Commercial Cooking

# a. Sector description

Commercial cooking refers to the cooking of meat, including steak, hamburger, poultry, pork, and seafood, and french fries on five different cooking devices: chain-driven (conveyorized) charbroilers, underfired charbroilers, deep-fat fryers, flat griddles and clamshell griddles.

# b. Epa-developed commercial cooking emissions data

The approach to estimating emissions from commercial cooking in 2014 consists of three general steps, as follows:

* Determine county-level activity, i.e., the number of restaurants in each county in 2014 (see Section c);
* Determine the fraction of restaurants with commercial cooking equipment, the average number of units of each type of equipment per restaurant, and the average amount of food cooked on each type of equipment (see Section e); and
* Applying emission factors to each type of food for each type of commercial cooking equipment (see Section d).

For this source category, EPA estimated emissions for the SCCs listed in Table 1.

Table 1. Source Classification Codes used in the commercial cooking sector

| **SCC** | **SCC Description, level 3** | **SCC Descriptions, level 4** |
| --- | --- | --- |
| 2302002100 | Commercial Cooking – Charbroiling | Conveyorized Charbroiling |
| 2302002200 | Commercial Cooking – Charbroiling | Under-fired Charbroiling |
| 2302003000 | Commercial Cooking – Frying | Deep Fat Fying |
| 2302003100 | Commercial Cooking – Frying | Flat Griddle Frying |
| 2302003200 | Commercial Cooking – Frying | Clamshell Griddle Frying |

# c. Activity data

Data on the number of restaurants in each county are available from the U.S. Census Bureau County Business Patterns database, which reports the number of restaurants (categorized by NAICS code) in each county. The 2002 NEI, which is the most recent inventory in which the emissions from commercial cooking were estimated using restaurant-level data, rather than population data used by the Dun and Bradstreet industry database, which contains more specific information on the type of restaurant in each county. The documentation from the 2002 NEI identifies five specific categories of restaurants that are likely to have the equipment that matches the source categories for commercial cooking emissions, including: Ethnic food restaurants, Fast food restaurants, Family restaurants, Seafood restaurants, and Steak & Barbecue restaurants. Because Dun and Bradstreet data for 2014 were not readily available, the number of restaurants in each county was estimated using a two-step process. First the number of restaurants in 2002 was estimated using the following equation:

|  |  |  |
| --- | --- | --- |
|  |  | (1) |

where:

*RESTi,2002* = the total number of restaurants in county *i* in 2002

*Eijmn­,2002 =* the emissions of pollutant *n* from food *m* cooked on source category *j* in county *i* in 2002, as reported in the National Emissions Inventory

*FRACj =* the fraction of restaurants in those categories that have equipment in source ­*j*

*UNITSj* = the average number of units of source category *j* in each restaurant

*FOOD­jm =* the average amount of food *m* cooked on source category ­*j*

*EF­jmn =* the emission factor for pollutant *n* from food *m* cooked on source category *j*

The values of *FRACi, UNITSi,* and *FOODi*, came from Potepan (2001, see Section e). The emission factors are from an E.H. Pechan and Associates memorandum (see Section d).

Next, a growth factor based on the change in the number of restaurants in each county between 2002 and 2014 was generated using data from the U.S. Census Bureau County Business Patterns database for NAICS code 722511 (*Full-Service Restaurants*) and NAICS code 722513 (*Limited-Service Restaurants*) (United States Census Bureau, 2014). For example, if the number of restaurants in a particular county increased from 100 to 125 between 2002 and 2014, the growth factor would be 1.25; in some cases the number of restaurants decreased, and the growth factor was less than 1. This growth factor was multiplied by the number of restaurants in each county in 2002, as shown in equation 2, to estimate the number of restaurants in 2014:

|  |  |  |
| --- | --- | --- |
|  |  | (2) |

where *GFi*is the growth factor for county *i*.

# d. Emission factors

Emission factors for each type of food on each type of commercial cooking equipment (*EFjmn*)came from a technical memorandum developed by E.H. Pechan and Associates (2003). This information remains the most complete catalog of emission factors for commercial cooking; a recent review of the literature on emissions from cooking revealed no new studies with a similar breadth of pollutants analyzed (Abdullahi et al., 2013). The particulate matter (PM) emission factors from E.H. Pechan and Associates only contain primary PM. The emission factors for filterable PM were derived by applying ratios to primary PM (Table 2). The condensable particulate matter (PM-CON) emission factors were derived by subtracting PM10-FIL from PM10-PRI. See Table 5 at the end of this document for a complete list of the emissions factors.

