Sonoma Technology, Inc.
Air Quality Research and Innovative Solutions

April 23, 2010

To: Dr. Phil Martien — STI-909034-3859
Bay Area Air Quality Management District (BAAQMD)

From: Stephen B. Reid, Manager, Emissions Assessment
Erin K. Pollard, Atmospheric Modeler
Yuan Du, Emissions Inventory Specialist

Re: Draft documentation of the preparation of future-year emissions inventories of toxic air contaminants for the San Francisco Bay Area (Contract No. 2009-127)

This memorandum documents work performed for the project referenced above, which was part of an ongoing effort by the Bay Area Air Quality Management District's (District) Community Air Risk Evaluation (CARE) program to characterize and reduce health risks from toxic air contaminants (TACs) emitted in the San Francisco Bay Area. In support of the CARE program's goals, Sonoma Technology, Inc. (STI) collaborated with District staff to prepare future-year 2015 and 2020 screening-level gridded emissions inventories of TACs for the nine counties (or partial counties) in the District's jurisdiction.[1]

In general, the methods used to develop the future-year TAC inventories are the same as those STI previously used to develop base-year (2000 and 2005) TAC inventories for the District (Reid et al., 2006; Reid, 2008). Chemical speciation profiles and unit risk factors/reference concentrations were applied to the District's projected total organic gas (TOG) and particulate matter less than 10 microns (PM_{10}) emissions inventories to generate mass-based and risk-weighted TAC inventories. These inventories were then spatially distributed to the District's 1-km x 1-km modeling domain using gridded surrogate data developed by STI. However, several new sources of data were utilized in the development of the future-year TAC inventories, including socioeconomic forecasts from the Association of Bay Area Governments (ABAG), which STI used to develop spatial surrogate data for 2015 and 2020. Also, additional steps were required to develop the future-year inventories, including an assessment of the impact of diesel regulations passed by the California Air Resources Board (ARB) on future-year diesel particulate matter (DPM) emissions from on-road and non-road mobile sources. A complete list of tasks completed during the development of the 2015 and 2020 TAC inventories is provided below:

- Task 1 – Review future-year spatial surrogate options
- Task 2 – Estimate the impact of diesel regulations on future-year DPM emissions
- Task 3 – Acquire and review future-year emissions inventories

[1] The District regulates air pollution in Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, southwestern Solano, and southern Sonoma counties.

- Task 4 – Apply speciation profiles, toxicity weighting factors, and DPM control factors
- Task 5 – Spatially distribute TAC emissions
- Task 6 – Assign temporal profiles to individual source categories
- Task 7 – Set up emissions modeling files

The methods and data sets used to perform each task associated with the development of the future-year TAC emissions inventories are described in the remainder of this document.

REVIEW FUTURE-YEAR SPATIAL SURROGATE OPTIONS (TASK 1)

For the 2015 and 2020 future-year TAC inventories, new spatial allocation factors were developed that reflect projected changes in the geographic distribution of emissions sources. A review of available spatial data assessed whether any of the data used to develop the current 2005 surrogates have been updated, and whether new data sources are available for development of future-year surrogates. To develop and assign future-year surrogates to the 2015 and 2020 toxic emissions inventories, STI followed the same method it used to develop base- and future-year gridded surrogates for the state of California for ARB (Funk et al., 2001; Reid, 2008). This method produced three types of future-year surrogates:

- The future-year surrogate is the same as the base-year surrogate and has not been updated because the underlying spatial data are likely to remain representative of future years (or no alternative projected data are available).
- The future-year surrogate is the same as the base-year surrogate, but the underlying spatial data have been updated with projected future-year data.
- The future-year surrogate is not the same as the base-year surrogate because the underlying spatial data are not available for future years, so a new surrogate is developed as a replacement.

Appendix A provides a list of the spatial surrogates that were used to develop spatial allocation factors for the 2015 and 2020 toxic emissions inventories. Fifteen future-year spatial surrogates are new or updated with new data (see Table A1), and 28 surrogates will be the same as the base-year surrogates (see Table A2).

For surrogates related to rural land use categories (e.g. rangeland) and transportation networks (e.g. rail lines), the future-year surrogate remained the same as for 2005 because forecasted land use for the Bay Area was not available. For surrogates based on urban land use categories (e.g., commercial land use), the future-year surrogates were developed using projected demographic and economic categories (population, employment, etc.) from ABAG's Projection 2009 data set. For most location-based surrogates, such as gas stations, a combined surrogate was developed using the base-year business locations to represent known emissions-producing activities (under the assumption that most business locations will remain unchanged between 2005 and the future years of interest) and using projected household data to represent future changes in emissions-producing activities. For construction activities, computed surrogates were developed from projected demographic and economic data to simulate the new growth and maintenance of cities.

ESTIMATE THE IMPACT OF DIESEL REGULATIONS (TASK 2)

In recent years, ARB has passed numerous regulations designed to reduce DPM emissions from on-road and non-road diesel vehicles, including the On-Road Heavy-Duty Truck In-Use Regulation[2] that was adopted on December 12, 2008, and a fuel sulfur requirement for ocean-going vessels[3] that was adopted on July 24, 2008. STI worked with the District to identify all ARB regulations that will affect future-year DPM emissions in the Bay Area and to estimate the impact of these regulations on DPM emissions in 2015 and 2020.

To begin this process, the District provided STI with a list of ARB Airborne Toxic Control Measures (ATCMs) that had been developed internally for port-related analyses (Murphy, 2009). STI compared this list with a compendium of ARB diesel regulations (Union of Concerned Scientists, 2009) and diesel regulations listed on ARB's website (California Air Resources Board, 2010) and compiled a table of recommended regulations to be considered for the development of future-year TAC inventories. District staff reviewed the regulations internally and also submitted the list to ARB for review. At the conclusion of this process, a final list of diesel regulations was established by STI and the District.

For each diesel regulation considered, STI obtained and reviewed ARB technical support documents that describe the emissions sources affected by each regulation and provide estimates of future-year emissions reductions resulting from the implementation of each regulation. **Table 1** provides a list of pertinent diesel regulations identified by STI and the District, the source categories affected by each regulation, and the emissions reductions estimated for each source category for 2015 and 2020. Emission reductions in this table represent changes from 2015 and 2020 base (i.e., uncontrolled) emissions levels, and these numbers are largely based on ARB analyses of statewide emissions inventories. However, for the marine and locomotive diesel fuel regulation, ARB documentation provided regional emissions reductions for the Bay Area and other regions with ports.

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[2] This regulation requires owners of diesel truck fleets to install exhaust retrofit devices and to accelerate the replacement of older trucks (see http://www.arb.ca.gov/msprog/onrdiesel/onrdiesel.htm).
[3] See http://www.arb.ca.gov/ports/marinevess/ogv.htm.

Table 1. ARB diesel regulations and associated emission reductions for 2015 and 2020.

Source Type	Regulation	Description	2015 Reduction[a]	2020 Reduction[a]
Off-road	Transportation Refrigeration Unit (TRU) Regulation	Requires the installation of emission-control devices on TRUs.	51%	63%
	Stationary Compression – Ignition Engines ATCM	Establishes new emissions standards for diesel-fueled compression ignition (CI) engines.	55.4%	47%
	Marine and Locomotive Diesel Fuel Regulation	Extends requirements for low-sulfur diesel fuel to intrastate locomotives and harbor craft.	10% for locomotives; 8.7 % for harbor craft	10% for locomotives; 8.7 % for harbor craft
	Cargo Handling Equipment Regulation	Establishes performance standards for newly purchased or leased equipment and retrofit requirements for in-use equipment.	66%	39%
	Stationary Agricultural Engine Regulation	Requires engines to meet emission limits equal to ARB and EPA Tier 3 or Tier 4 certification standards for new off-road CI engines.	48%	57%
	In-Use Off-road Diesel Regulation	Requires equipment owners to retrofit or replace their oldest diesel equipment starting in 2010, with increasingly stringent requirements through 2025.	60%	74%
	Shore Power Regulation	Requires vessel fleet operators to turn off auxiliary engines and connect to shore power while berthed at California ports.	51%	75%
	Fuel Sulfur Requirements for Ocean-going Vessels	Requires domestic and foreign vessels to use cleaner marine distillate fuel instead of heavy fuel oil when visiting California ports.	83%	83%
On-road	PM Control Measure for Solid Waste Collection Vehicles	Requires the use of Best Available Control Technology (BACT) to reduce PM emissions from trucks used in waste collection.	71-85%	67-82%
	Transit Fleet Vehicle Rule	Requires transit fleet vehicles to meeting declining fleet average PM emissions standards.	63%	61%
	Public Fleet Rule ATCM	Requires public agencies and private utilities to reduce diesel PM emissions from existing on-road vehicles through the use of BACT.	59%	42%
	Drayage Truck ATCM	Prohibits trucks with 1993 or older engines from operating at ports and intermodal yards. By 12/31/13, all port trucks must meet 2007 engine standards.	87%	87%
	On-road Heavy Duty Diesel Vehicle In-Use Regulation	Requires affected trucks and buses to meet performance requirements between 2011 and 2023.	68%	33%

[a]Emission reductions in this table represent changes from 2015 and 2020 base (i.e., uncontrolled) emissions levels.

For off-road sources, the emissions reductions from Table 1 were applied directly to the 2015 and 2020 DPM emissions estimated for the source categories affected by each regulation. In addition, the District instructed STI to apply a 50% reduction to emissions from selected off-road diesel equipment types, including construction and industrial equipment, to account for an overestimate in county-level emissions estimates produced for these sources by ARB's OFFROAD model[4] (Martien, 2010). (Appendix B provides a list of specific Emissions Inventory Codes, or EICs, affected by each regulation, as well as sources of data for the emission reduction estimates associated with each regulation).

For on-road sources, 2015 and 2020 PM emissions data provided by the District were aggregated by emissions mode (exhaust, brake wear, and tire wear), so the emissions reductions from Table 1 could not be directly applied. Rather, the fraction of total PM exhaust emissions associated with affected vehicle types (e.g., solid waste collection vehicles) was quantified first. Then the values from Table 1 were used to develop overall emissions reductions associated with each regulation. District staff performed this analysis and provided the county-level PM exhaust emissions reductions for each on-road regulation listed in Table B3 of Appendix B. Each of these reductions was applied to the on-road PM exhaust inventories for 2015 and 2020 supplied by the District. However, it should be noted that these estimated emissions reductions are preliminary, as questions remain about the implementation schedule for some ARB regulations, particularly the On-road Heavy Duty Diesel Vehicle In-Use Regulation. As a result, TAC and risk-weighted emissions estimates and graphical summaries presented in the sections that follow primarily refer to "base" 2015 and 2020 inventories (i.e., reductions from ARB diesel regulations and the District's correction for diesel equipment are not included). However, estimates of the individual and collective impact of off-road and on-road diesel regulations and the District's correction for diesel equipment on 2015 and 2020 DPM emissions are provided in the section that begins on page 21.

ACQUIRE AND REVIEW FUTURE-YEAR EMISSIONS INVENTORIES (TASK 3)

The District provided STI with a number of future-year emissions inventories and data sets for use in this project:

- County-level area and non-road mobile source inventories of TOG and PM_{10} for 2015 and 2020.
- Gridded (1-km resolution) on-road mobile source inventories of TOG and PM_{10} emissions for 2015 and 2020 annual average weekdays.
- A database of growth and control factors that could be used to project 2005 point source emissions inventories of criteria pollutants (including TOG and PM_{10}) to 2015 and 2020.

STI reviewed these inventories by making spatial plots of on-road and point source emissions and by comparing the 2015 and 2020 emissions data to the 2000 and 2005 base-year emissions inventories that STI previously prepared for the District. **Figure 1** shows that the District's total TOG inventory is projected to decrease by about 25% between 2000 and 2020,

[4] The District relies on the OFFROAD model to estimate emissions from most off-road equipment types. However, using a fuel-based approach, the District has determined that OFFROAD overestimates equipment usage by a factor of two for diesel-powered off-road equipment. Affected source categories are listed in Table B4 of Appendix B.

primarily due to decreases in on-road mobile source emissions. This figure also shows an increase in the District's total PM_{10} inventory of about 8% over that same period, primarily due to increases in area and non-road mobile source emissions. **Figures 2 and 3** illustrate the distribution of total TOG and PM_{10} emissions by major source category (point, on-road mobile, and area/non-road) for 2015 and 2020. The remainder of this section is a summary of the District's emissions inventories for each major source category.

