September 15, 2019

SPECIFICATION SHEET: ONROAD 2016beta Platform

Description: Mobile onroad vehicle emissions developed with SMOKE-MOVES using the MOVES2014a model, for simulating 2016 and future year U.S. air quality

1. EXECUTIVE SUMMARY

This document details the approach and data sources to be used for developing gridded, hourly emissions for the mobile onroad vehicle sector that are suitable for input to an air quality model in terms of the format, grid resolution, and chemical species. Onroad mobile sources include all emissions from motor vehicles that operate on roadways such as passenger cars, motorcycles, minivans, sport-utility vehicles, light-duty trucks, heavy-duty trucks, and buses; this also includes emissions from those vehicles while parked and refueling. Onroad mobile source emissions are processed for air quality modeling using emission factors output from the Motor Vehicle Emissions Simulator (http://www.epa.gov/otaq/models/moves/index.htm). These factors are then combined with activity data to produce emissions within the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system. The collection of programs that the compute the onroad mobile source emissions are known as SMOKE-MOVES. SMOKE-MOVES uses a combination of vehicle activity data, emission factors from MOVES, meteorology data, and temporal allocation information needed to estimate hourly onroad emissions. Additional types of ancillary data are used for the processing, such as spatial surrogates which ensure emissions are developed on the grid used by the air quality model. California emissions are given special treatment in collaboration with the California Air Resources Board (CARB). SMOKE-MOVES processes onroad emissions in four streams, which are run separately and then merged. Onroad emissions for future years incorporate projections of activity data and future-year-specific MOVES emission factors. The development of onroad mobile source emissions with SMOKE-MOVES is the most computationally intensive emissions modeling sector in terms of computational time and memory requirements – typically taking several days to complete. The development of the MOVES emission factors is not included in this time. California onroad mobile source emissions require special treatment because California provides emissions totals and those are temporally and spatially distributed in the same patterns as SMOKE-MOVES would produce. Summaries showing pollutant totals from the onroad sector nationally and of key pollutants by state are provided. Some example maps of key pollutants are also provided.

2. INTRODUCTION

Onroad mobile source emissions result from motorized vehicles that are normally operated on public roadways. These include passenger cars, motorcycles, minivans, sport-utility vehicles, light-duty trucks, heavy-duty trucks, and buses. The sources are further divided between diesel, gasoline, E-85, and compressed natural gas (CNG) vehicles. The sector characterizes emissions from parked vehicle processes (e.g., starts, hot soak, and extended idle) as well as from on-network processes (i.e., from vehicles as they move along the roads). Except for California, all onroad emissions are generated using the SMOKE-MOVES emissions modeling framework that leverages MOVES-generated emission factors, county and SCC-specific activity data, and hourly meteorological data. The onroad SCCs in the modeling platform are more finely resolved than those in the National Emissions Inventory (NEI). The NEI SCCs distinguish vehicles and fuels. The SCCs used in the model platform also distinguish vehicles and fuels but also distinguish between emissions process (i.e., off-network, on-network, and extended idle), and by road type.

SMOKE-MOVES uses as input emission rate (i.e., “lookup”) tables generated by MOVES. These tables differentiate emissions by process (i.e., running, start, vapor venting, etc.), vehicle type, road type, temperature, speed, hour of day, etc. To generate the MOVES emission rates that could be applied across the U.S., an automated process is to run MOVES to produce emission factors for a series of temperatures and speeds for a set of “representative counties,” to which every other county in the country is mapped. Representative counties are used because it is impractical to generate a full suite of emission factors for the more than 3,000 counties in the U.S. The representative counties for which emission factors are generated are selected according to their state, elevation, fuels, age distribution, ramp fraction, and inspection and maintenance programs. Each county is then mapped to a representative county based on its similarity to the representative county with respect to those attributes. For age distributions and vehicle fuel types, rather than choose values specific to each representative county, a weighted average was computed for all counties represented by each representative county, and the mean of those averages was used. For the beta platform, there are 303 representative counties, which is same as in the 2014v7.1 emissions modeling platform. A detailed discussion of the representative counties is in the 2014NEIv2 Technical Support Document (TSD), Section 6.8.2[1].

[1] https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-technical-support-document-tsd

Once representative counties have been identified, emission factors are generated by running MOVES for each representative county for two "fuel months" – January to represent winter months and July to represent summer months – because different types of fuels are used in each season. MOVES is run for the range of temperatures that occur in each representative county for each season. SMOKE selects the appropriate MOVES emissions rates for each county, hourly temperature, SCC, and speed bin and multiplies the emission rate by appropriate activity data: VMT (vehicle miles travelled), VPOP (vehicle population), or HOTELING (hours of extended idle) to produce emissions. These calculations are done for every county and grid cell in the continental U.S. for each hour of the year. SMOKE-MOVES accounts for the temperature sensitivity of the on-road emissions counties by using the gridded hourly temperature information available from the meteorological model outputs used for air quality modeling.

In summary, the SMOKE-MOVES process for creating the model-ready emissions consists of the following steps:

1) Determine which counties will be used to represent other counties in the MOVES runs.
2) Determine which months will be used to represent other month's fuel characteristics.
3) Create inputs needed only by MOVES. MOVES requires county-specific information on vehicle populations, age distributions, speed distribution, temporal profiles, and inspection-maintenance programs for each of the representative counties.
4) Create inputs needed both by MOVES and by SMOKE, including temperatures and activity data.
5) Run MOVES to create emission factor tables for the temperatures and speeds that exist in each county during the modeled period.
6) Run SMOKE to apply the emission factors to activity data (VMT, VPOP, and HOTELING) to calculate emissions based on the gridded hourly temperatures in the meteorological data.
7) Aggregate the results to the county-SCC level for summaries and QA.

The onroad emissions are processed as four components that are merged together into the final onroad sector emissions:

- rate-per-distance (RPD) uses VMT as the activity data plus speed and speed profile information to compute on-network emissions from exhaust, evaporative, permeation, refueling, and brake and tire wear processes;
- rate-per-vehicle (RPV) uses VPOP activity data to compute off-network emissions from exhaust, evaporative, permeation, and refueling processes;
- rate-per-profile (RPP) uses VPOP activity data to compute off-network emissions from evaporative fuel vapor venting, including hot soak (immediately after a trip) and diurnal (vehicle parked for a long period) emissions; and

- rate-per-hour (RPH) uses hoteling hours activity data to compute off-network emissions for idling of long-haul trucks from extended idling and auxiliary power unit process.

California is the only state agency for which submitted onroad emissions are used. California uses their own EPA-approved emission model, EMFAC, which uses emission inventory codes (EICs) to characterize the emission processes instead of SCCs. The EPA and California worked together to develop a code mapping to better match EMFAC's EICs to EPA MOVES' detailed set of SCCs that distinguish between off-network and on-network and brake and tire wear emissions. This detail is needed for modeling but not for the NEI. This code mapping is provided in "2014v1_EICtoEPA_SCCmapping.xlsx." which is found in the supporting data for the 2014 NEI v2 TSD[2]. California provided their CAP and HAP emissions by county using EPA SCCs after applying the mapping. This allows us to reflect the unique rules in California, while leveraging the more detailed SCCs and the highly resolved spatial patterns, temporal patterns, and speciation from SMOKE-MOVES. California emissions are run through SMOKE-MOVES as a separate sector called "onroad_ca_adj", as opposed to the "onroad" sector which includes US states except California. Further details regarding how SMOKE-MOVES is run to match California's emissions data are provided in the Emissions Processing Requirements section.

3. Inventory Development Methods

Onroad emissions are computed within SMOKE-MOVES by multiplying specific types of activity data by the appropriate emission factors. This section includes discussions of the activity data and the emission factor development.

Activity data development

SMOKE-MOVES uses vehicle miles traveled (VMT), vehicle population (VPOP), and hours of hoteling, to calculate emissions. These datasets are collectively known as "activity data". For each of these activity datasets, first a national dataset is developed; this national dataset is called the "EPA default" dataset. Second, data submitted by state agencies is incorporated where available, in place of the EPA default data. EPA default activity is used for California, but the emissions are scaled to California-supplied values during the processing.