HAP emissions from deep-fat frying, flat griddle frying, and clamshell griddle frying are estimated using speciation factors from EPA’s SPECIATE database (U.S. Environmental Protection Agency, 2016). These speciation factors are listed in Table 6.

Table 2. Ratio of filterable particulate matter to primary particulate matter for PM2.5 and PM10 by SCC.

|  |  |  |  |
| --- | --- | --- | --- |
| **Cooking Device** | **SCC** | **PM25-FIL / PM25-PRI** | **PM10-FIL / PM10-PRI** |
| Conveyorized Charbroiling | 2302002100 | 0.00321 | 0.00331 |
| Underfired Charbroiling | 2302002200 | 0.00287 | 0.00297 |
| Flat Griddle Frying | 2302003100 | 0.00201 | 0.00264 |
| Clamshell Griddle Frying | 2302003200 | 0.00241 | 0.00283 |

# e. Emissions

After determining the number of establishments in 2014 using Equation 2, the amount of emissions in 2014 was determined by rearranging Equation 1:

|  |  |  |
| --- | --- | --- |
|  |  | (3) |

where *Eijmn,*2014 is the emissions of pollutant *n* from food *m* cooked on commercial equipment *j* in county *i* in 2014.

The fraction of restaurants with commercial cooking equipment (*FRACj*), the average units of equipment per restaurant (*UNITSj*), and the average amount of each type of food cooked on each type of equipment (*FOODj*), were obtained from Potepan (2001). Because Potepan reports the fraction of restaurants with commercial cooking equipment broken down by subcategories of restaurant types (Ethnic food restaurants, Fast food restaurants, Family restaurants, Seafood restaurants, and Steak & Barbecue restaurants), a weighted average of these fractions was calculated to determine an overall fraction of the number of all restaurants across all five subcategories that utilize commercial cooking equipment. Furthermore, because Potepan reports that 31% of all restaurants fall into one of those five subcategories, the weighted averages were multiplied by 0.31 to determine the fraction of all restaurants in each county with commercial cooking equipment. These numbers are reported in Table 3. The percentage of restaurants with under-fired charbroilers (12.5%) is similar to a more recent survey in North Carolina, which found that 13% of surveyed restaurants employed charbroilers (NC Division of Air Quality 2013). The North Carolina survey did not include the other types of commercial cooking equipment reported here.

Table 3. Fraction of restaurants with source category equipment and average number of units per restaurant.

|  |  |  |  |
| --- | --- | --- | --- |
| **Source Category** | **SCC** | **Percent of Restaurants with Equipment (*FRACj*)** | **Average Number of Units Per Restaurant (*UNITSj*)** |
| Conveyorized Charbroiling | 2302002100 | 3.6% | 1.3 |
| Under-fired Charbroiling | 2302002200 | 12.5% | 1.5 |
| Deep Fat Frying | 2302003000 | 28.0% | 2.5 |
| Flat Griddle Frying | 2302003100 | 18.4% | 1.6 |
| Clamshell Griddle Frying | 2302003200 | 2.8% | 1.7 |

Potepan also estimated the average annual amount of food cooked on each type of commercial cooking equipment (*FOODj*). These numbers are reported in Table 4 below. The amount of french fried potatoes cooked in deep-fat fryers was estimated by dividing the total weight of frozen potatoes utilized in domestic food service (6.9 million tons, United States Potato Board, 2011) by the estimated number of deep-fryers in the United States (303,918 deep-fryers).