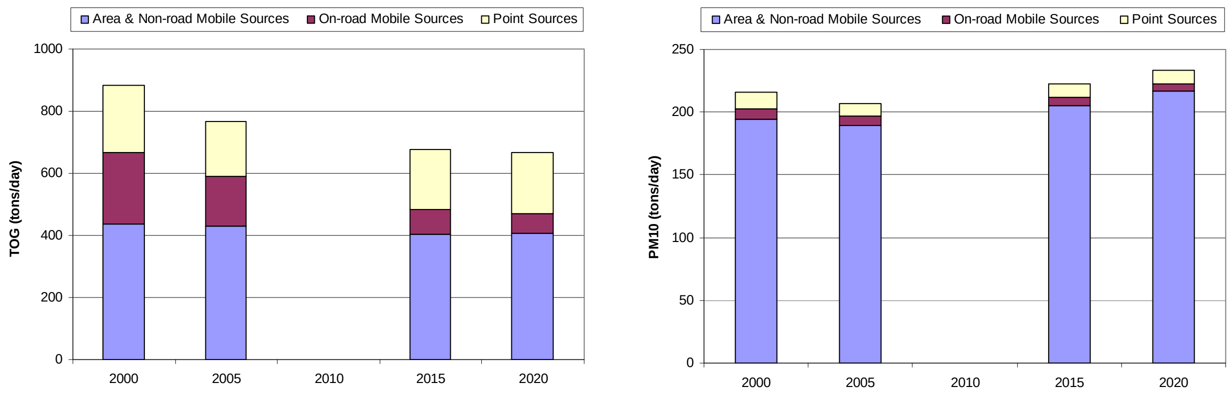

Figure 1. District TOG (left) and PM_{10} (right) emissions by year and major source type (note: emissions inventories were not evaluated for the intermediate year of 2010).

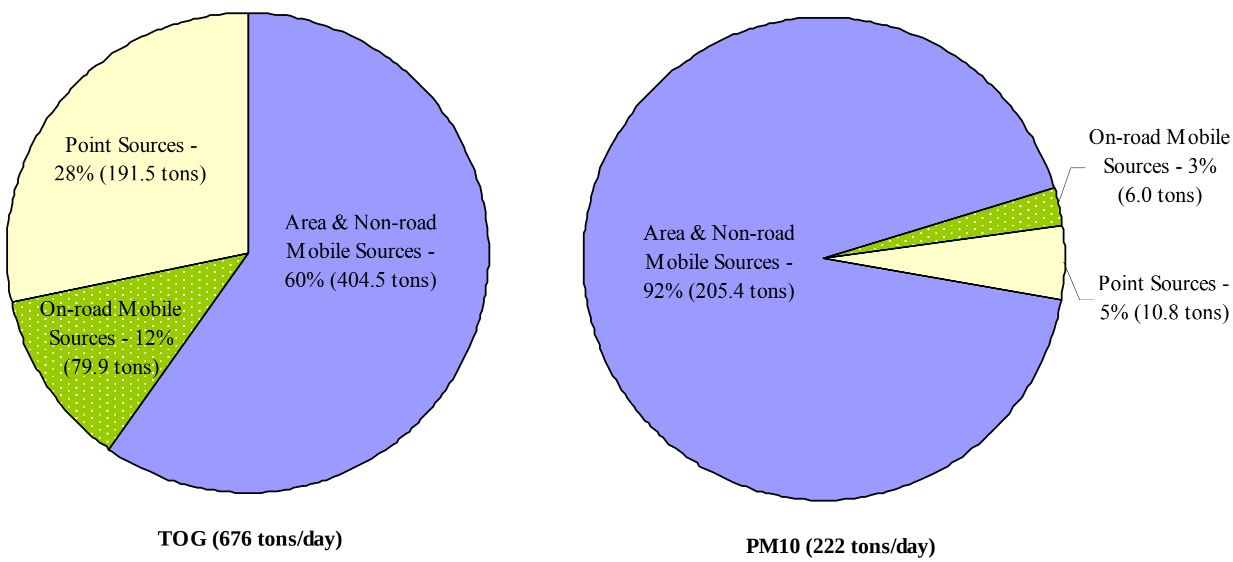

Figure 2. District TOG (left) and PM_{10} (right) emissions by major source type for 2015.

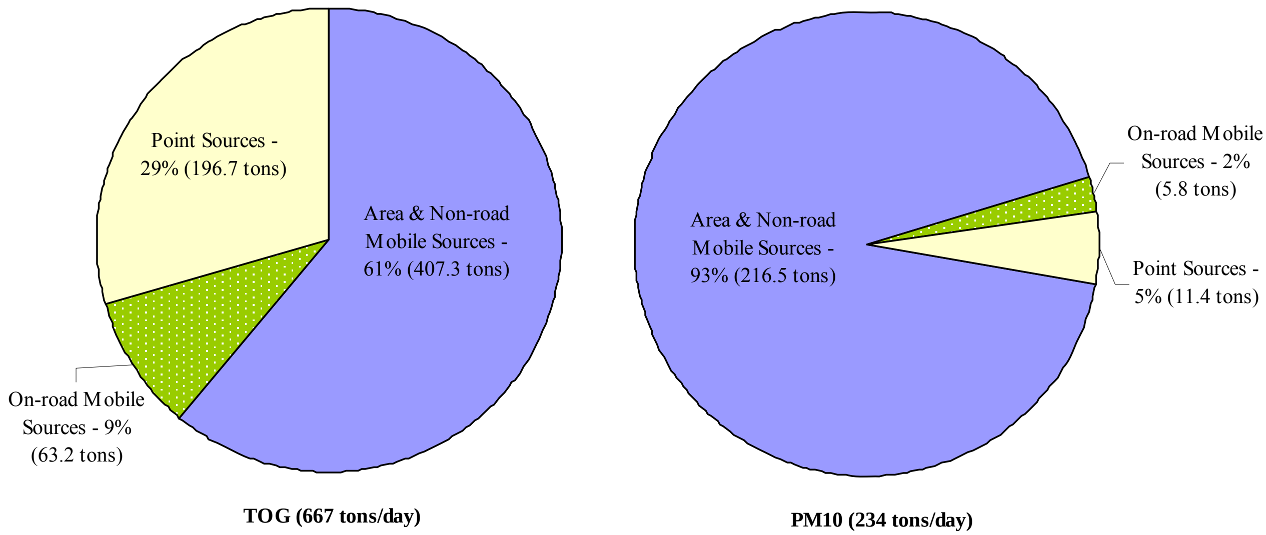

Figure 3. District TOG (left) and PM_{10} (right) emissions by major source type for 2020.

Area and Non-road Mobile Sources

The District provided STI with county-level area and non-road mobile source inventories of projected 2015 and 2020 TOG and PM_{10} emissions. These data were reported according to the same emissions inventory codes (EICs) used in the 2005 area and non-road mobile source inventories.

The District also provided STI with forecasted data for 2015 and 2020 on general aviation aircraft operations at all airports within District boundaries. These data were used to estimate lead emissions from general aviation aircraft, because available speciation profiles for this source type do not account for lead. In keeping with a recent U.S. Environmental Protection Agency's (EPA) Technical Support Document, STI assumed a lead content of 2.12 grams per gallon for aviation gasoline, and a 5% retention value to reflect the lead that is retained in an aircraft's engine or exhaust system (U.S. Environmental Protection Agency, 2008).[5] District land-and-takeoff (LTO) operations data for each airport were converted to fuel consumption estimates using fuel consumption data for civilian aircraft provided in an EPA guidance document (U.S. Environmental Protection Agency, 1992). EPA fuel consumption data for two representative engines (Continental O-200 and Lycoming O-320) were averaged to produce an estimate of 1.9 gallons per LTO. Lead emissions for each airport were then calculated as follows (general aviation LTO data from Sky Ranch Airport in Petaluma are used in the following example):

$$\text{Sky Ranch}_{Pb} = 29{,}310 \text{ LTOs/year} \times 1.9 \text{ gal/LTO} \times 2.12 \text{ grams}_{Pb}\text{/gal} \times 0.95$$

$$= 112{,}158 \text{ grams/year } (247.3 \text{ lb/year})$$

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[5] During the development of the 2005 TAC inventories, STI assumed a lead content of 2.0 grams per gallon and a retention value of 25% based on EPA's documentation for the National Emission Inventory (U.S. Environmental Protection Agency, 2003). These values have recently been updated by EPA.

Under this method, District-wide lead emissions from general aviation aircraft operations were estimated to be 8,747 pounds per year for 2015 and 9,515 pounds per year for 2020. These lead emissions were combined with other TAC emission estimates for area and non-road mobile sources produced by applying the speciation profiles described below (Speciation and Toxicity Weighting, Task 5).

County-level area and non-road mobile source emissions were spatially distributed using geographic information system (GIS) databases that were acquired primarily from ABAG. An emission density plot of area and non-road mobile source TOG emissions for 2015 is shown in **Figure 4**, and the spatial distribution process is described in more detail below.

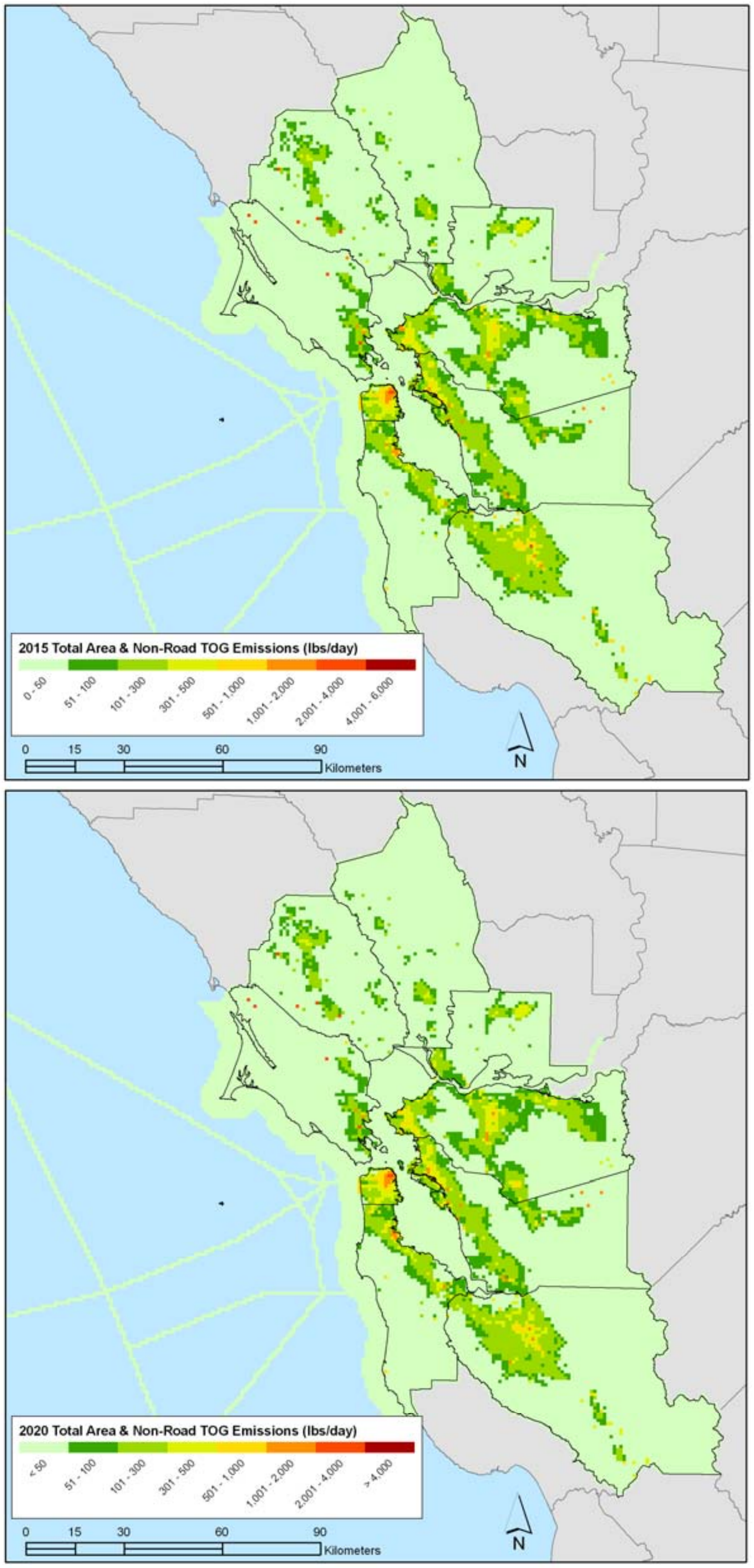


Figure 4. Emission density plots of 2015 and 2020 area and non-road mobile source TOG emissions.