Vehicle Miles Traveled (VMT)

The EPA default VMT dataset for beta platform is the same as the VMT dataset from the preceding alpha platform and is a projection of the 2014NEIv2 VMT to year 2016. 2014-to-2016 projection factors are based on state-level VMT data from the FHWA VM-2 report. VMT

[2] ftp://newftp.epa.gov/air/nei/2014/doc/2014v2_supportingdata/onroad/

projection factors are calculated for each state. For most states, separate factors are calculated for urban VMT and rural VMT. Some states have a very different distribution of urban activity versus rural activity between 2014NEIv2 and the FHWA data; for those states, a single state-wide projection factor was applied to all VMT independent of road type. The following states used a single state-wide projection factor: AK, GA, IN, ME, MA, NE, NM, NY, ND, TN, and WV. Also, state-wide projection factors in Texas and Utah were developed from alternative VMT datasets provided by their respective Departments of Transportation. The VMT projection factors for all states are provided in Table 1.

Table 1. Factors Applied to project VMT from 2014 to 2016

State	Rural roads	Urban roads
Alabama	5.36%	5.47%
Alaska	8.27%	8.27%
Arizona	1.07%	6.35%
Arkansas	4.80%	5.36%
California	1.06%	2.39%
Colorado	5.97%	6.67%
Connecticut	1.33%	1.45%
Delaware	4.42%	6.75%
District of Columbia	0.00%	2.68%
Florida	10.27%	6.64%
Georgia	10.10%	10.10%
Hawaii	6.14%	4.21%
Idaho	5.51%	7.80%
Illinois	3.40%	1.96%
Indiana	5.02%	5.02%
Iowa	6.17%	6.05%
Kansas	2.42%	6.52%
Kentucky	2.52%	3.26%
Louisiana	-5.49%	7.10%
Maine	3.75%	3.75%
Maryland	4.98%	4.75%
Massachusetts	7.42%	7.42%
Michigan	5.62%	0.66%
Minnesota	2.66%	2.97%
Mississippi	1.83%	4.96%
Missouri	4.70%	4.17%
Montana	3.32%	4.34%
Nebraska	5.54%	5.54%
Nevada	8.30%	5.30%
New Hampshire	5.00%	3.65%
New Jersey	5.41%	2.83%
New Mexico	10.01%	10.01%
New York	-4.90%	-4.90%

State	Rural roads	Urban roads
North Carolina	7.47%	8.41%
North Dakota	-7.35%	-7.35%
Ohio	4.61%	5.42%
Oklahoma	4.72%	1.23%
Oregon	8.05%	4.84%
Pennsylvania	-4.30%	4.73%
Rhode Island	3.26%	3.26%
South Carolina	9.70%	8.89%
South Dakota	3.23%	2.64%
Tennessee	6.29%	6.29%
Texas	7.82%	7.82%
Utah	11.62%	11.62%
Vermont	5.55%	2.24%
Virginia	-4.93%	9.78%
Washington	6.86%	4.43%
West Virginia	2.21%	2.21%
Wisconsin	4.15%	9.32%
Wyoming	-1.38%	-1.53%
Puerto Rico	0.00%	0.00%
Virgin Islands	0.00%	0.00%

For the beta platform, VMT data submitted by state and local agencies were incorporated and used in place of EPA defaults, as described below. Note that VMT data needs to be provided to SMOKE for each county and SCC. The onroad SCCs include the resolution of MOVES fuel type, source type, emissions process, and road type. Any VMT provided at a different resolution than this must be converted to a full county-SCC resolution before it can be used by SMOKE.

For CO, CT, GA, IL, MD, NJ, NC, VA, WI, and Pima County, AZ: these agencies provided VMT data for the year 2016 by county and HPMS vehicle type. That level of detail is sufficient for MOVES, but SMOKE also needs VMT broken out by MOVES vehicle type (which is more detailed than HPMS vehicle type), and by fuel type and road type. In other words, SMOKE needs VMT by full SCC. To get VMT by full SCC, the county-HPMS VMT data provided by the states was loaded into the county databases (CDBs) that are used to run MOVES. MOVES CDBs include fuel type splits, road type splits, and VPOP by MOVES vehicle type. Using those tables, county-HPMS VMT data can be converted into the county-SCC VMT data that is needed by SMOKE. One exception to the use of local data in these states is in North Carolina, where EPA default VMT for buses were used along with state-submitted VMT for other vehicle types.

In Massachusetts (MA), VMT data were provided at the county-HPMS level, but it was discovered that the distribution of county total VMT to HPMS vehicle type was the same in every county in the state, which is not realistic. Therefore, a new set of county-specific HPMS vehicle type splits was developed in MA. The starting point for this new set of HPMS splits was a dataset of county-specific road type splits that MA had also provided. The FHWA VM-4 report for 2015 (this report is not available for 2016) includes state-level HPMS vehicle type splits by road type. Those two datasets were combined to create county-specific HPMS vehicle type splits for each county in MA. For example, according to the FHWA VM-4 report, interstate traffic consists of a higher proportion of combination trucks than does non-interstate highway traffic. So, it stands to reason that counties in MA which have a higher proportion of interstates, based on the county-specific road type data provided bythis state , also have a higher proportion of combination trucks than do other counties in the state. Using the FHWA VM-4 report together with MA road type splits allowed us to account for that when allocating county total VMT to HPMS vehicle type. The new county-specific HPMS splits were scaled so that the state total HPMS splits matched the state-wide splits as provided by MA. Thus, the final VMT in MA matches the state's original dataset with respect to both county totals and state-wide HPMS splits, but now has varying HPMS splits between counties. The VMT was then split to full SCCs using a similar procedure as in other states that submitted VMT at the county-HPMS level.

South Carolina (SC) is similar to MA in that they submitted VMT by county-HPMS but is using the same HPMS splits in every county in the state. The difference in SC is that we did not receive county-specific road type splits for this state like we did for MA. Instead, a new set of county-specific HPMS splits was developed from the EPA default VMT. For all HPMS types except 25 (light cars and trucks), county-HPMS ratios were calculated from the EPA default VMT, and then scaled up or down so that the overall state-HPMS ratio would match South Carolina's state-HPMS ratio. For HPMS type 25, we set the county-HPMS ratios equal to the remainder within each county so that all ratios within each county sum to 1. The new VMT by county-HPMS varies by county while respecting the state-wide HPMS splits in South Carolina's original VMT dataset. The VMT was then split to full SCC level using a similar procedure as other states that submitted VMT at the county-HPMS level.

Pennsylvania and New Hampshire submitted VMT for 2016 beta platform at the full county-SCC level, already in the FF10 format needed by SMOKE. These data were used directly, except for the redistribution of light duty VMT (see last item in this subsection).

Michigan and Minnesota submitted VMT by county and by road type. Fuel and vehicle type distributions from the EPA default VMT were used to convert their data to full SCC.
West Virginia submitted county total VMT only. Fuel, vehicle, and road type distributions from the EPA default VMT were used to convert their data to full SCC.

Clark County, NV, submitted VMT by county and MOVES vehicle type, which is more detailed than HPMS vehicle type, but nevertheless cannot be imported into MOVES CDBs as easily to facilitate the creation of VMT at the full SCC detail. Fuel and road type distributions from the EPA default VMT were used to convert their data to full SCC.

One more step was performed on all state-submitted VMT. The distinction between a "passenger car" (MOVES vehicle type 21) versus a "passenger truck" (MOVES vehicle type 31) versus a "light commercial truck" (MOVES vehicle type 32) is not always consistent between different datasets. This distinction can have a noticeable effect on the resulting emissions, since MOVES emission factors for passenger cars are quite different than those for passenger trucks and light commercial trucks. To ensure consistency in the 21/31/32 splits across the country, all state-submitted VMT for MOVES vehicle types 21, 31, and 32 (all of which are part of HPMS vehicle type 25) was summed, and then re-split using the 21/31/32 splits from the EPA default VMT. This was done for all states and counties listed above where 21/31/32 splits were not already based on the EPA default VMT (all but MI, MN, and WV). Most of the states listed above did not provide VMT down to the source type, so resplitting LD VMT does not create an inconsistency with state-provided data in most states. Exceptions to that are NH and PA: those two states provided SCC-level VMT, but these were reallocated to 21/31/32 so that the splits are performed in a consistent way across the country. The 21/31/32 splits in the EPA default VMT can be traced back to the 2014NEIv2 VPOP data obtained from IHS-Polk.

<u>Speed activity (SPEED / SPDPRO)</u>

SMOKE-MOVES uses two datasets related to the average speed of vehicles, which affects the selection of MOVES emission factors for on-network emissions. One such dataset is the SPEED inventory read by the SMOKE program Smkinven, which includes a single overall average speed for each county, SCC, and month. The second dataset is the SPDPRO dataset read by the SMOKE program Movesmrg, which includes an average speed for each county, SCC, and hour of the day, with separate hourly values for weekdays and weekends. SMOKE still requires the SPEED dataset exist even when hourly speed data is available, even though only the hourly speed data affects the selection of emission factors.