Table 4. Average amount of food cooked per year (tons/year) on each type of commercial cooking equipment.

| **Food** | **Conveyorized Charbroiling** | **Under-fired Charbroiling** | **Deep Fat Frying** | **Flat Griddle Frying** | **Clamshell Griddle Frying** |
| --- | --- | --- | --- | --- | --- |
| Steak | 6.1 | 4.7 | 4.7 | 4.3 | 2.4 |
| Hamburger | 20.7 | 7.0 | 7.1 | 9.4 | 34.2 |
| Poultry | 10.7 | 8.4 | 14.9 | 5.2 | 5.7 |
| Pork | 1.5 | 3.8 | 1.5 | 2.9 | 3.1 |
| Seafood | 3.1 | 3.7 | 4.1 | 2.4 | 16.4 |
| Other | - | 1.1 | 7.1 | 1.5 | - |
| Potatoes | - | - | 21.3 | - | - |

# f. Sample calculations

Determining the Number of Restaurants in Each County in 2002

|  |  |  |
| --- | --- | --- |
|  |  |  |

Emissions of PM2.5 from underfired charbroilers in county *i* in 2002 were 8.76 tons. To determine the number of restaurants that generated these emissions in 2002, the emissions are divided by the fraction of restaurants that use underfired charbroilers (0.125), the average number of underfired charbroilers used at each restaurant (1.54), the average amount of hamburger cooked on each underfired charbroiler (7.02 tons/year), and the emission factor for PM2.5 from hamburger cooked on underfired charbroilers (0.032 tons PM2.5 per ton of hamburger). The result shows that there were 203 restaurants in county *i* in 2002. This process is repeated for each SCC (Table 1) and each type of food (Table 4) in each county.

Determining the Number of Restaurants in Each County in 2014

Using the estimated number of restaurants in 2002, the number of restaurants in 2014 was determined by employing a growth factor based on the change in the number of restaurants between 2002 and 2014 as determined by the U.S. Census Bureau County Business Statistics Database.

|  |  |  |
| --- | --- | --- |
|  |  |  |

There were 203 restaurants estimated to be in county *i* in 2002. Data from the U.S. Census Bureau show that there was a 16% increase in the number of restaurants in county *i* between 2002 and 2014. The growth factor (1.16) was multiplied by 203 to estimate that there were 235 restaurants in county *i* in 2014. Note that the actual number of restaurants in 2014 as determined from the U.S. Census Bureau County Business Statistics database is not equal to *RESTi,*2014as determined by the equation above because the emissions from the 2002 NEI were calculated using activity data from the Dun and Bradstreet database, rather than the U.S. Census Bureau County Business Statistics database.

Determining the Emissions in 2014

The emissions in 2014 were determined using the following equation:

|  |  |  |
| --- | --- | --- |
|  |  |  |

There were 235 restaurants in county *i* in 2014. This was multiplied by the fraction of restaurants that use underfired charbroilers (0.125), the average number of underfired charbroilers used at each restaurant (1.54), the average amount of hamburger cooked on each underfired charbroiler (7.02 tons/year), and the emission factor for PM2.5 from hamburger cooked on underfired charbroilers (0.032 tons PM2.5 per ton of hamburger). The result shows that the emissions of PM2.5 in county *i* were 10.16 tons in 2014.

# g. Changes from 2011 methodology

The growth factors were updated using data on the number of restaurants in 2002 and 2014 from the U.S. Census Bureau County Business Statistics Database.

# h. Puerto rico and us virgin islands emissions calculations

Since insufficient data exists to calculate emissions for the counties in Puerto Rico and the US Virgin Islands, emissions are based on two proxy counties in Florida: 12011, Broward County for Puerto Rico and 12087, Monroe County for the US Virgin Islands. The total emissions in tons for these two Florida counties are divided by their respective populations creating a tons per capita emission factor. For each Puerto Rico and US Virgin Island county, the tons per capita emission factor is multiplied by the county population (from the same year as the inventory’s activity data) which served as the activity data. In these cases, the throughput (activity data) unit and the emissions denominator unit are “EACH”.

# i. References

Abdullahi, K.L, J.M. Delgado-Saborit, and R.M. Harrison. 2013. Emissions and indoor concentrations of particulate matter and its specific chemical components from cooking: a review. Atmospheric Environment, 71: 260–294.

E.H. Pechan and Associates. 2003. Methods for Developing a National Inventory for Commercial Cooking Processes: Technical Memorandum

North Carolina Division of Air Quality. [2013. Supplement Section 110(a)(1) Maintenance Plan - February 2013, Appendix B, Section 4.4.4](https://ncdenr.s3.amazonaws.com/s3fs-public/Air%20Quality/planning/attainment/Triad/Triad_Supplement_SIP_Narrative_04122013.pdf)., (accessed May 2019)

Potepan, M. 2001. [Charbroiling Activity Estimation. Public Research Institute, report for the California Air Resources Board and the California Environmental Protection Agency](https://ww3.arb.ca.gov/research/apr/reports/l943.pdf), available (accessed May 2019)

United States Census Bureau, 2014 [County Business Patterns](https://www.census.gov/programs-surveys/cbp.html), available at (accessed May 2019)

U.S. Environmental Protection Agency. [2016. SPECIATE Database v4.5](https://www.epa.gov/air-emissions-modeling/speciate).