On-road Mobile Sources

The District provided STI with annual average 2015 and 2020 gridded on-road mobile source inventories of TOG and PM_{10} emissions in Modeling Emissions Data System (MEDS) format. District staff generated future-year on-road mobile source emission estimates using the ARB's EMFAC2007 model and gridded the emissions to the District's 1-km x 1-km modeling grid using the California Department of Transportation's (Caltrans) Direct Travel Impact Model (DTIM4).

Districtwide on-road mobile source TOG emissions for 2015 and 2020 were projected as 50% lower and 60% lower, respectively, than corresponding year-2005 emissions, decreasing from 158.1 tons per day in 2005 to 79.9 tons per day in 2015 and 63.2 tons per day in 2020. Projected on-road mobile source PM_{10} emissions decreased by about 20% between the base and future years, decreasing from 7.6 tons per day in 2005 to 6.0 tons per day in 2015 and 5.8 tons per day in 2020. **Figure 5** shows an emission density plot of the 2015 gridded on-road mobile source inventories provided by the District.

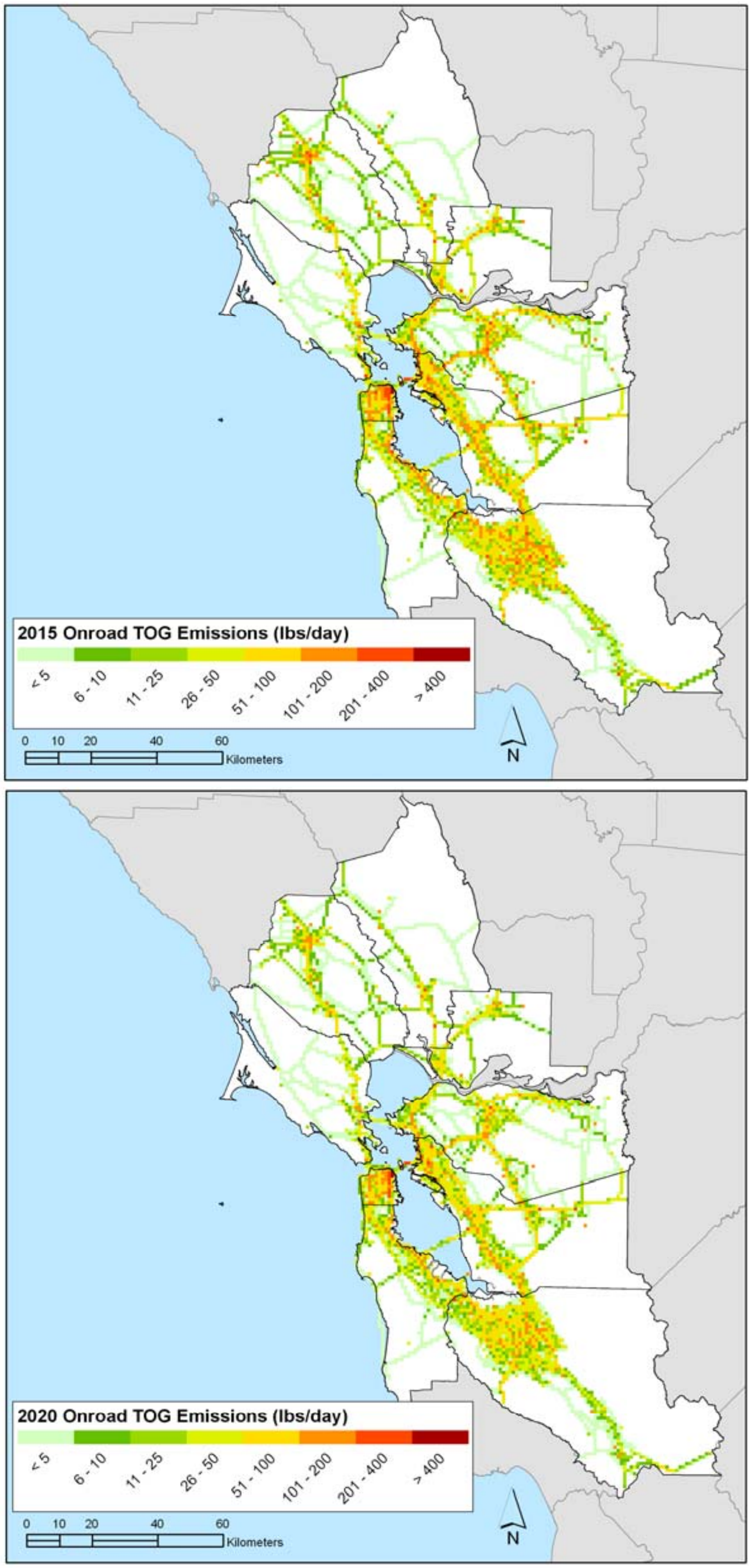


Figure 5. Emission density plots of 2015 and 2020 on-road mobile source TOG emissions (1-km grid resolution).

Point Sources

The District provided STI with the latest 2005 inventories of TAC and criteria pollutant emissions from point sources within the District, as well as a database of combined growth-and-control factors (GCFs) that could be used to project 2005 criteria pollutant emissions to 2015 and 2020. The GCFs were pollutant specific (i.e., different factors were provided for TOG, PM, etc.), and the District also provided a cross-reference table that matched the GCFs to facilities and processes in the point source inventories on the basis of a District point source category number.

To develop 2015 and 2020 inventories of TAC emissions from point sources, STI worked with the District to apply the GCFs for PM and TOG to the existing 2005 point source TAC inventory. First, STI grouped the 2005 point source TAC inventory by pollutant and examined the mix of sources associated with each pollutant, as well as the ARB speciation profile assigned to each source (the speciation profiles provide a summary of the individual species associated with each source type, including toxic species). In most cases, the sources associated with a given toxic pollutant could be clearly tied to PM or TOG emissions (e.g., processes that utilize solvents are sources of TOG). However, in some instances, neither PM- or TOG-based GCFs seemed appropriate; for example, methyl tert-butyl ether [MTBE] emissions were associated with site remediation activities, which may be complete by 2015 or 2020. In addition, District Regulation 11, Rule 16, calls for a phase-out of all perchloroethylene use in dry cleaning operations by January 1, 2023. Multiple schedules are under consideration for this phase-out, with the current proposal requiring 440 of the 490 dry cleaners currently using perchloroethylene to convert to alternate cleaning methods by 2015, and an additional 45 dry cleaners to convert to alternate methods by 2020 (Nash, 2009).[6]

On the basis of these considerations, STI provided the District with a table of initial recommendations for applying the PM and TOG GCFs to the point source TAC inventory, and finalized this table based on comments received from the District. Appendix C summarizes the GCF assignments used to project the 2005 point source TAC inventory to 2015 and 2020, and **Figure 6** shows a comparison between the future-year point source TAC inventories and the base-year (2005) inventory. Overall, point source TAC emissions for 2015 are 2% lower than 2005 levels, while TAC emissions for 2020 are 3% higher than 2005 levels. Emissions reductions resulting from the phase out of perchloroethylene in dry cleaning operations and increases in ammonia emissions associated with wastewater treatment plants, oil refineries, and power plants account for most of the difference between the base and future years.

STI also spatially distributed all point source TAC emissions by using GIS software to determine the grid cell occupied by each source in the District's 1-km x 1-km modeling domain. **Figure 7** illustrates the geographic distribution of benzene emissions (a TAC example) from point sources.

[6] This phase-out schedule was used to develop initial emission reductions for perchloroethylene dry cleaners of 0.898 (440/490) for 2015 and 0.990 for 2020 (485/490). However, these reductions may need to be altered in the future if the District adopts a different phase-out schedule.

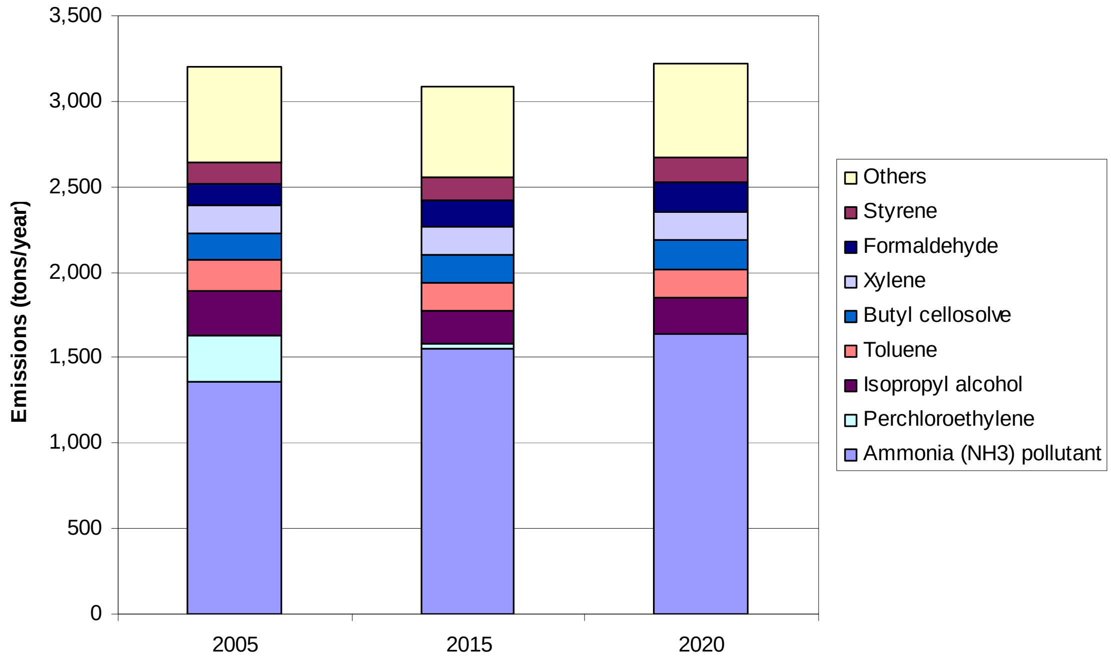


Figure 6. Point source TAC emissions by pollutant and year.