The SPEED and SPDPRO datasets are both carried over from 2014NEIv2 and are based on a combination of CRC A-100 data and MOVES CDBs.

<u>Vehicle population (VPOP)</u>

The EPA default VPOP dataset is based on the EPA default VMT dataset described above. For each county, fuel type, and vehicle type, a VMT/VPOP ratio (miles per vehicle per year) is calculated based on the 2014NEIv2 VMT and VPOP datasets. Then, that ratio is applied to the 2016 EPA default VMT, to produce an EPA default VPOP projection.

As with VMT, several state and local agencies submitted VPOP data, which is incorporated into the beta platform VPOP in place of the EPA default VPOP. The VPOP SCCs used by SMOKE are similar to the VMT SCCs, except the process represented as “00” because it is not relevant to vehicle population data.

For GA, MD, MA, NJ, NC, WI, and Pima County, AZ: These agencies provided VPOP data for the year 2016 by county and MOVES vehicle type. That level of detail is sufficient for MOVES, but SMOKE also needs VPOP broken out by fuel type. To get VPOP by full SCC, the county-vehicle VPOP data provided by the states was loaded into the county databases (CDBs) that are used to run MOVES. Using fuel type tables in the CDBs, it is possible to take county-vehicle VPOP data and create county-SCC VPOP data that is needed by SMOKE. For Massachusetts, based on quality assurance checks, we did not need to make additional modifications to their VPOP like we did for their VMT. Wisconsin provided VPOP for 2016 by county and HPMS vehicle type instead of by MOVES vehicle type, but the same procedure was applied as for other states in this group. In North Carolina EPA default VPOP data were used for buses along with the state-submitted VPOP for other vehicle types, consistent with the VMT.

West Virginia and Clark County, Nevada also provided VPOP for 2016 by county and MOVES vehicle type. Because they did not provide VMT by county-HPMS, they were not put into MOVES databases for splitting. Instead, the VPOP was split to full SCC using county-vehicle to county-SCC ratios calculated from the 2016 beta VMT - not the EPA default VMT, but the final VMT incorporating state data and split to full SCC within MOVES CDBs. So effectively, MOVES CDBs were used to split their VPOP to full SCC, but only indirectly. WV’s VPOP dataset did not include any intercity buses (MOVES vehicle type 41), so intercity bus VPOP was taken from the EPA default VPOP in West Virginia.

Pennsylvania and New Hampshire provided VPOP by county-SCC in FF10 format, which was used directly.

For states that submitted VMT but did not submit VPOP, which includes CO, CT, IL, MI, MN, SC, and VA, EPA default VPOP was used, except in SC. The new VMT that SC provided, in addition to the recalculation of HPMS splits between counties, introduced some issues with VMT/VPOP ratios when comparing beta VMT with EPA default beta VPOP. The largest VMT/VPOP ratio issues were for HD vehicles. The LD VPOP is based on the IHS-Polk data, which is considered a fairly trustworthy dataset; therefore, only HD VPOP was modified in SC from the EPA defaults.

For HD VPOP in SC: new VPOP = EPA default VPOP * (beta VMT / alpha VMT). In other words, the same alpha-to-beta changes that were made to the VMT as a result of the new state data were also made to the VPOP on a percentage basis. This preserves VMT/VPOP ratios for HD vehicles in SC compared to the EPA default data, which generally had acceptable ratios. This procedure did result in some changes to the overall HD VPOP total in SC, both at the county level and state level.

Hoteling hours (HOTELING)

Hoteling hours activity is used to calculate emissions from extended idling and auxiliary power units (APUs). Many states have commented that EPA estimates of hoteling hours, and therefore emissions resulting from hoteling, are too high. Therefore, recent hoteling activity datasets, including 2014NEIv2 and 2016 alpha platform, include reductions to hoteling activity data based on the availability of truck stop parking spaces in each county, as described below. The methodology and underlying data for these reductions were updated for beta platform. For the alpha platform, reductions were first applied to 2014NEIv2 hoteling, and then the reduced hoteling was projected to 2016. For the beta platform, we did the opposite: first we projected *unreduced* 2014NEIv2 hoteling to 2016, and then we applied reductions directly to the 2016 projections based on parking space availability in areas where more hours were assigned to the county than the available parking spaces could support if they were full every hour of every day.

To project hoteling activity to 2016, a version of the 2014NEIv2 hoteling without any reductions applied was used as the starting point. Then, VMT/HOTELING ratios were calculated for each county using the 2014NEIv2 VMT (long-haul combination trucks on restricted roads only) and unreduced 2014NEIv2 hoteling. Those ratios were applied to the 2016 beta VMT (long-haul combination trucks on restricted roads only) to calculate unreduced 2016 beta HOTELING.
For calculating reductions, a dataset of truck stop parking space availability was used, which includes a total number of parking spaces per county. This same dataset is used to develop the spatial surrogate for hoteling emissions. For beta platform, the parking space dataset includes several updates compared to alpha platform, based on new truck stops opening and other new information. There are 8,784 hours in the year 2016; therefore, the maximum number of possible hoteling hours in a particular county is equal to 8,784 * the number of parking spaces in that county. Hoteling hours were capped at that theoretical maximum value for 2016 in all counties, with some exceptions as outlined below.

Because the truck stop parking space dataset may be incomplete in some areas, and trucks may sometimes idle in areas other than designated spaces, it was assumed that every county has at least 12 parking spaces, even if fewer parking spaces are found in the parking space dataset. Therefore, hoteling hours are never reduced below 105,408 hours for the year in any county. If the unreduced hoteling hours were already below that maximum, the hours were left unchanged; in other words, hoteling activity are never increased as a result of this analysis. A handful of high activity counties that would otherwise be subject to a large reduction were analyzed individually to see if their parking space count seemed unreasonably low. In the following counties, the parking space count and/or the reduction factor was manually adjusted:

- 17043 / DuPage IL (reset adjustment factor to 0.50 instead of 0.05)
- 39061 / Hamilton OH (parking spot count increased to 20 instead of the minimum 12)
- 47147 / Robertson TN (parking spot count increased to 52 instead of just 26)
- 51015 / Augusta VA (parking space count increased to 48 instead of the minimum 12)
- 51059 / Fairfax VA (parking spot count increased to 20 instead of the minimum 12)

Two states submitted hoteling activity for the beta platform: Georgia and New Jersey. For these states, the EPA default projection was replaced with their state data. New Jersey provided their hoteling activity in a series of HotellingHours MOVES-formatted tables, which include separate activity for weekdays and weekends and for each month and which have units of hours-per-week. This data first needed to be converted to annual totals by county.

Four states requested that no reductions be applied to the hoteling activity based on parking space availability: CO, ME, NJ, and NY. For these states, we did not apply any reductions based on parking space availability and left the unreduced EPA default projections; or in the case of New Jersey, their submitted activity; unchanged. Otherwise, the submitted data from NJ would have been subjected to reductions. The submitted data from Georgia did not exceed the maximum value in any county, and so their submitted data did not need to be reduced at all.

Finally, the county total hoteling must be split into separate values for extended idling (SCC 2202620153) and Auxiliary Power Units (APUs) (SCC 2202620191). New Jersey's submittal of hoteling activity specified a 30% APU split, and this was used throughout NJ. For the rest of the country, a 12.4% APU split was used, meaning that during 12.4% of the hoteling hours auxiliary power units are assumed to be running.

Emission factor table development

MOVES2014a was run in emission factor mode to create emission factor tables using CB6 speciation for the years 2016, 2023, and 2028, for all representative counties and fuel months, and was also run for all counties in Alaska, Hawaii, and Virgin Islands, and for a single representative county in Puerto Rico. The county databases used to run MOVES to develop the emission factor tables were the same as those used to develop the 2014NEIv2, including the state-specific control measures such as the California LEV program, except that fuels were updated to represent calendar year 2016. In addition, the range of temperatures run along with the average humidities used were specific to the year 2016. The remaining settings for the CDBs are documented in the 2014NEIv2 TSD.