United States Potato Board. 2011. Potato Sales and Utilization Estimates 2001-2010

Table 5. Emissions factors for commercial cooking.

| **SCC** | **Cooking Device** | **Pollutant Description** | **Pollutant Code** | **Emissions Factor (lbs. per ton throughput)** |
| --- | --- | --- | --- | --- |
| 2302002200 | Under-fired Charbroiling | 4-NITROPHENOL | 100027 | 0.005624 |
| 2302002100 | Conveyorized Charbroiling | 4-NITROPHENOL | 100027 | 0.003826 |
| 2302002200 | Under-fired Charbroiling | ETHYL BENZENE | 100414 | 0.044503 |
| 2302002100 | Conveyorized Charbroiling | ETHYL BENZENE | 100414 | 0.023188 |
| 2302002100 | Conveyorized Charbroiling | STYRENE | 100425 | 0.110143 |
| 2302002200 | Under-fired Charbroiling | STYRENE | 100425 | 0.222409 |
| 2302002200 | Under-fired Charbroiling | P-CRESOL | 106445 | 0.003632 |
| 2302002100 | Conveyorized Charbroiling | P-CRESOL | 106445 | 0.001988 |
| 2302002200 | Under-fired Charbroiling | ETHYLENE DICHLORIDE | 107062 | 0.018742 |
| 2302002100 | Conveyorized Charbroiling | ETHYLENE DICHLORIDE | 107062 | 0.008116 |
| 2302002100 | Conveyorized Charbroiling | TOLUENE | 108883 | 0.11594 |
| 2302002200 | Under-fired Charbroiling | TOLUENE | 108883 | 0.232132 |
| 2302002100 | Conveyorized Charbroiling | PHENOL | 108952 | 0.013333 |
| 2302002200 | Under-fired Charbroiling | PHENOL | 108952 | 0.02601 |
| 2302002200 | Under-fired Charbroiling | ANTHRACENE | 120127 | 0.001622 |
| 2302002100 | Conveyorized Charbroiling | ANTHRACENE | 120127 | 0.001669 |
| 2302002100 | Conveyorized Charbroiling | PROPIONALDEHYDE | 123386 | 0.044057 |
| 2302002200 | Under-fired Charbroiling | PROPIONALDEHYDE | 123386 | 0.092009 |
| 2302002100 | Conveyorized Charbroiling | PYRENE | 129000 | 0.002508 |
| 2302002200 | Under-fired Charbroiling | PYRENE | 129000 | 0.003087 |
| 2302002100 | Conveyorized Charbroiling | XYLENES | 1330207 | 0.016232 |
| 2302002200 | Under-fired Charbroiling | XYLENES | 1330207 | 0.033076 |
| 2302002200 | Under-fired Charbroiling | BENZO[G,H,I,]PERYLENE | 191242 | 0.000196 |
| 2302002100 | Conveyorized Charbroiling | BENZO[G,H,I,]PERYLENE | 191242 | 0.000256 |
| 2302002200 | Under-fired Charbroiling | INDENO[1,2,3-C,D]PYRENE | 193395 | 0.000115 |
| 2302002100 | Conveyorized Charbroiling | INDENO[1,2,3-C,D]PYRENE | 193395 | 0.000162 |
| 2302002200 | Under-fired Charbroiling | FLUORANTHENE | 206440 | 0.002287 |
| 2302002100 | Conveyorized Charbroiling | FLUORANTHENE | 206440 | 0.001863 |
| 2302002200 | Under-fired Charbroiling | ACENAPHTHYLENE | 208968 | 0.005542 |
| 2302002100 | Conveyorized Charbroiling | ACENAPHTHYLENE | 208968 | 0.007423 |
| 2302002200 | Under-fired Charbroiling | FORMALDEHYDE | 50000 | 0.46992 |
| 2302002100 | Conveyorized Charbroiling | FORMALDEHYDE | 50000 | 0.227822 |
| 2302002200 | Under-fired Charbroiling | BENZO[A]PYRENE | 50328 | 0.000187 |
| 2302002100 | Conveyorized Charbroiling | BENZO[A]PYRENE | 50328 | 0.000275 |
| 2302002200 | Under-fired Charbroiling | BENZ[A]ANTHRACENE | 56553 | 0.000441 |
| 2302002100 | Conveyorized Charbroiling | BENZ[A]ANTHRACENE | 56553 | 0.000477 |
| 2302002200 | Under-fired Charbroiling | BENZENE | 71432 | 0.586544 |