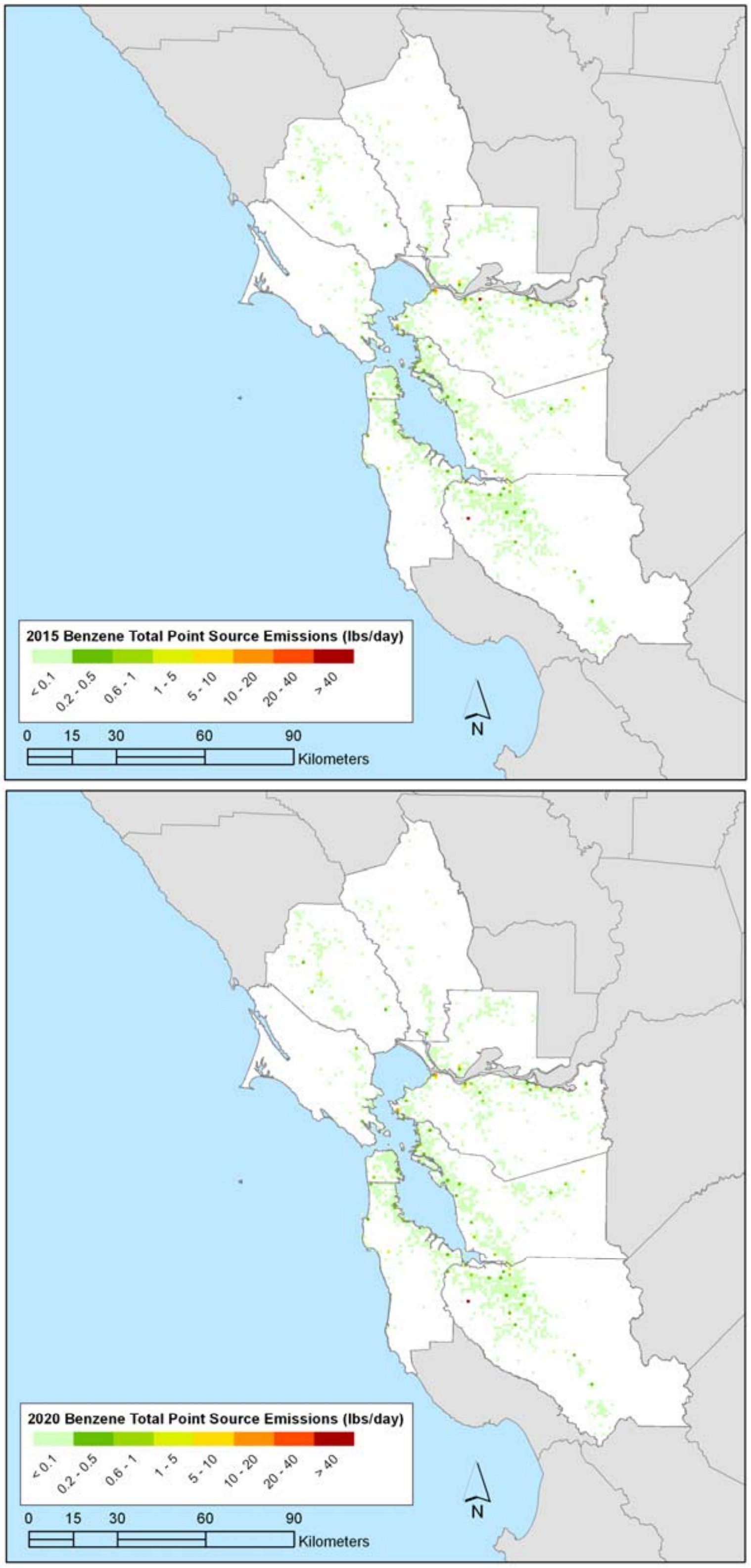


Figure 7. Emission density plot of 2015 and 2020 benzene emissions from point sources (1-km grid resolution).

APPLY SPECIATION PROFILES, TOXICITY WEIGHTING FACTORS, AND DPM CONTROL FACTORS (TASK 5)

Chemical Speciation

STI used speciation profiles to transform TOG and PM_{10} emissions into individual chemical species so that TAC emissions from area, on-road mobile, and non-road mobile sources could be estimated. STI assigned an appropriate speciation profile to each EIC or source classification code (SCC) in the inventories, primarily on the basis of ARB-recommended profile-to-source code assignments. The ARB has developed a cross-reference file that indicates which TOG or PM_{10} speciation profile should be assigned to a given source type, and many of these assignments are specific to the emissions inventory year (to account for changes to fuel compositions, for example). When developing the base-year (2000 and 2005) TAC inventories, we used the speciation profiles recommended by ARB for most source categories. However, in some cases, ARB did not provide a recommended profile or did not recommend a default composite profile. For these cases, we identified appropriate speciation profiles available from the Desert Research Institute (DRI) or listed in EPA's SPECIATE database.

Prior to the development of the future-year TAC inventories, STI reviewed the latest speciation profiles and cross-reference files from ARB to determine whether the data sets used to speciate the base-year inventories required any updates. For both TOG and PM, all pertinent speciation profiles and profile assignments remained the same for the future-year inventories. However, the latest ARB cross-reference file did contain new $PM_{2.5}$ size fractions[7] for two profiles, as shown in **Table 2**. These size fractions were updated in the 2015 and 2020 speciation databases and were used to convert the District's PM_{10} emission estimates to $PM_{2.5}$.

Table 2. Updates to ARB $PM_{2.5}$ size fractions.

Profile Number	Profile Name	2005 $PM_{2.5}$ Size Fraction	Updated $PM_{2.5}$ Size Fraction
470	Unpaved road dust	0.126	0.0594
471	Paved road dust	0.0772	0.0686

Once TAC emissions from area, non-road mobile, and on-road mobile sources were estimated by applying speciation profiles, these emissions were combined with the inventories of 2015 and 2020 TAC emissions from point sources provided by the District to form complete future-year inventories of TACs. TAC emissions by pollutant and source category can be seen in **Figures 7 and 8.**[8] Overall, TAC emissions from all sources in the District were estimated to be 84 tons per day for 2015 and 79 tons per day for 2020. The 2015 and 2020 TAC emissions are 27% and 31% lower, respectively, than the 115 tons per day of TAC emissions estimated for the

[7] These values represent the fraction of total PM that is smaller than 2.5 microns in diameter. The $PM_{2.5}$ size fractions are divided by corresponding PM_{10} size fractions to develop ratios that can be used to convert PM_{10} emissions to $PM_{2.5}$ emissions.
[8] Ship and commercial boat emissions occurring more than three miles off-shore have been excluded from Figures 7 and 8.

year 2005. (Note that these are "uncontrolled" estimates that do not reflect the impact of ARB diesel regulations on DPM emission levels.)

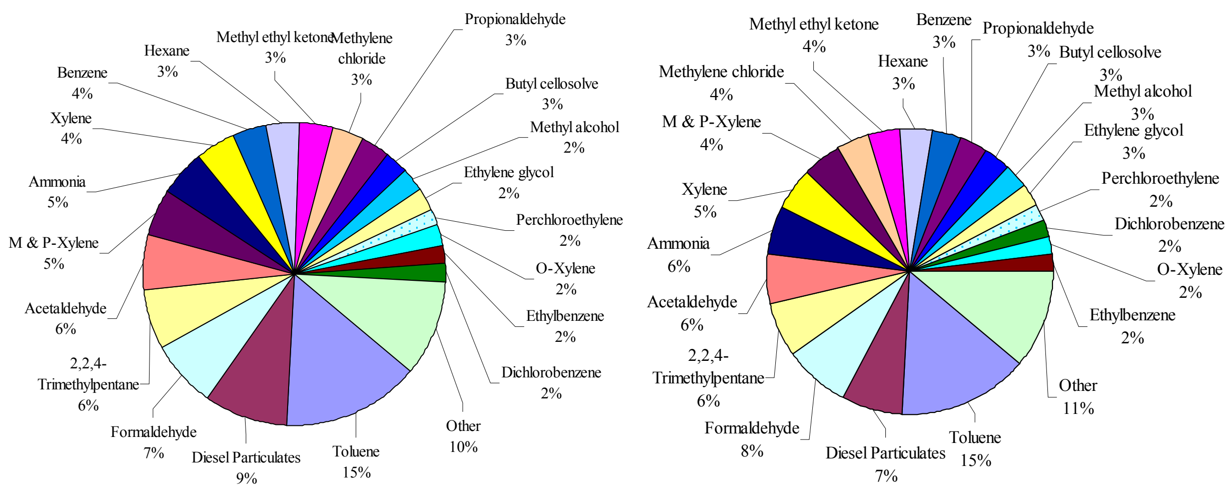


Figure 7. Average daily TAC emissions by species for 2015 (left) and 2020 (right).

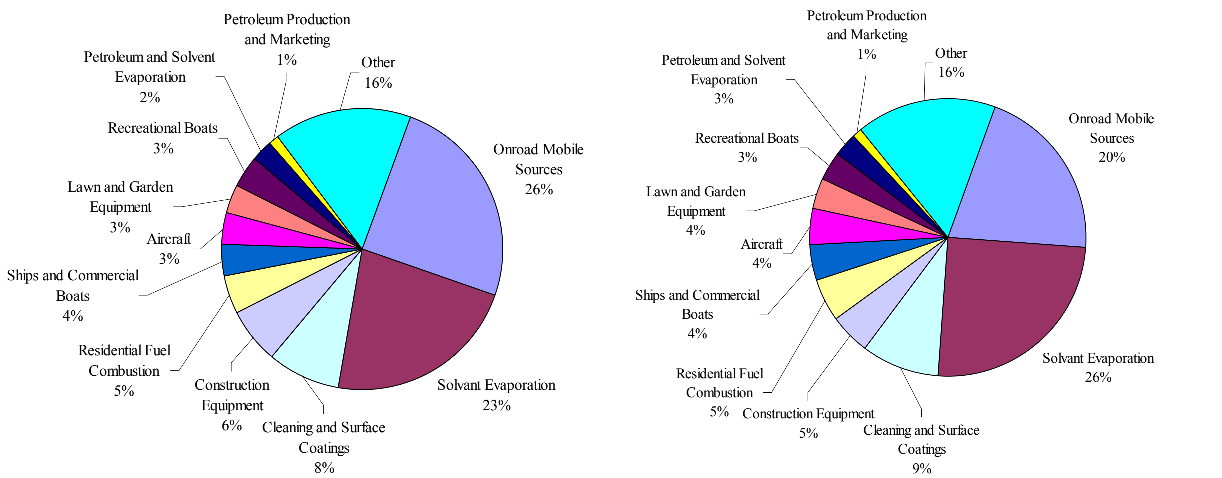


Figure 8. Average daily TAC emissions by source category for 2015 (left) and 2020 (right).

<u>Toxicity Weighting</u>

To develop toxicity-weighted emissions inventories, STI applied available cancer unit risk (UR) factors and non-cancer reference concentrations (RfC) for the inhalation exposure pathway. UR factors estimate the expected change in the rate of observed adverse effects per unit change in dose (or air concentration). An RfC is a regulatory definition that indicates the dose at which no adverse effects are expected, plus a safety margin allowing for measurement uncertainty, plus another safety margin based on professional toxicologists' judgment. UR factors and RfCs were compiled from the following information sources in declining order of preference: ARB in conjunction with EPA's Office of Environmental Health Hazard

Assessment (OEHHA), the EPA's Integrated Risk Information System (IRIS), and the EPA's Technology Transfer Network. Secondary sources were used to estimate factors for important TACs not available in the preferred references. The same URs and RfCs used in the development of the year-2005 TAC inventories were applied to the future-year TAC inventories for consistency. However, STI reviewed the latest ARB and EPA databases and determined that several updates had been made to URs and RfCs since the development of the year-2005 TAC inventories. These changes were noted in the tables of URs and RfCs provided in Appendix D, though the updated URs and RfCs were not used during this round of future-year TAC inventory development.

Mass-based emissions for all TACs were converted to toxicity-weighted emissions for cancer, chronic, and acute risks. Toxicity-weighted emissions are reported in units of "mass equivalents per unit time." For risks of cancer due to inhalation, the mass equivalent of a specific TAC is the estimated mass of hypothetical compound "X" that poses a cancer risk equal to that of the emitted mass of the TAC of interest (where "X" is defined as having a UR factor equal to 1 $(\mu g/m^3)^{-1}$). Thus, toxicity-weighted emissions for cancer due to inhalation exposure are calculated according to Equation 1.

$$\text{Emissions} \times UR_i \div UR_X = \text{Toxicity-Weighted Emissions} \qquad \textbf{(1)}$$

where:

Emissions = Mass-based emissions of a TAC species *i*; tons/day

UR_i = UR factor for TAC species *i*, or the estimated probability of a person contracting cancer as a result of constant exposure to an ambient concentration one microgram per cubic meter of species *i* over a 70-year lifetime; $(\mu g/m^3)^{-1}$

UR_X = UR factor for a hypothetical compound "X" ≡ 1 $(\mu g/m^3)^{-1}$

Toxicity-Weighted Emissions = Equivalent emissions of hypothetical compound "X," which would be expected to pose a risk equal to that of the emissions of the TAC species *i*; equivalent tons/day

"Uncontrolled" (i.e., estimated without considering the impact of ARB diesel regulations) cancer toxicity-weighted emissions for 2015 were estimated to be 2.756×10^{-6} equivalent tons/day, which is 37% lower than the 4.397×10^{-6} equivalent tons/day estimated for the 2005 TAC inventories. Cancer toxicity-weighted emissions for 2020 were estimated to be 2.219×10^{-6} equivalent tons/day, which represents a 50% reduction from 2005 levels.