The original plan for beta platform was to use the same emission factor tables as were used for the alpha platform. However, during quality assurance checks of beta platform emissions for 2023, it was discovered that incorrect fuels were used to run MOVES for 2016. Therefore, MOVES was rerun to create a new set of emission factor tables for 2016 for the beta platform. The alpha platform did not include the future year inventories.
To create the emission factors, MOVES was run separately for each representative county and fuel month for each temperature bin needed for calendar year 2016. The MOVES results were post-processed into CSV-formatted emission factor tables that can be read by SMOKE-MOVES.

California inventory development

The California Air Resources Board (CARB) provides their own onroad emissions inventories based on their EMFAC2014 model. EMFAC2014 was run by CARB for model years 2014 and 2017. Since those two inventories were run at different times with different methodologies, they have some inconsistencies. For instance, the 2017 inventory does not include refueling or NH3, and does not distinguish off-network emissions from on-network emissions. Therefore, the 2014 and 2017 inventories cannot be interpolated directly. Instead, the 2017 inventory was used to project the 2014 inventory, which includes refueling and NH3 and has more detailed SCCs, to 2016. Three-year projection factors by county and pollutant are calculated from the two inventories, and then the resulting growth factors are multiplied by 2/3 to get a two-year growth factor for 2016, which is then applied to the 2014 inventory.

Details on how SMOKE-MOVES emissions are adjusted to match the CARB-based 2016 inventory are provided in the Emissions Processing Requirements section of this document.

SCC descriptions

SCCs in the onroad sector follow the format 220**FVV**0**RPP**, where:

- F = MOVES fuel type (1 for gasoline, 2 for diesel, 3 for CNG, 5 for E-85, and 9 for electric)
- VV = MOVES vehicle type (see Table 2)
- R = MOVES road type (1 for off-network, 2 for rural restricted, 3 for rural unrestricted, 4 for urban restricted, 5 for urban unrestricted)
- PP = SMOKE aggregate process. In the activity data, the last two digits of the SCC are always 00, because activity data is process independent. MOVES separately tracks over a dozen processes, but for computational reasons it is not practical to model all of these

processes separately within SMOKE-MOVES. Instead, “aggregate” processes are used in SMOKE. To support this, the MOVES processes are mapped to SMOKE aggregate processes according to Table 3.

Regarding electric vehicle activity: The only emissions created by electric vehicles are PM from brake and tire. MOVES2014a does not create separate emission factors for electric vehicles. To capture brake and tire emissions from electric vehicles, VMT from electric vehicles is mapped to gasoline SCCs within SMOKE using the SCCXREF file, but for the brake and tire processes only. Brake and tire emission factors are assumed to be independent of fuel type. This assumption allows brake and tire emissions from electric vehicles to be modeled using the brake and tire emission factors for gasoline vehicles. Since electric vehicle VMT is *not* mapped to the exhaust or evaporative processes, exhaust and evaporative emissions are not generated from electric vehicles. Since all brake and tire emissions are on-network, only the VMT dataset, and not the VPOP dataset, needs to include electric vehicles. For this reason, electric vehicle VPOP is often removed from the inventory prior to running SMOKE-MOVES.

Table 2. MOVES vehicle types

MOVES vehicle type	description	HPMS vehicle type
11	Motorcycle	10
21	Passenger Car	25
31	Passenger Truck	25
32	Light Commercial Truck	25
41	Intercity Bus	40
42	Transit Bus	40
43	School Bus	40
51	Refuse Truck	50
52	Single Unit Short-haul Truck	50
53	Single Unit Long-haul Truck	50
54	Motor Home	50
61	Combination Short-haul Truck	60
62	Combination Long-haul Truck	60

Table 3: SMOKE-MOVES aggregate processes

MOVES Process ID	Process description	SMOKE aggregate process
01	Running Exhaust	72
02	Start Exhaust	72
09	Brakewear	40
10	Tirewear	40
11	Evap Permeation	72
12	Evap Fuel Vapor Venting	72
13	Evap Fuel Leaks	72
15	Crankcase Running Exhaust	72
16	Crankcase Start Exhaust	72
17	Crankcase Extended Idle Exhaust	53
18	Refueling Displacement Vapor Loss	62
19	Refueling Spillage Loss	62
90	Extended Idle Exhaust	53
91	Auxiliary Power Exhaust	91

4. ANCILLARY DATA

Spatial Allocation

Onroad activity is allocated to a national 12km grid for EPA air quality modeling applications using spatial surrogates. The surrogates are derived based on various types of spatial data and referred to by a name and a three-digit code. Technically, within SMOKE-MOVES, activity is gridded first, and then emissions are calculated based on gridded activity data for each month. VMT is allocated using spatial surrogates based on Annual Average Daily Travel (AADT) for restricted roads and unrestricted roads. To eliminate the impact of discrepancies in urban and rural classifications between activity data and the underlying AADT data, we do not use spatial surrogates specific to urban or rural road types. Such discrepancies have caused problematic hot spots in the past when using surrogates specific to rural or urban roads.

Hoteling emissions use a truck stops surrogate (205), which is based on the same truck stop parking space data that was used when applying reductions to hoteling activity. The four states for which hoteling reductions were not applied (CO, ME, NJ, and NY) also requested that we not spatially allocate hoteling emissions using the truck stops surrogate, because doing so may have resulted in overallocation of hoteling emissions to a small area (i.e. hot spots). Instead, hoteling emissions in those four states are allocated using the All Restricted AADT surrogate (242).
The AADT and truck stop surrogates were updated for the beta platform. Off-network emissions use surrogates that depend on the vehicle type. Reports summarizing total emissions by spatial surrogate at the state and county level have been developed.

Onroad emissions totals, because of SMOKE-MOVES' dependence on gridded meteorology, can vary between grid resolutions. To ensure consistency in onroad emissions between different grid resolutions, when processing emissions at 36km resolution, emissions at 12km resolution are aggregated to 36km resolution instead of rerunning SMOKE-MOVES directly at the 36km resolution. One minor exception is for EPA's 36US3 grid, which includes part of Southeast Alaska. For Southeast Alaska only, SMOKE-MOVES is run for the 36US3 grid using activity and emission factors for Alaska. Alaska onroad emissions are treated as a separate sector called "onroad_nonconus" and then merged with onroad and onroad_ca_adj, which are both aggregated from 12km to 36km.

A table of total onroad emissions by spatial surrogate for the continental US is provided in Table 4.

Table 4. 2016ff onroad Continental US emissions by spatial surrogate (tons/year)

Surrogate	Description	CO	NH3	NOX	PM10_PRI	PM25_PRI	SO2	VOC
205	Extended Idle Locations	74,863	499	177,484	2,315	2,129	72	32,817
239	Total Road AADT							6,021
242	All Restricted AADT	4,829,703	35,855	1,316,007	65,968	41,161	8,564	205,314
244	All Unrestricted	8,655,999	64,487	1,929,809	190,662	75,033	17,881	517,975

Surrogate	Description	CO	NH3	NOX	PM10_PRI	PM25_PRI	SO2	VOC
	AADT							
258	Intercity Bus Terminals	538		141	2	2	0	31
259	Transit Bus Terminals	5,532		82	4	4	0	180
304	NLCD Open + Low	29,687		762	19	17	1	2,698
306	NLCD Med + High	316,122		15,478	314	283	18	17,706
307	NLCD All Development	5,985,182		584,068	12,680	11,221	945	1,142,084
308	NLCD Low + Med + High	415,741		41,226	788	698	64	60,234

Temporal Allocation

For on-network and hoteling emissions, VMT and HOTELING activity are temporalized from annual or monthly values to hourly and SMOKE is run for every day of the year. The VMT inventory is monthly for all sources. Some of the original VMT data sources did not specify monthly values, in which case monthly values for VMT were filled into the inventory prior to running SMOKE. In those instances, monthly temporalization is usually based on an existing monthly inventory (e.g. EPA default data). The hoteling activity dataset is annual and is temporalized to monthly within SMOKE using the MOVES default monthly profile for combination trucks.

For off-network emissions, VPOP is strictly treated as an annual value and does not need to be temporalized. For RPH, the HOTELING inventory is annual and was temporalized to month, day of the week, and hour of the day through temporal profiles. This is an analogous process to RPD except that speed is not included in the calculation of RPH.

In addition to temporalization of activity, emissions temporalization is affected by meteorology. Meteorology is not used in the development of the temporal profiles, but rather it impacts the calculation of the hourly emissions through the program Movesmrg. The result is that the emissions vary at the hourly level by grid cell. More specifically, the on-network (RPD) and the off-network parked vehicle (RPV, RPH, and RPP) processes use the gridded meteorology (MCIP) directly. Movesmrg determines the temperature for each hour and grid cell and uses that information to select the appropriate emission factor (EF) for the specified SCC/pollutant/mode combination. RPP uses the gridded minimum and maximum temperature for the day. The combination of these four processes (RPD, RPV, RPH, and RPP) make up the total onroad sector emissions.