| 2302002100 | Conveyorized Charbroiling | BENZENE | 71432 | 0.292169 |
| 2302002200 | Under-fired Charbroiling | ACETALDEHYDE | 75070 | 0.340875 |
| 2302002100 | Conveyorized Charbroiling | ACETALDEHYDE | 75070 | 0.163475 |
| 2302002200 | Under-fired Charbroiling | ACENAPHTHENE | 83329 | 0.000219 |
| 2302002100 | Conveyorized Charbroiling | ACENAPHTHENE | 83329 | 0.000415 |
| 2302002200 | Under-fired Charbroiling | DIBUTYL PHTHALATE | 84742 | 0.002049 |
| 2302002100 | Conveyorized Charbroiling | DIBUTYL PHTHALATE | 84742 | 0.001113 |
| 2302002200 | Under-fired Charbroiling | PHENANTHRENE | 85018 | 0.00746 |
| 2302002100 | Conveyorized Charbroiling | PHENANTHRENE | 85018 | 0.008221 |
| 2302002200 | Under-fired Charbroiling | FLUORENE | 86737 | 0.001698 |
| 2302002100 | Conveyorized Charbroiling | FLUORENE | 86737 | 0.001806 |
| 2302002200 | Under-fired Charbroiling | NAPHTHALENE | 91203 | 0.022748 |
| 2302002100 | Conveyorized Charbroiling | NAPHTHALENE | 91203 | 0.034368 |
| 2302002200 | Under-fired Charbroiling | BIPHENYL | 92524 | 0.002233 |
| 2302002100 | Conveyorized Charbroiling | BIPHENYL | 92524 | 0.003623 |
| 2302002200 | Under-fired Charbroiling | O-XYLENE | 95476 | 0.037336 |
| 2302002100 | Conveyorized Charbroiling | O-XYLENE | 95476 | 0.01913 |
| 2302002200 | Under-fired Charbroiling | O-CRESOL | 95487 | 0.001799 |
| 2302002100 | Conveyorized Charbroiling | O-CRESOL | 95487 | 0.000974 |
| 2302002200 | Under-fired Charbroiling | ACETOPHENONE | 98862 | 0.002804 |
| 2302002100 | Conveyorized Charbroiling | ACETOPHENONE | 98862 | 0.001409 |
| 2302002200 | Under-fired Charbroiling | Carbon Monoxide | CO | 12.81754 |
| 2302003100 | Flat Griddle Frying | Carbon Monoxide | CO | 0.733239 |
| 2302003000 | Deep Fat Frying | Carbon Monoxide | CO | 0 |
| 2302003200 | Clamshell Griddle Frying | Carbon Monoxide | CO | 0 |
| 2302002100 | Conveyorized Charbroiling | Carbon Monoxide | CO | 13.364824 |
| 2302002200 | Under-fired Charbroiling | Nitrogen Oxides | NOX | 0 |
| 2302002200 | Under-fired Charbroiling | PM10-PRI | PM10-PRI | 32.666124 |
| 2302003100 | Flat Griddle Frying | PM10-PRI | PM10-PRI | 5.922517 |
| 2302003200 | Clamshell Griddle Frying | PM10-PRI | PM10-PRI | 1.006137 |
| 2302003000 | Deep Fat Frying | PM10-PRI | PM10-PRI | 0 |
| 2302002100 | Conveyorized Charbroiling | PM10-PRI | PM10-PRI | 15.996058 |
| 2302002200 | Under-fired Charbroiling | PM25-PRI | PM25-PRI | 31.577929 |
| 2302003100 | Flat Griddle Frying | PM25-PRI | PM25-PRI | 4.501113 |
| 2302003200 | Clamshell Griddle Frying | PM25-PRI | PM25-PRI | 0.852257 |
| 2302003000 | Deep Fat Frying | PM25-PRI | PM25-PRI | 0 |
| 2302002100 | Conveyorized Charbroiling | PM25-PRI | PM25-PRI | 15.506208 |
| 2302002200 | Under-fired Charbroiling | Sulfur Dioxide | SO2 | 0 |
| 2302002200 | Under-fired Charbroiling | Volatile Organic Compounds | VOC | 3.918318 |
| 2302003000 | Deep Fat Frying | Volatile Organic Compounds | VOC | 0.129029 |
| 2302003100 | Flat Griddle Frying | Volatile Organic Compounds | VOC | 0.35508 |
| 2302003200 | Clamshell Griddle Frying | Volatile Organic Compounds | VOC | 0.036472 |
| 2302002100 | Conveyorized Charbroiling | Volatile Organic Compounds | VOC | 4.002084 |