For non-cancer risks due to inhalation (whether acute or chronic), the mass equivalent of a specific TAC is the estimated mass of hypothetical compound "Y," which would be expected to pose a risk equal to that of the emitted mass of the TAC of interest (where "Y" is defined as having an RfC equal to unity). Thus, toxicity-weighted emissions for acute or chronic effects due to inhalation exposure are calculated according to Equation 2.

$$\text{Emissions} \div \text{RfC}_i \times \text{RfC}_Y = \text{Toxicity-Weighted Emissions} \quad \textbf{(2)}$$

where:

Emissions = Mass-based emissions of a TAC species *i*; tons/day

RfC_i = RfC for TAC species *i*; μg/m^3

RfC_Y = RfC for hypothetical compound "Y" ≡ 1 μg/m^3

Toxicity-Weighted Emissions = Equivalent emissions of hypothetical compound "Y," which would be expected to pose a risk equal to that of the emissions of the TAC species *i*; equivalent tons/day

"Uncontrolled" (i.e., estimated without considering the impact of ARB diesel regulations) chronic effects of toxicity-weighted emissions for 2015 were estimated to be 16.7 equivalent tons/day, which is 20% lower than the 20.9 equivalent tons/day estimated for the 2005 TAC inventories. For 2020, chronic toxicity-weighted emissions were estimated to be 15.9 equivalent tons/day, which represents a 24% reduction from 2005 levels. Uncontrolled acute effects of toxicity-weighted emissions for 2015 were estimated to be 3.1 equivalent tons/day, which is 26% lower than the 4.2 equivalent tons/day estimated for the 2005 TAC inventories. For 2020, acute toxicity-weighted emissions were estimated to be 3.0 equivalent tons/day, which represents a 29% reduction from 2005 levels.

Figures 9 through 14[9] show toxicity-weighted emissions by pollutant and source category for cancer-related, chronic, and acute effects caused by inhalation exposure. DPM constitutes 80% of cancer toxicity-weighted emissions in 2015 and 74% of cancer toxicity-weighted emissions in 2020. On-road mobile sources, construction-related activities, and commercial marine vessels contribute over 70% of the cancer toxicity-weighted emissions for both 2015 and 2020. When considering toxicity-weighted emissions for chronic effects, acrolein, formaldehyde, and DPM appear significant. On-road mobile sources, construction equipment, and aircraft contribute about 60% of these chronic toxicity-weighted emissions. For acute effects of the toxicity-weighted emissions, acrolein constitutes about 97% for both 2015 and 2020. On-road mobile sources, construction equipment, and aircraft are the most important source categories for acute risks, contributing over 70% of acute toxicity-weighted emissions for both 2015 and 2020.

[9] Ship and commercial boat emissions occurring more than 3 miles offshore have been excluded from Figures 9 through 14.

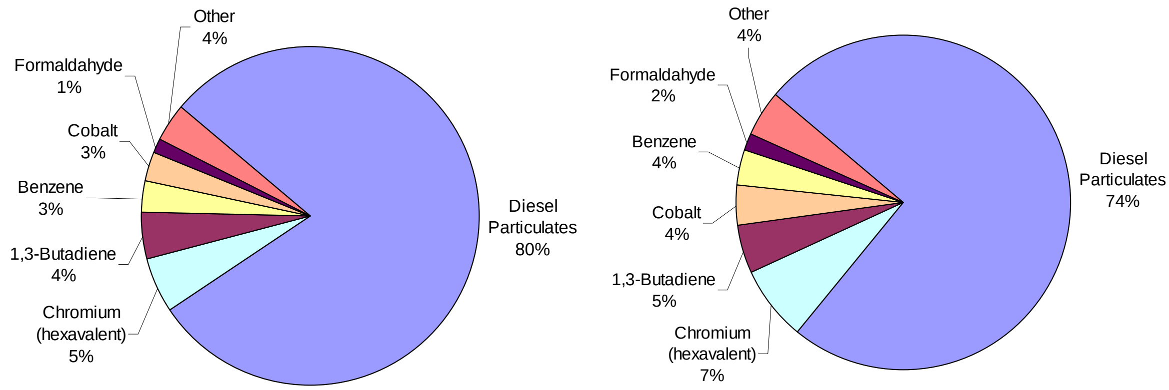


Figure 9. Cancer toxicity-weighted emissions by pollutant for 2015 (left) and 2020 (right).

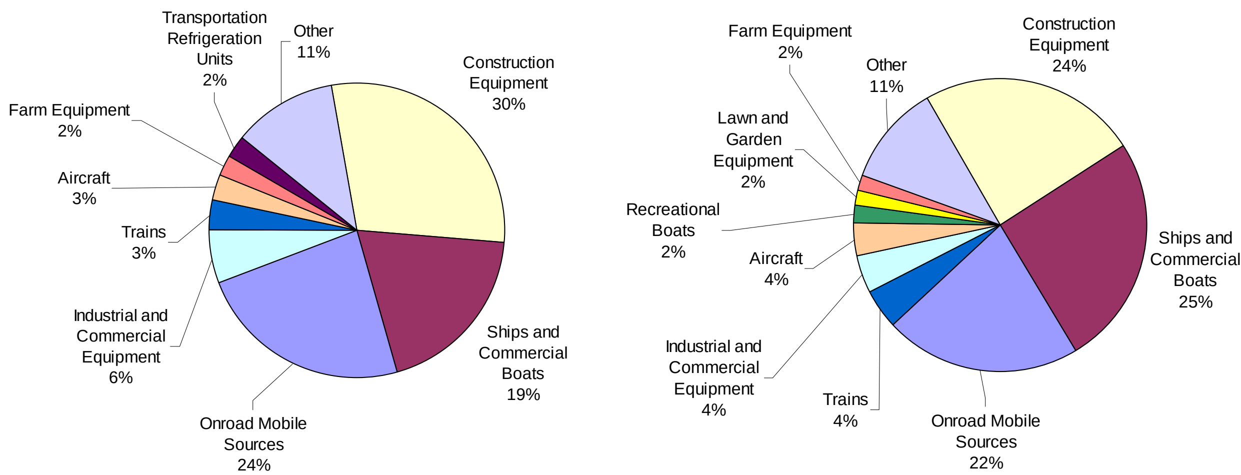


Figure 10. Cancer toxicity-weighted emissions by source category for 2015 (left) and 2020 (right).

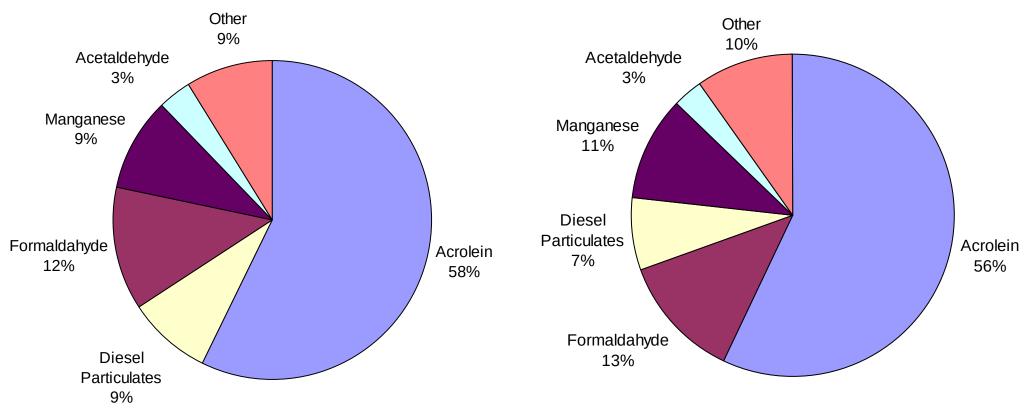


Figure 11. Chronic toxicity-weighted emissions by pollutant category for 2015 (left) and 2020 (right).

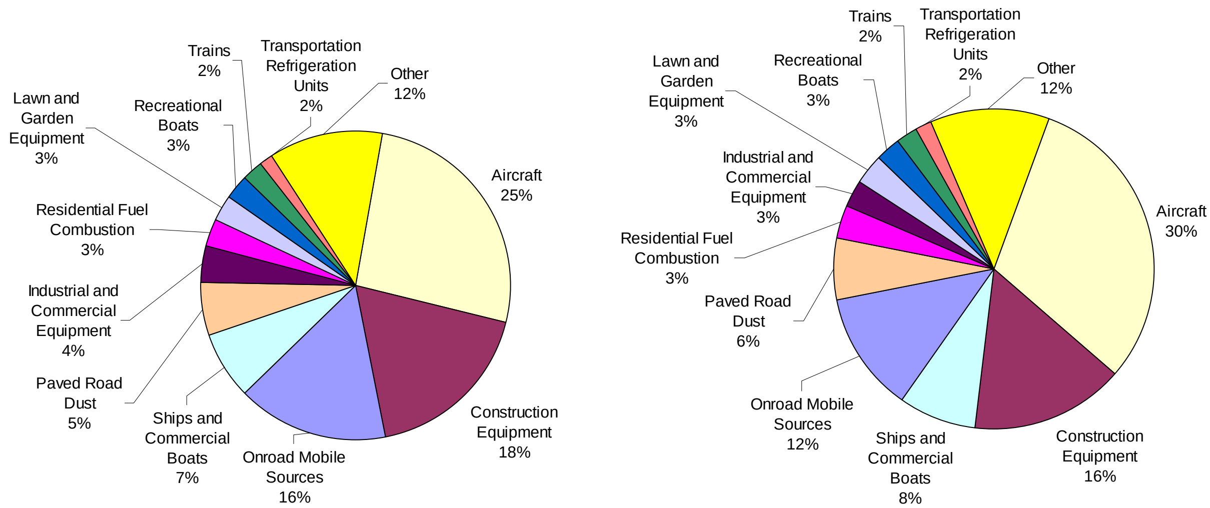


Figure 12. Chronic toxicity-weighted emissions by source category for 2015 (left) and 2020 (right).

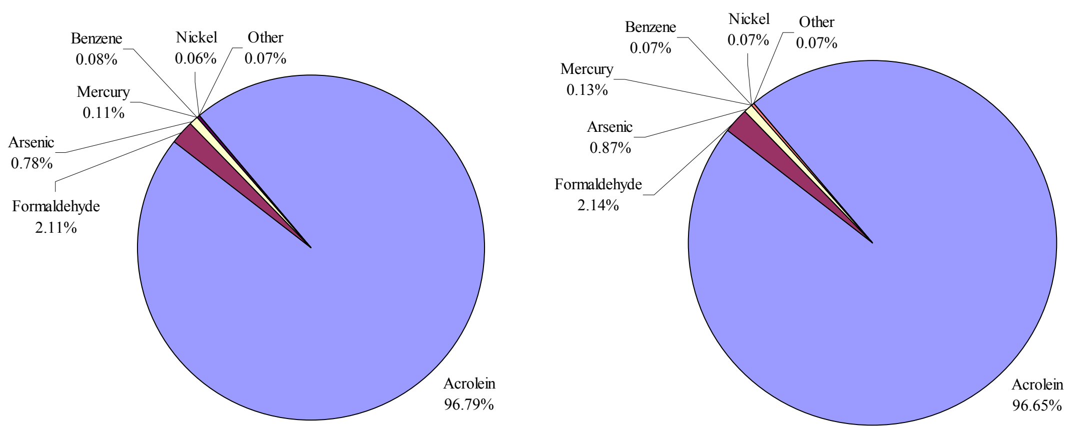
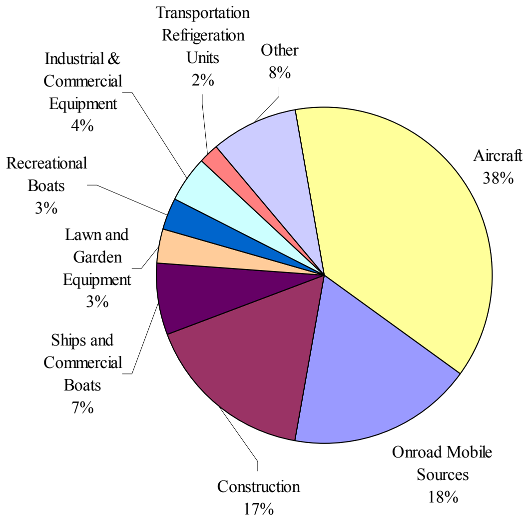


Figure 13. Acute toxicity-weighted emissions by pollutant for 2015 (left) and 2020 (right).



