2002 NEI PM2.5 Emissions Density for Alaska and Hawaii (tons/year/mi ^{2})



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