Table 6. VOC speciation factors for deep fat frying, flat griddle frying, and clamshell griddle frying. HAP emissions are estimated by multiplying the speciation factors by VOC emissions.

| **SCC** | **Cooking Device** | **Pollutant Code** | **Pollutant Description** | **Speciation Factor (tons emissions per ton VOC emissions)** |
| --- | --- | --- | --- | --- |
| 2302003000 | Deep Fat Frying | 120127 | Anthracene | 5.2E-05 |
| 2302003000 | Deep Fat Frying | 123386 | Propionaldehyde (or Propanal; 1-Propanone; 1-Propanal) | 0.060611 |
| 2302003000 | Deep Fat Frying | 129000 | Pyrene | 0.000165 |
| 2302003000 | Deep Fat Frying | 206440 | Fluoranthene | 0.000165 |
| 2302003000 | Deep Fat Frying | 208968 | Acenaphthylene | 0.000165 |
| 2302003000 | Deep Fat Frying | 50000 | Formaldehyde | 0.107369 |
| 2302003000 | Deep Fat Frying | 75070 | Acetaldehyde | 0.180968 |
| 2302003000 | Deep Fat Frying | 85018 | Phenanthrene | 0.000719 |
| 2302003000 | Deep Fat Frying | 91203 | Naphthalene | 0.002927 |
| 2302003100 | Flat Griddle Frying | 120127 | Anthracene | 5.2E-05 |
| 2302003100 | Flat Griddle Frying | 123386 | Propionaldehyde (or Propanal; 1-Propanone; 1-Propanal) | 0.060611 |
| 2302003100 | Flat Griddle Frying | 129000 | Pyrene | 0.000165 |
| 2302003100 | Flat Griddle Frying | 206440 | Fluoranthene | 0.000165 |
| 2302003100 | Flat Griddle Frying | 208968 | Acenaphthylene | 0.000165 |
| 2302003100 | Flat Griddle Frying | 50000 | Formaldehyde | 0.107369 |
| 2302003100 | Flat Griddle Frying | 75070 | Acetaldehyde | 0.180968 |
| 2302003100 | Flat Griddle Frying | 85018 | Phenanthrene | 0.000719 |
| 2302003100 | Flat Griddle Frying | 91203 | Naphthalene | 0.002927 |
| 2302003200 | Clamshell Griddle Frying | 120127 | Anthracene | 5.2E-05 |
| 2302003200 | Clamshell Griddle Frying | 123386 | Propionaldehyde (or Propanal; 1-Propanone; 1-Propanal) | 0.060611 |
| 2302003200 | Clamshell Griddle Frying | 129000 | Pyrene | 0.000165 |
| 2302003200 | Clamshell Griddle Frying | 206440 | Fluoranthene | 0.000165 |
| 2302003200 | Clamshell Griddle Frying | 208968 | Acenaphthylene | 0.000165 |
| 2302003200 | Clamshell Griddle Frying | 50000 | Formaldehyde | 0.107369 |
| 2302003200 | Clamshell Griddle Frying | 75070 | Acetaldehyde | 0.180968 |
| 2302003200 | Clamshell Griddle Frying | 85018 | Phenanthrene | 0.000719 |
| 2302003200 | Clamshell Griddle Frying | 91203 | Naphthalene | 0.002927 |