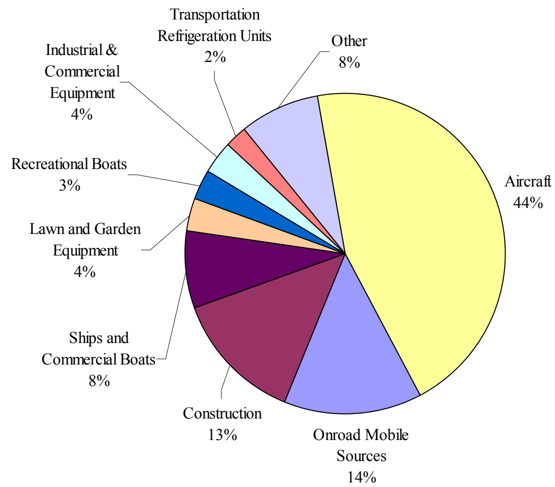


Figure 14. Acute toxicity-weighted emissions by source category for 2015 (left) and 2020 (right).

DPM Control Factors

To investigate the potential impact of ARB diesel regulations on future DPM emissions in the Bay Area, the control factors for diesel sources described above and listed in Appendix B were applied to the 2015 and 2020 TAC and risk-weighted inventories. In addition, the District instructed STI to apply a 50% reduction to emissions from selected off-road diesel equipment types, including construction and industrial equipment, to account for an overestimate in county-level emissions estimates produced for these sources by ARB's OFFROAD model[10] (Martien, 2010). **Table 3** provides a summary of the impact of individual ARB off-road and on-road diesel regulations and the District's diesel equipment correction on 2015 and 2020 DPM emissions for affected source categories, and **Figures 15 and 16**[11] show the collective impact of all regulations and corrections on total 2015 and 2020 DPM and TAC emissions. When all ARB diesel regulations and the District's diesel correction are applied, DPM emissions for 2015 are reduced by 72%, and DPM emissions for 2020 are reduced by 63%. For total TAC emissions, the application of ARB diesel regulations and the District's diesel correction results in a 6% reduction of emissions for 2015 and a 4% reduction of emissions for 2020.

[10] The District relies on the OFFROAD model to estimate emissions from most off-road equipment types. However, using a fuel-based approach, the District has determined that OFFROAD overestimates equipment usage by a factor of 2 for diesel-powered off-road equipment. Affected source categories are listed in Table B4 of Appendix B.
[11] Ship and commercial boat emissions occurring more than 3 miles off-shore have been excluded from Figures 15 and 16.

Table 3. Impact of ARB diesel regulations and the District's diesel correction on 2015 and 2020 DPM emissions.

Source Type	Regulation	DPM (lb/day)[a]			
		2015 Uncontrolled	2015 Controlled	2020 Uncontrolled	2020 Controlled
Off-road	Transportation Refrigeration Unit (TRU) Regulation	413	202	150	56
	Stationary Compression – Ignition Engines ATCM	153	68	115	61
	Marine and Locomotive Diesel Fuel Regulation	614	553	649	584
	Cargo Handling Equipment Regulation	62	21	44	27
	Stationary Agricultural Engine Regulation[b]	--	--	--	--
	In-Use Off-road Diesel Regulation	5,667	2,267	3,342	869
	Shore Power Regulation	850	417	1,000	250
	Fuel Sulfur Requirements for Ocean-going Vessels	159	27	186	32
	District Diesel Equipment Correction	6,486	3,243	3,732	1,866
On-road	PM Control Measure for Solid Waste Collection Vehicles	3,543	3,389	2,586	2,473
	Transit Fleet Vehicle Rule	3,543	3,437	2,586	2,481
	Public Fleet Rule ATCM	3,543	3,505	2,586	2,571
	Drayage Truck ATCM[c]	3,543	--	2,586	--
	On-road Heavy Duty Diesel Vehicle In-Use Regulation	3,543	1,639	2,586	1,962

[a]All emissions shown represent totals for all source categories affected by the listed regulation. For on-road sources, emissions reductions for individual control measures were based on the overall on-road PM exhaust inventories for 2015 and 2020, so the numbers in this table represent DPM from all on-road sources in the inventories.
[b]The District's 2015 and 2020 DPM inventories did not include any sources affected by the Stationary Agricultural Engine Regulation.
[c]Drayage trucks operating at the Port of Oakland are not explicitly included in the 2015 and 2020 DPM inventories, so for this round of inventory development, no reduction was applied for this regulation.

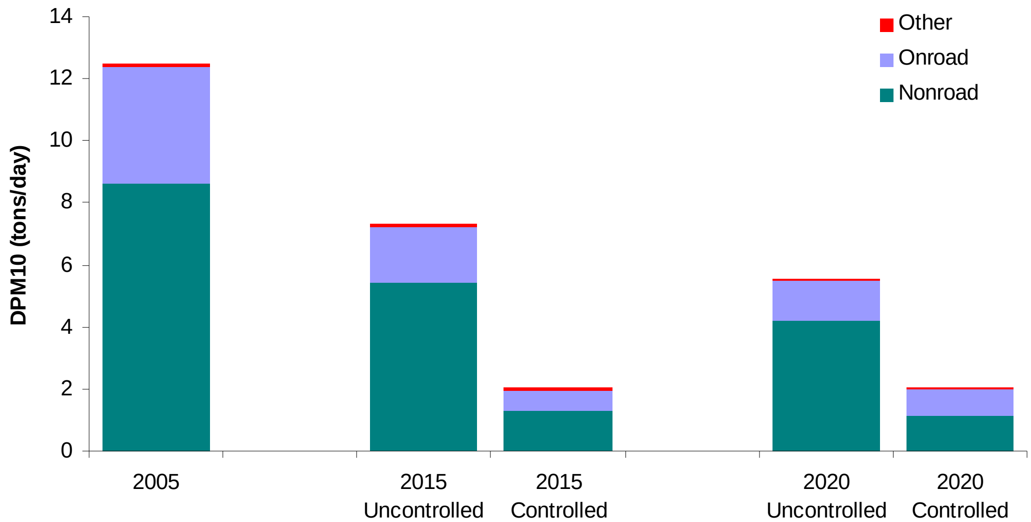


Figure 15. Total DPM emissions by year and control case.

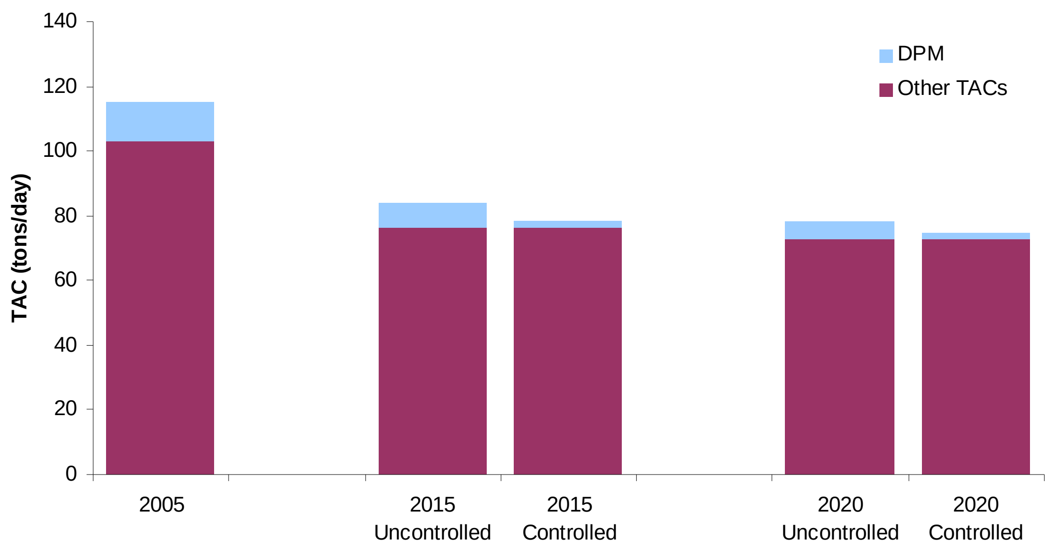


Figure 16. Total TAC emissions by year and control case.

SPATIALLY DISTRIBUTE TAC EMISSIONS (TASK 5)

County-level area and non-road mobile source emissions were geographically distributed to the spatial resolution of the District's 1-km x 1-km modeling domain using the spatial surrogate data described above and listed in Appendix A. County-level emissions were allocated to individual grid cells proportionally according to the spatial patterns of the surrogate GIS data. Spatial allocation factors for individual grid cells were developed by processing the surrogate GIS data within a customized ArcGIS Visual Basic (VBA) program that outputs allocation factors by grid cell to Microsoft Access database tables. In addition, spatial allocation factors were converted to a format that is compatible with the Sparse Matrix Operator Kernel Emissions Modeling System (SMOKE), which will be used to generate emissions inputs for the District's air quality modeling efforts.

For on-road mobile sources, the District provided STI with annual average 2015 and 2020 inventories of TOG and PM_{10} emissions in MEDS format that had already been gridded to the District's 1-km x 1-km modeling domain using DTIM4. However, because these data are not readable by SMOKE, the District's gridded on-road mobile source inventories were used to generate spatial allocation factors in SMOKE-ready format so that SMOKE can be used to spatially distribute the 2015 and 2020 TAC inventories in a way that is consistent with the District's gridded TOG and PM_{10} inventories.

Spatial distributions of emissions of DPM and acrolein, two prominent TACs, are illustrated in **Figures 17 and 18**. In addition, spatial distributions of cancer toxicity-weighted, chronic toxicity-weighted, and acute toxicity-weighted emissions are shown in **Figures 19 through 21**. (Note that these plots represent "uncontrolled" emissions that do not reflect the impact of ARB diesel regulations on DPM emission levels.)