VMT was also temporalized from month to day of the week, and then to hourly through temporal profiles. Day-of-week and hour-of-day temporal profiles are mostly based on Coordinating Research Council (CRC)-sponsored A-100 data assembled developed for use in 2014NEIv2. These profiles include a combination of county-specific, MSA-specific, and regional average profiles. The CRC A-100 data includes distinct profiles for passenger vehicles, commercial trucks, and combination trucks. CRC A-100 does not provide profiles for buses, refuse trucks, or motor homes. For motor homes, passenger vehicle weekly profiles and commercial truck hourly profiles were used. For intercity and transit buses, the weekly and hourly profiles for commercial trucks were used. School buses and refuse trucks use the hourly profiles for commercial trucks and a weekly profile called LOWSATSUN. This profile attributes most emissions to weekdays and only a very small amount on weekends, since the vast majority of school bus and refuse truck activity occurs on weekdays. Hoteling activity uses the same weekly profiles as the VMT, but uses inverted hourly profiles, since most hoteling activity occurs when vehicles are *not* driving. Additional details on the CRC A-100 project can be found on the CRC web site Coordinating Research Council (CRC). Report A-100. Improvement of Default Inputs for MOVES and SMOKE-MOVES. Final Report. February 2017[3]. Additional information on the CRC A-100 implementation into the modeling platform can be found in the TSD Preparation of Emission Inventories for the 2014v7.1 2014 Emissions Modeling Platform (EPA, 2018).

The RPD processes require a speed profile (SPDPRO) that consists of vehicle speed by hour for a typical weekday and weekend day. Unlike other sectors, the temporal profiles and SPDPRO will impact not only the distribution of emissions through time but also the total magnitude of emissions. Because SMOKE-MOVES (for RPD) calculates emissions from VMT, speed and meteorology, if one shifted the VMT or speed to different hours, it would align with different temperatures and hence different emission factors. In other words, two SMOKE-MOVES runs with identical annual VMT, meteorology, and MOVES emission factors, will have different total emissions if the temporalization of VMT changes.

In California, weekly and hourly temporal profiles provided by CARB for the 2011 platform were used.

Alaska, Hawaii, Puerto Rico, and Virgin Islands all use regional average temporal profiles from the CRC A-100 data. AK/HI use the West region average; PR/VI use the South region average.

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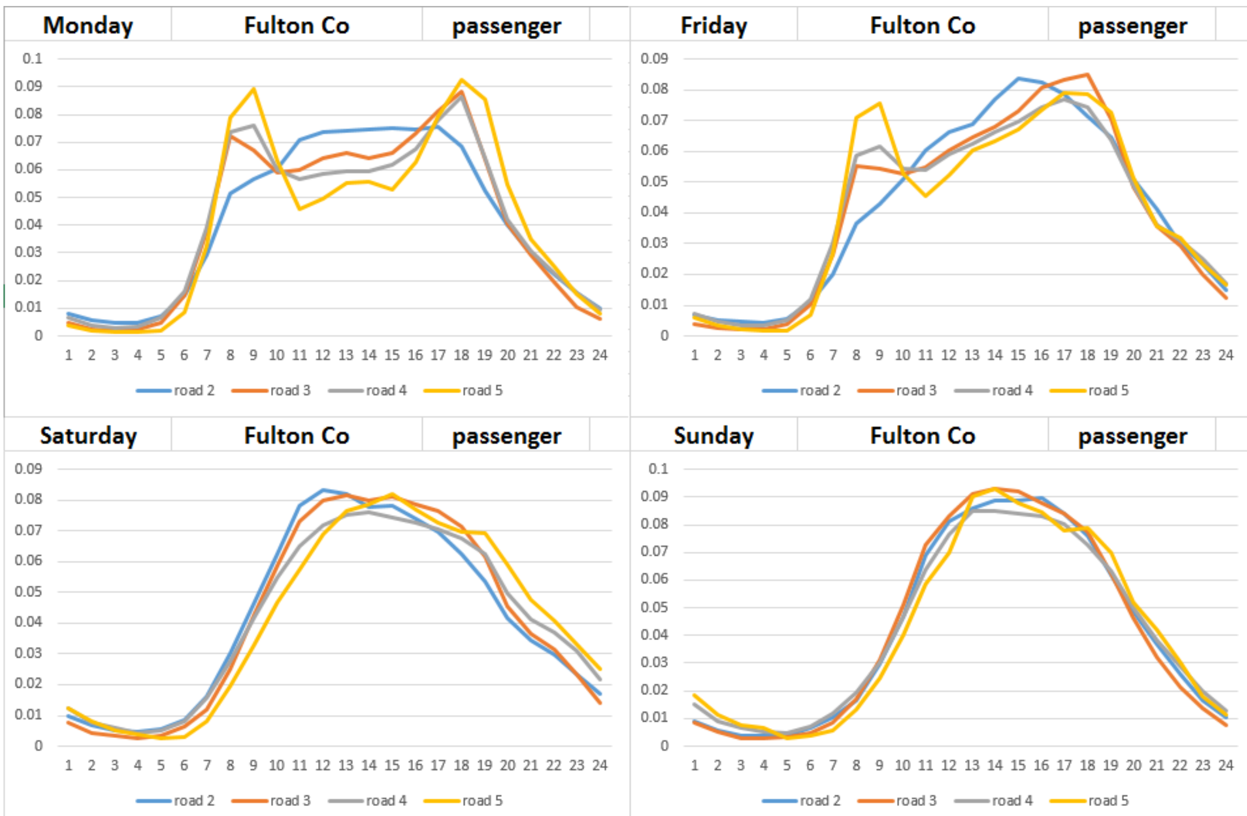
[3] https://crcao.org/reports/recentstudies2017/A-100/ERG_FinalReport_CRCA100_28Feb2017.pdf.

Plots of hour-of-day profiles for passenger vehicles and combination trucks in Fulton County, GA, are shown in Figure 1. Separate plots are shown for Monday, Friday, Saturday, and Sunday, and each line corresponds to a particular MOVES road type (i.e., road type 2 = rural restricted, 3 = rural unrestricted, 4 = urban restricted, and 5 = urban unrestricted). Figure 2 shows which counties have temporal profiles specific to that county, and which counties use regional average profiles.