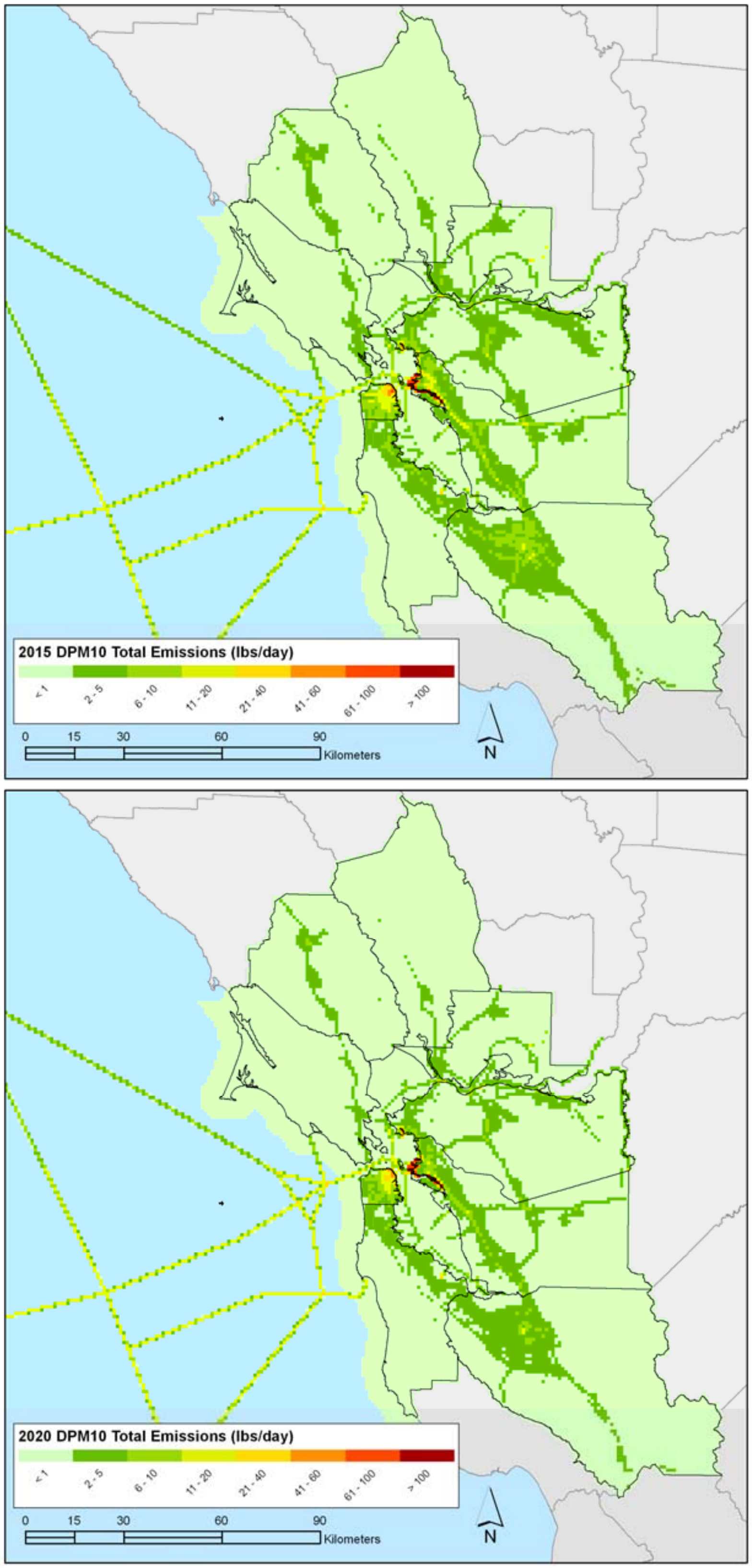


Figure 17. Emission density plots of 2015 and 2020 DPM emissions.

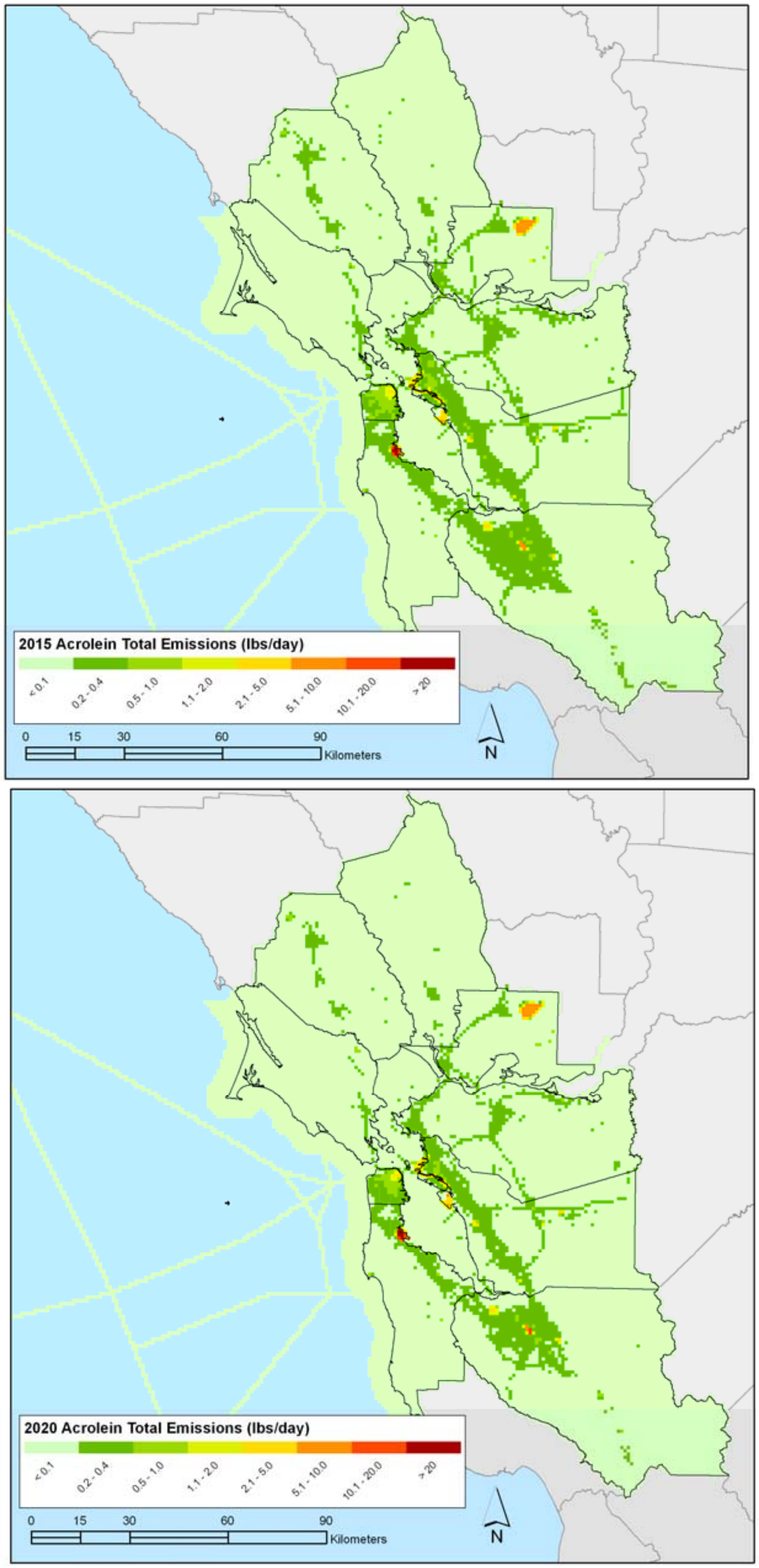


Figure 18. Emission density plots of 2015 and 2020 acrolein emissions.

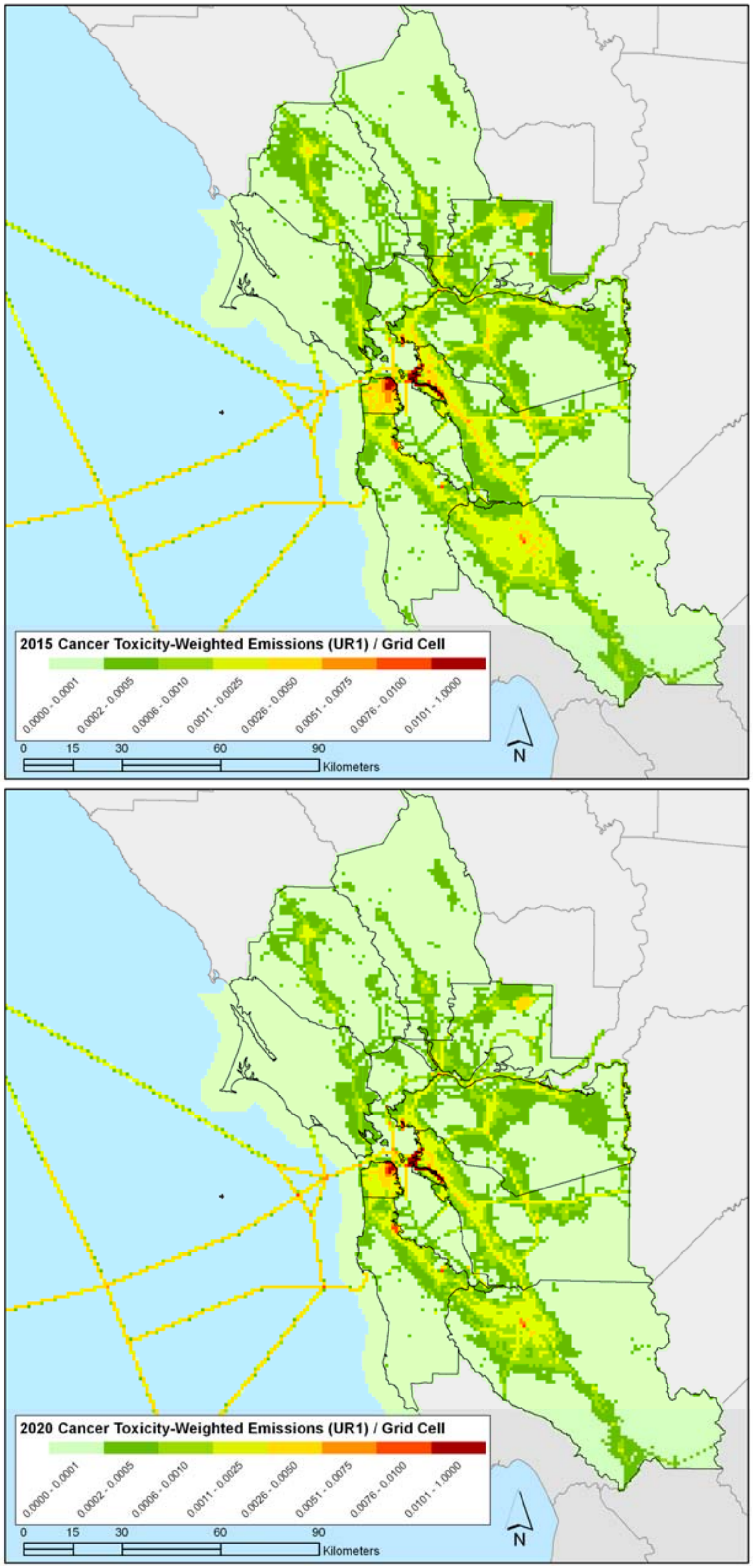


Figure 19. Emission density plots of 2015 and 2020 cancer toxicity-weighted emissions.