Figure 1. Sample onroad diurnal profiles for Fulton County, GA



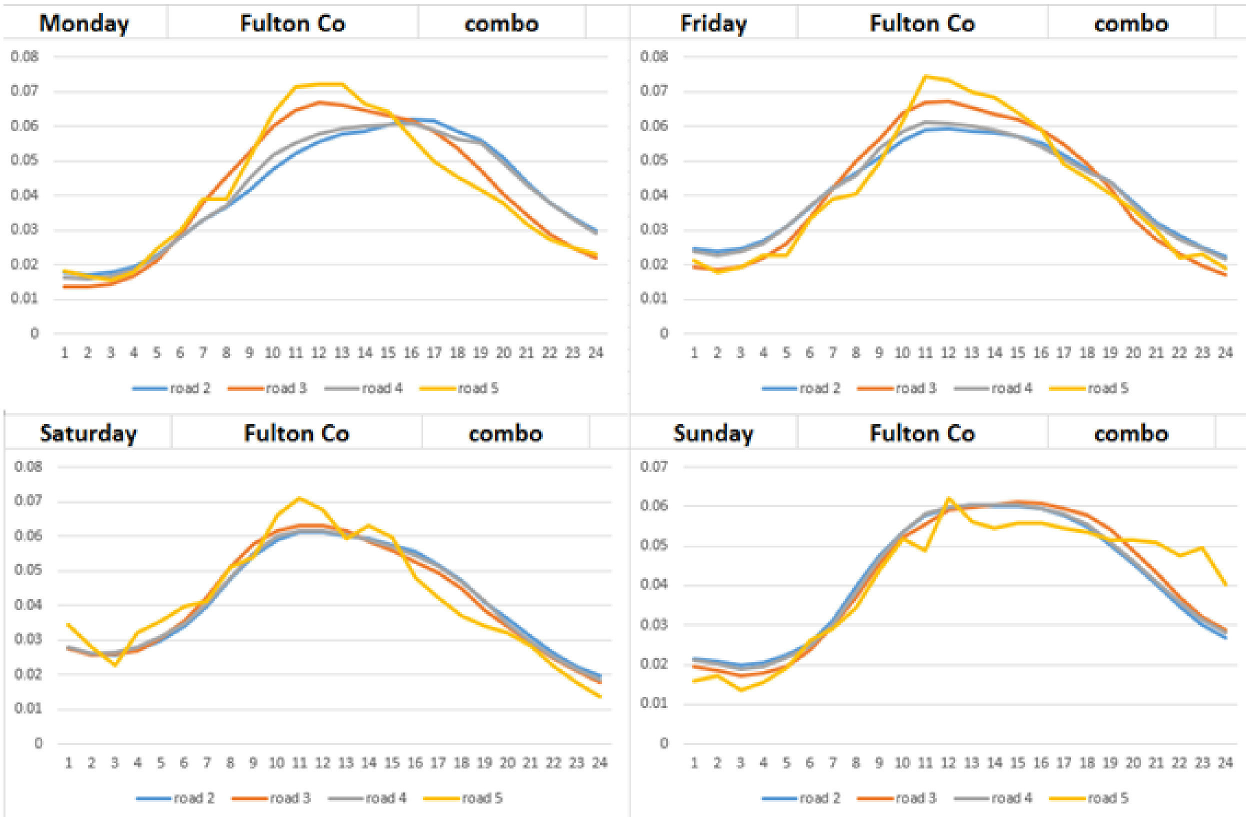
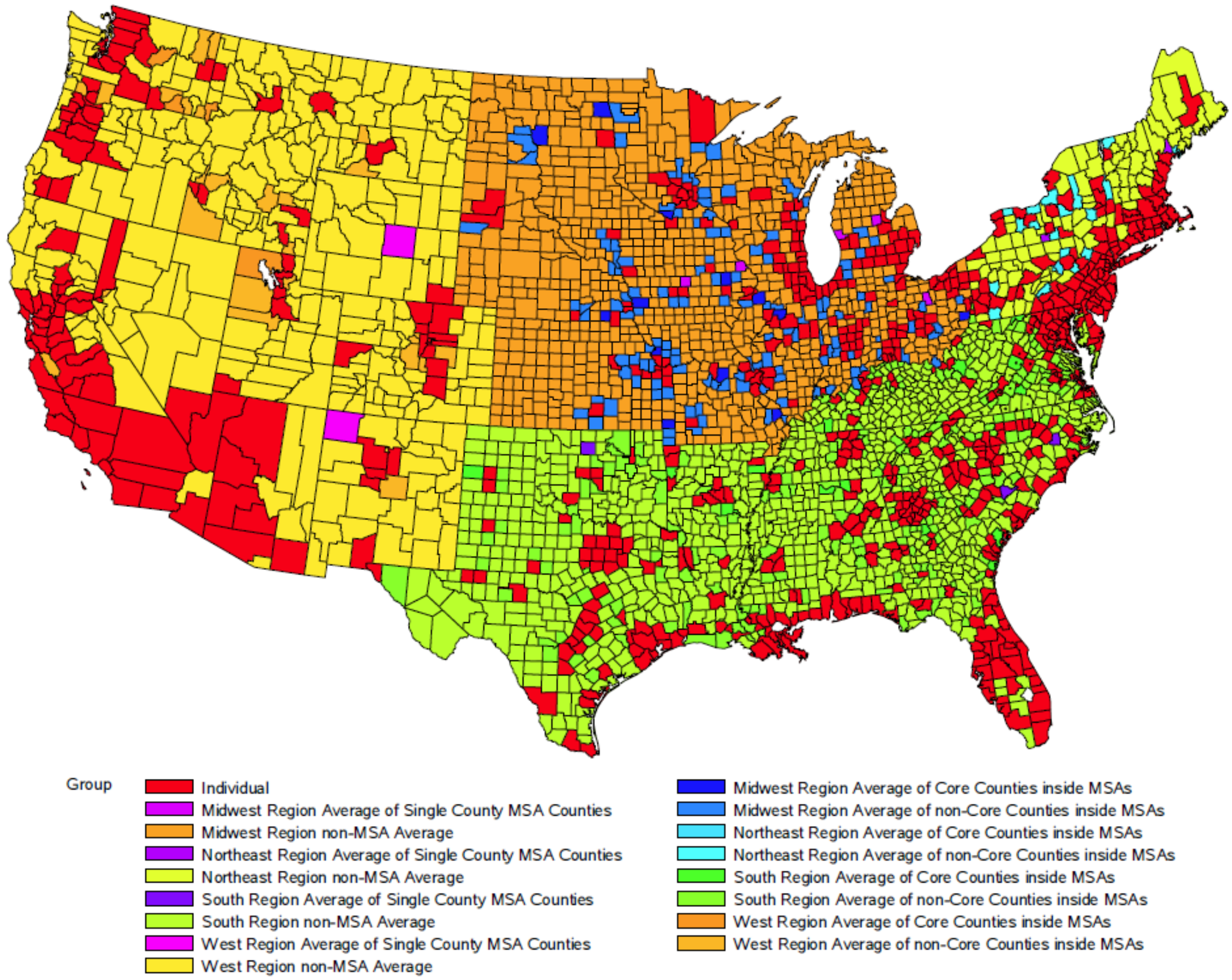

Monday
Fulton Co
combo
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
road 2
road 3
road 4
road 5
Friday
Fulton Co
combo
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
road 2
road 3
road 4
road 5
Saturday
Fulton Co
combo
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
road 2
road 3
road 4
road 5
Sunday
Fulton Co
combo
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
road 2
road 3
road 4
road 5

Figure 2. MOVES Speeds and Temporal Profiles used in CRC A-100



Chemical Speciation

Chemical speciation of onroad emissions is internal to MOVES2014a except for brake and tire-wear PM speciation which occurs in SMOKE. MOVES has access to more detailed data and can produce a more accurate speciation than could SMOKE. The emission factor tables from MOVES include both unspeciated emissions totals in grams for CAPs and HAPs, and speciated emissions totals for CB6 model species in moles (or grams for PM). The GSREF and GSPRO used by SMOKE-MOVES do not do any actual speciation. The GSREF has no function and only exists to prevent a SMOKE error. The GSPRO and MEPROC work in tandem to select which species and pollutants to include in SMOKE outputs. Generally speaking, the MEPROC includes all unspeciated pollutants, and the GSPRO maps unspeciated pollutants to individual model species (e.g. PM2_5 to all individual PM species). Model-ready emissions files will include all species in the GSPRO that are mapped to one or more pollutants present in the MEPROC. Movesmrg reports include all of those model species, plus all of the pollutants listed in the MEPROC.

In California, as described in the Emissions Processing Requirements section, the SMOKE-MOVES emissions are adjusted so that annual emissions totals match CARB-provided data. For pollutants that are speciated, such as NOX, PM2.5, and VOC, only the unspeciated emissions are matched to the totals provided by CARB. All speciation is determined by MOVES, even in California. For example, the same adjustment factors are applied to all VOC species as well as VOC_INV, resulting in a VOC total that matches CARB-supplied data, but a VOC speciation that matches MOVES.

One catch is that MOVES2014a created emission factors for an older version of the CB6 mechanism, used for CAMx modeling. CMAQ uses a newer version of the CB6 mechanism, in which the XYL species is replaced with XYLMN and NAPH, and includes an additional tracer called SOAALK. The emission factor tables include XYL and a species called NAPHTHALENE. After SMOKE-MOVES finishes, an extra step is needed to convert the emissions from CB6-CAMx to CB6-CMAQ. To do this, three formulas are applied:

NAPH = NAPHTHALENE
XYLMN = XYL – 0.966*NAPH (the 0.966 accounts for differences in molecular weights)
SOAALK = 0.108*PAR (create SOAALK as a function of PAR)

This conversion is performed with a program called “combine”. All model species except for XYL and NAPHTHALENE are carried forward as-is during the conversion.
Additional details on Speciation for MOVES and SMOKE-MOVES can be found in the TSD Preparation of Emission Inventories for the 2014v7.1 2014 Emissions Modeling Platform (EPA, 2018).

Other Ancillary Files Needed for SMOKE-MOVES

SMOKE-MOVES requires several other types of ancillary files:

- MCXREF: Maps individual counties to representative counties.
- MFMREF: Maps actual months to fuel months for each representative county. May through September are mapped to the July fuel month, and all other months to the January fuel month. All representative counties must be listed in this file.
- MRCLIST: Lists emission factor table filenames for each representative county.

- MEPROC: Lists which pollutants to include in the SMOKE run; see Chemical Speciation section for more information.
- METMOVES: Gridded daily minimum and maximum temperature data. This file is created by the SMOKE program Met4moves and is used for RatePerProfile (RPP) processing.
- CFPRO: Applies adjustment factors to emissions. This is described in the Emissions Processing Requirements section.

5. Emissions Projection Methods

To process future year emissions for the onroad sector, VMT, VPOP, and Hoteling activity data were projected for each future year and MOVES emission factors were developed for each future year. For the beta platform, the future years of interest are 2023 and 2028. For California, future year inventories provided by the Air Resources Board (CARB) were used.

Activity data development

Vehicle Miles Traveled (VMT)

Annual Vehicle Miles Traveled data from the AEO2018 reference case was used to calculate national projection factors for VMT by fuel and vehicle type. Specifically, the following two AEO2018 tables were used:

- For Light Duty: Light-Duty Vehicle Miles Traveled by Technology Type (table #51: https://www.eia.gov/outlooks/aeo/data/browser/#/?id=51-AEO2018&region=0-0&cases=ref2016&start=2016&end=2050&f=A&sourcekey=0)
- For Heavy Duty: Freight Transportation Energy Use (table #58: https://www.eia.gov/outlooks/aeo/data/browser/#/?id=58-AEO2018&region=0-0&cases=ref2016&start=2016&end=2050&f=A&sourcekey=0)

MOVES fuel/vehicle classes were mapped to AEO fuel/vehicle classes as follows:

- Gas light duty (motorcycles + cars + light trucks) are mapped to the combination of Gasoline ICE, Plug-in Gasoline Hybrids, Electric-Gasoline Hybrids, and also Natural Gas, Propane, and Methanol (those last three are minor).
- Diesel light duty are mapped to TDI Diesel ICE + Electric-Diesel Hybrid.
- E-85 light duty are mapped to Ethanol-Flex Fuel ICE.
- Electric light duty are mapped to all Electric Vehicle classes + Fuel Cell Hydrogen.

- Gas buses and single unit trucks are mapped to all Motor Gasoline vehicles from the AEO Freight report.
- Diesel buses and single unit trucks are mapped to all Diesel vehicles from the AEO Freight report.
- CNG buses are mapped to all CNG vehicles from the AEO Freight report.
- Gas combination trucks are mapped to only the “Heavy” Motor Gasoline vehicles.
- Diesel combination trucks are mapped to only the “Heavy” Diesel vehicles.

Total VMT for each MOVES fuel/vehicle grouping was calculated for the years 2016, 2023, and 2028 based on the AEO-to-MOVES mappings above. From these totals, 2016-2023 and 2016-2028 VMT trends were calculated for each fuel/vehicle grouping. Those trends became the national VMT projection factors. These factors are provided in Table 5.

Table 5. Factors to Project 2016 VMT to 2023 and 2028

SCC6	description	2023 factor	2028 factor
220111	LD gas	3.47%	1.72%
220121	LD gas	3.47%	1.72%
220131	LD gas	3.47%	1.72%
220132	LD gas	3.47%	1.72%
220142	Buses gas	15.07%	26.63%
220143	Buses gas	15.07%	26.63%
220151	MHD gas	15.07%	26.63%
220152	MHD gas	15.07%	26.63%
220153	MHD gas	15.07%	26.63%
220154	MHD gas	15.07%	26.63%
220161	HHD gas	-22.13%	-29.78%
220221	LD diesel	119.40%	247.72%
220231	LD diesel	119.40%	247.72%
220232	LD diesel	119.40%	247.72%
220241	Buses diesel	10.74%	16.94%
220242	Buses diesel	10.74%	16.94%
220243	Buses diesel	10.74%	16.94%
220251	MHD diesel	10.74%	16.94%
220252	MHD diesel	10.74%	16.94%
220253	MHD diesel	10.74%	16.94%
220254	MHD diesel	10.74%	16.94%
220261	HHD diesel	6.01%	8.74%
220262	HHD diesel	6.01%	8.74%
220342	Buses CNG	58.69%	69.39%
220521	LD E-85	2.57%	0.49%
220531	LD E-85	2.57%	0.49%
220532	LD E-85	2.57%	0.49%
220921	LD Electric	809.81%	2071.63%

SCC6	description	2023 factor	2028 factor
220931	LD Electric	809.81%	2071.63%
220932	LD Electric	809.81%	2071.63%

The base factors for VMT projections are national factors only. But, VMT trends can be different in different parts of the country, especially for passenger vehicles due to varying human population trends in different parts of the country. Human population data were available from the BenMAP model by county for several years, including 2017, 2023, and 2028. These human population data were used to create modified county-specific VMT projection factors for LD vehicles only. The same human population dataset was used in the 2011 platform (population_projections_11jan2016, v1). Note that 2017 is being used as the base year since 2016 human population is not available in this dataset. A newer human population dataset was assessed but it did not have trustworthy near-term (e.g., 2023/2028) projections, and was not used; for example, rural areas of NC were projected to have more growth than urban areas, which is the opposite of what one would expect.

Using the national VMT projection factors as a baseline, counties which are projected to have higher than average human population growth have their LD VMT projection factors increased compared to the national average, and vice versa. National total projected VMT will not be affected, but LD VMT growth will vary from county to county based on the human population trend in each county. The formula is:

*projection factor for county X = national factor * pop_factor_dampened*
where *pop_factor = (pop trend in county X)/(pop trend nationwide)*,
and *pop_factor_dampened = 1 + 0.5*(pop_factor - 1).*

"Dampening" of the pop_factor is applied so that human population does not have an outsized effect on the LD VMT growth. The dampening factor of 0.5 is based on analysis performed for the 2011 platform and was preferred over factors of 0.25 or 1.0.

For example, if nationally LD VMT is grown by 2%, and human population growth in County X is 25% higher than the national average population growth, then the LD VMT in County X will grow by 14.75%. (If dampening were not applied, LD VMT would grow by 27.5% in this county.) If in County Y, human population growth is 10% less than the national average growth, then LD VMT is decreased by 3.1% in this county.

The human population dataset does not include AK/HI/PR/VI (i.e., nonCONUS), so no human population adjustments were applied in nonCONUS areas. In 2011 platform, nonCONUS areas were not projected at all because they were not needed for the modeling studies being performed, but they are needed in the beta platform.

Future year projections of VMT based on both AEO2018 and human population are known as EPA projections. Note that EPA projections include projections of state-submitted 2016 VMT where available, and they are not a national projection of 2016 EPA default VMT. VMT submitted by state and local agencies were also considered for the future year activity data. Several agencies provided future year VMT:

- CT, GA, NJ, NC, WI, Pima County AZ* (future VMT provided by HPMS type)
- NH (future VMT provided by SCC/month)
- OH (future VMT provided by road type)
- Clark County NV (future VMT provided by vehicle type)
- MA (future VMT provided by county total only)
- *Pima AZ provided VMT for 2022, which was used to represent 2023 as-is. Pima did not provide 2028 VMT, so the EPA projection was used for 2028 Pima VMT.*

Where necessary, state-provided data was split to SCC/month (full FF10) using SCC and month distributions from the EPA projection. We also redistributed VMT between the light duty car and truck vehicle types (21/31/32) based on splits from the EPA projection, using the same procedure as for 2016 activity data.

In North Carolina, VMT for buses used the EPA projection and VMT for other vehicles used state data, consistent with the 2016 VMT.

<u>Vehicle Population (VPOP)</u>

The first step for creating future year projections of VPOP is to calculate VMT/VPOP ratios for each county, fuel, and vehicle type from the 2016 VMT and VPOP, and then apply those ratios to the future year projected VMT. This results in a future year projection of VPOP.

The second step is to incorporate future year VPOP submitted by state and local agencies. Future year VPOP was provided by local agencies in NH, NJ, NC, WI, and in Pima County, AZ and Clark County, NV. For Pima County, just like with the VMT, future year VPOP was only provided for 2022 (used directly for 2023) and not for 2028. Where necessary, VPOP was split to SCC (full FF10) using SCC distributions from the EPA projection.

Just like with VMT, we also redistributed VPOP between the light duty car and truck vehicle types (21/31/32) based on splits from the EPA projection, and used the EPA projection for buses in North Carolina and state-provided VPOP for all other vehicles in North Carolina.