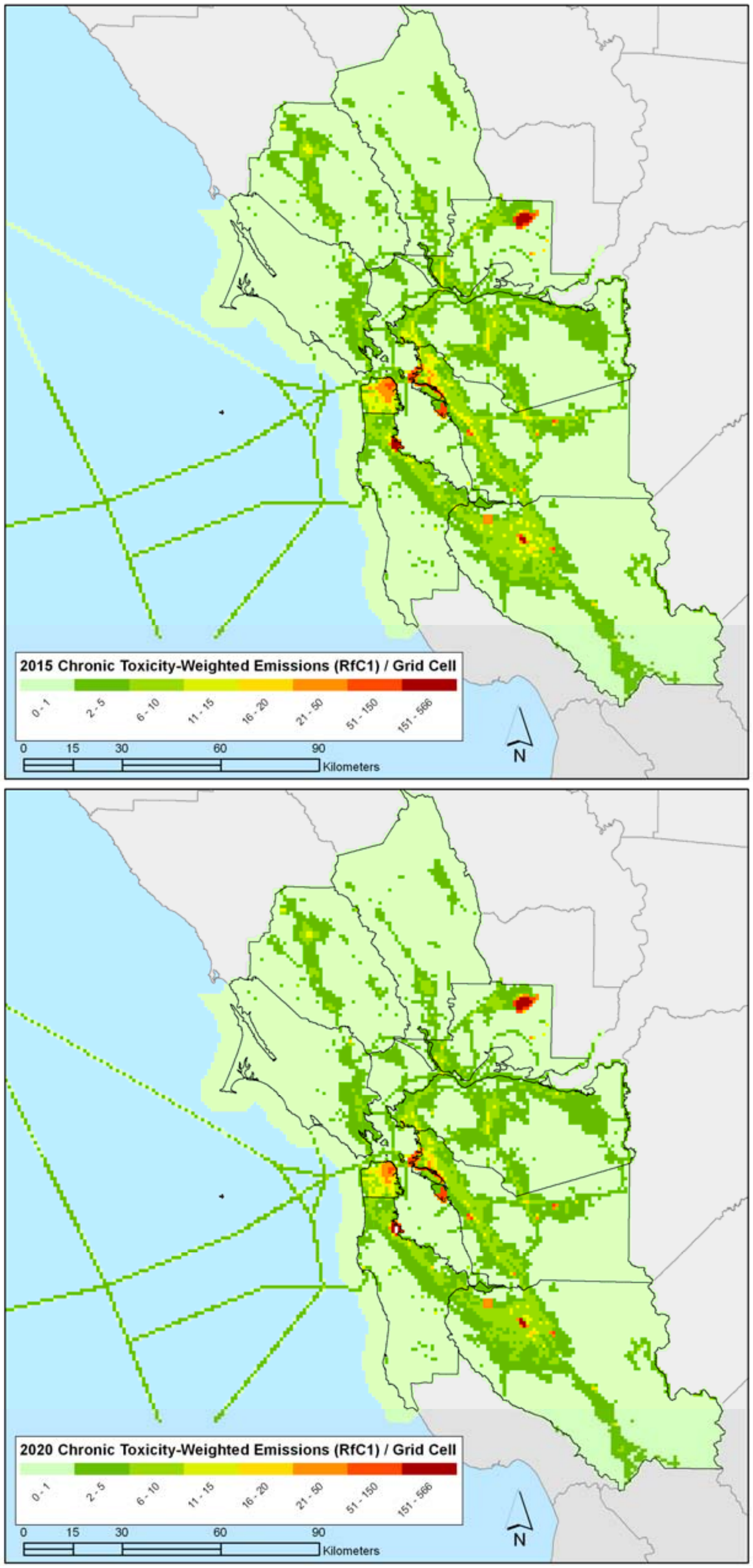
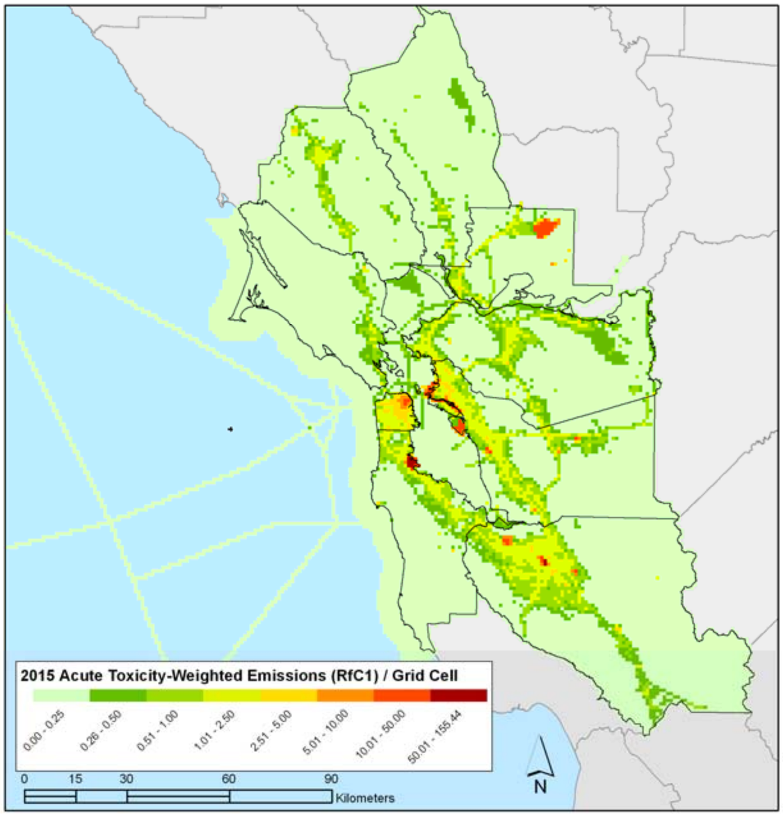


Figure 20. Emission density plots of 2015 and 2020 chronic toxicity-weighted emissions.



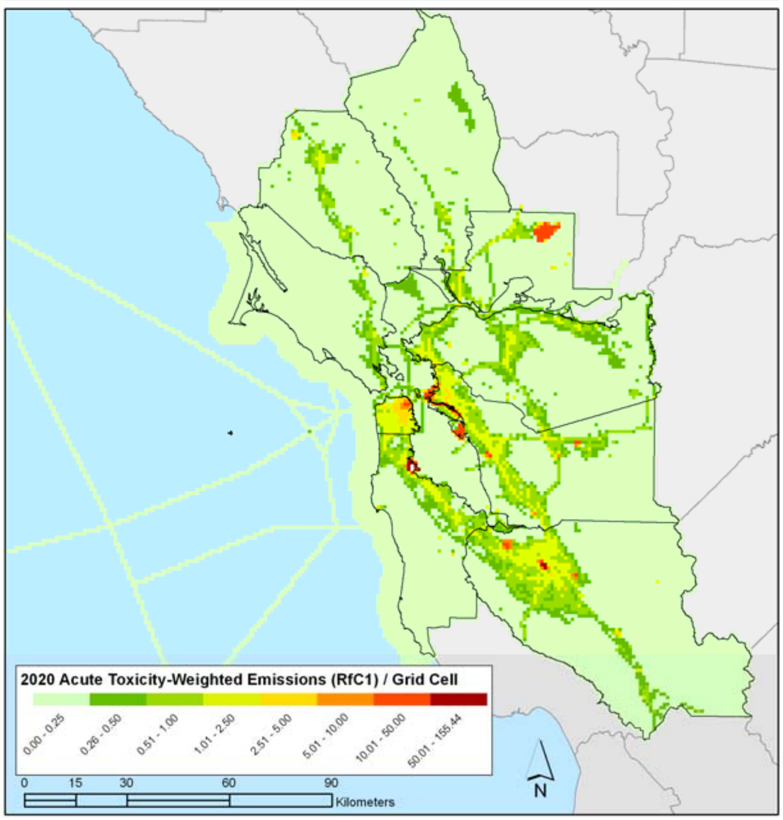


Figure 21. Emission density plots of 2015 and 2020 acute toxicity-weighted emissions.

ASSIGN TEMPORAL PROFILES (TASK 6)

The 2015 and 2020 TAC inventories developed by STI contain annualized emissions (average lb/day). However, for air quality modeling purposes it is desirable to resolve emissions on an hourly basis. During the development of the District's 2005 TAC inventories, STI assigned a diurnal profile to each area, non-road mobile, and point source category; these assignments were based on a database of ARB temporal profiles and an ARB cross-reference file that matches an appropriate diurnal profile to all EIC codes and point source processes. STI incorporated tables with ARB diurnal profiles and profile assignments in the point source and area and non-road mobile source databases that contain TAC emission estimates, and also developed SMOKE-ready versions of these diurnal profiles and cross-reference files. For on-road sources, STI developed SMOKE-ready diurnal profiles from hourly outputs from EMFAC2007, the model used to develop the District's on-road mobile source TOG and PM inventories (see **Figure 22**).

For the future-year TAC inventories, STI reviewed the profile assignments made to area, non-road mobile, and point source categories and ran EMFAC2007 for 2015 and 2020 to determine whether hourly emissions patterns for those years varied from EMFAC2007 runs previously performed for 2005. We determined that the profiles applied to the 2005 TAC inventories were suitable for use with the 2015 and 2020 TAC inventories, so all temporal profile assignments are consistent across the base and future years.

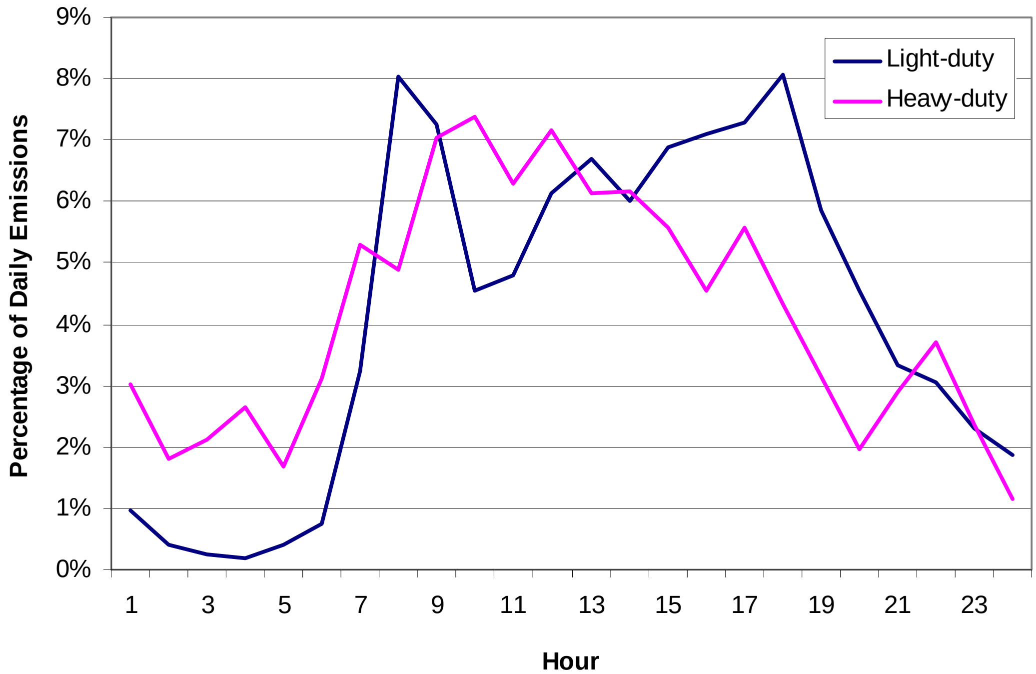


Figure 22. Diurnal profiles applied to emissions from light-duty and heavy-duty vehicles.

SET UP EMISSIONS MODELING FILES (TASK 7)

To support air quality modeling efforts that the District will be using to investigate future-year atmospheric concentrations of air toxics in the Bay Area, STI set up input files and scripts for the SMOKE emissions modeling system, which can be used to generate emissions inputs for the Comprehensive Air Quality Model with extensions (CAMx) and other photochemical grid models. This work followed the same approach used to develop a SMOKE-based emissions modeling stream for the District's 2005 TAC inventories, which was described in detail in Reid and Gilliland (2008). In summary, the emissions modeling setup consisted of the following steps:

- Set up and run Perl scripts to convert the 2015 and 2020 TAC inventories to SMOKE-ready format;
- Convert temporal profiles and spatial allocation factors developed for the 2015 and 2020 TAC inventories to SMOKE-ready format;
- Set up SMOKE control packets to apply emissions reductions associated with ARB diesel regulations to the 2015 and 2020 TAC inventories;
- Set up and test SMOKE input files, assigns files,[12] and scripts for 2015 and 2020.

All of the files described above, as well as other files used in the development of the 2015 and 2020 TAC inventories, are being provided to the District with this document.

SUMMARY

In support of the CARE program's goals, STI prepared 2015 and 2020 screening-level gridded emissions inventories of TACs for the San Francisco Bay Area. In general, the methods used to develop the future-year TAC inventories are the same as those STI previously used to develop base-year (2000 and 2005) TAC inventories for the District (Reid et al., 2006; Reid, 2008). Chemical speciation profiles and unit risk factors/reference concentrations were applied to the District's projected TOG and PM_{10} emissions inventories to generate mass-based and risk-weighted TAC inventories. These inventories were then spatially distributed to the District's 1-km x 1-km modeling domain using gridded surrogate data developed by STI. However, several new sources of data were utilized in the development of the future-year TAC inventories; for example, socioeconomic forecasts from ABAG were used to develop spatial surrogate data for 2015 and 2020. Additional steps were required to develop the future-year inventories, including an assessment of the impact of diesel regulations passed by the ARB on future-year DPM emissions from on-road and non-road mobile sources.

Overall, TAC emissions from all sources in the District were estimated to be 84 tons per day for 2015 and 79 tons per day for 2020. The 2015 and 2020 TAC emissions are 27% and 31% lower, respectively, than the 115 tons per day of TAC emissions estimated for year 2005.

[12] SMOKE assigns files set the UNIX environment variables needed to successfully run SMOKE's various modules.

When ARB diesel regulations and the District's diesel correction are applied to the 2015 and 2020 inventories, TAC emissions are further reduced by 5 tons in 2015 and by 4 tons in 2020 due to reductions in DPM emissions.

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