Hoteling hours (HOTELING)

The first step for creating future year projections of hoteling hours is to calculate VMT/HOTELING ratios for each county from the 2016 HOTELING and VMT for combination long-haul trucks on restricted roads only, and then apply those ratios to the future year projected VMT for combination long-haul trucks on restricted roads only. Some counties had hoteling activity but did not have combination long-haul truck restricted road VMT in 2016; in those counties, the national AEO2018-based projection factor for diesel combination trucks was used to project 2016 hoteling to the future years. This procedure gives county-total hoteling for the future years. Each future year also has a distinct APU percentage based on MOVES input data that was used to split county total hoteling to each SCC: 22.6% APU for 2023, and 25.9% APU for 2028.

The second step is to incorporate future year hoteling submitted by state and local agencies. The only state that submitted future year hoteling activity was New Jersey. Their future year hoteling data was provided in the same format as the 2016 data, so the same procedure to convert to FF10 was applied as in 2016. New Jersey specified a 30% APU split for each future year, just like for 2016.

Emission factor table development

Emission factors for onroad vehicles are expected to vary significantly in the future as emissions per vehicle rates are decreased. This is primarily because cleaner cars are becoming more available due to various regulatory requirements and market-driven forces. To account for this, activity projections alone are not sufficient to estimate future year onroad emissions; therefore, the emission factors must be recalculated. To support this, the MOVES2014a model was run separately for each future year but using the same meteorological data as for the base year of 2016 and fuels that represent each future year. The remaining inputs to MOVES used were consistent with those in 2014NEIv2.

California inventory development

CARB provided EMFAC2014-based onroad emissions inventories for both 2023 and 2028. These inventories include separate totals for on-network and off-network, and include NH3, but do not include refueling. Details on how SMOKE-MOVES emissions are adjusted to match the CARB-based 2023 and 2028 inventories are provided in the Emissions Processing Requirements section of this document.

6. Emissions Processing Requirements

A component of the SMOKE[4] modeling system which features MOVES integration, called SMOKE-MOVES, is used to process onroad emissions. More background information on SMOKE-MOVES is provided in the Introduction section of this document.

Because of the special consideration given to onroad emissions in California, California emissions are run in a separate sector from the rest of the country. The California onroad sector is called “onroad_ca_adj”, while the “onroad” sector includes the rest of the country. Prior to running SMOKE-MOVES, the activity data (VMT, VPOP, HOTELING, and SPEED) must be subset to include all states except California (onroad sector), for the onroad_ca_adj sector to be California only.

Processing onroad emissions through SMOKE-MOVES consists of these steps:

1) Run the RatePerDistance (RPD), RatePerHour (RPH), RatePerProfile (RPP), and RatePerVehicle (RPV) components through SMOKE-MOVES. These components, which are described in the Introduction section of this document, must be run separately, with each producing a separate set of gridded 2-D emissions files.

2) Run the onroad merge job, which uses the SMOKE program Mrggrid to merge the RPD, RPH, RPP, and RPV emissions together, creating a single set of gridded 2-D emissions files for this sector. The onroad and onroad_ca_adj emissions are not together and instead are kept as separate sectors throughout this process.

3) If running CMAQ with CB6 speciation, the emissions from CB6-for-CAMx must be converted to CB6-for-CMAQ, as described in the Chemical Speciation section of this document.

<u>DAYS_PER_RUN</u>

For RPD/RPH/RPP/RPV processing, SMOKE-MOVES can be run more efficiently by processing multiple days of emissions at once. For example, Movesmrg can create one 7-day emissions file much more quickly than it can create seven individual 1-day emissions files. The primary drawback to using this multi-day Movesmrg functionality is an increase in the memory usage. To turn on this feature, EPA’s emissions modeling platform scripts feature a setting called DAYS_PER_RUN, to be set to the number of days you wish to process in a single Movesmrg instance. The recommended value for DAYS_PER_RUN is 7; but the default is 1 because some computer systems may not have enough memory to support the 7 day per run setting.

[4] http://www.smoke-model.org/index.cfm

DAYS_PER_RUN is strictly a script setting used to configure other files and parameters used by SMOKE and is not used by SMOKE directly.

If DAYS_PER_RUN > 1, Movesmrg will output a single multi-day emissions file. The run scripts will use the I/O API utility m3xtract to split up the multi-day emissions file into single day (25-hour) emissions files that can be used downstream.

Multi-day Movesmrg runs will never cross months. For example, if DAYS_PER_RUN = 7, then the last Movesmrg run of January will start on January 29th and end on January 31st (3 days), and the first Movesmrg run of February will start on February 1st and end on February 7th.

Using the multi-day Movesmrg functionality requires multi-day meteorology files output from MCIP. For example, if DAYS_PER_RUN = 7, the METCRO2D files used must be 7 days + 1 hour (169 hours) long. The m3xtract program can be used to concatenate METCRO2D files in support of this.

Memory and processing time considerations

Processing of RPD/RPH/RPP/RPV emissions in SMOKE-MOVES can be slow, even when using the DAYS_PER_RUN feature. Processing can also be memory intensive. On EPA systems, it takes 2 to 3 hours to process one 7-day block of RPD emissions, using up to 20 GB of memory. Run times and memory requirements for RPV are less than half that of RPD. RPP and RPH emissions do not have high run times or memory requirements. Decreasing the value of DAYS_PER_RUN will decrease the memory requirements.

Since most of the processing time in SMOKE-MOVES is spent reading emission factor tables, processing for sub-national domains (e.g., the Northeast US only) can be much faster, because SMOKE-MOVES only reads emission factor tables for counties that are inside the modeling domain.

If using a particularly large CFPRO file, as is done for the onroad_ca_adj sector described below, this can greatly impact the run time.

CFPRO file

Movesmrg supports an optional input called the CFPRO file[5], which can be used to adjust emissions from SMOKE-MOVES on the fly. The CFPRO was used for two purposes:

1. To zero out refueling emissions in 52 Colorado counties, since it was believed that these emissions double count a portion of the point source inventory. (This approach may be reconsidered for the 2016 v1 platform.) This is why a CFPRO is used for the onroad sector.
2. To adjust emissions in California so that annual emissions from SMOKE-MOVES equal CARB inventories (onroad_ca_adj sector).

Both CFPROs are provided in the beta platform package release, but here is a description of how the CFPRO for California is developed:

1. First, onroad emissions for California are processed through SMOKE-MOVES without any adjustments at all. These emissions are processed with the sector name “onroad_ca” (as opposed to onroad_ca_adj). For the onroad_ca sector, it is only necessary to process RPD/RPH/RPP/RPV, not the subsequent merge or CB6-CMAQ conversion steps. Also, only the emissions reports for onroad_ca are needed, not the gridded model-ready emissions.
2. Second, annual totals from onroad_ca (see Movesmrg report post-processing section below) are computed and compared to emissions totals from CARB-provided inventories for all CAPs. This comparison is done at the highest level of detail possible, depending on the resolution of the CARB inventory. In this case, that is by county, diesel/non-diesel, vehicle, on-network/off-network, and SMOKE-MOVES aggregate process.
3. Factors are calculated from that comparison for every county, SCC, pollutant, and species, and then converted to a CFPRO-formatted file for use in SMOKE-MOVES. All VOC species and VOC HAPs use the factors computed from VOC, which effectively means that we are matching CARB’s total VOC but using the VOC speciation from MOVES. The same applies for PM2.5 and its model species. To reduce the risk of processing errors, we set USE_EXP_CONTROL_FAC_YN = Y when running Movesmrg and specify each pollutant and model species in the CFPRO individually.
4. Onroad emissions for California are processed through SMOKE-MOVES a second time using the CFPRO. This is sector name “onroad_ca_adj”, and these emissions will be included in the final set of emissions for air quality modeling. Annual emissions totals in

[5] https://www.cmascenter.org/smoke/documentation/4.6/html/ch08s09s02.html#sect_input_cfpro

the onroad_ca_adj sector should match the CARB inventory at the same level of detail that was used to compare the inventories in Step 2.

Since the 2016 CARB inventory includes refueling and the future year CARB inventories do not, when preparing CFPRO files for the future years, the California CFPRO records for refueling SCCs were reused from 2016. This procedure is equivalent to projecting 2016 CARB refueling to the future year using trends based on unadjusted refueling from SMOKE-MOVES for each year.

Movesmrg report post-processing

For most sectors, an annual or monthly emissions inventory is available prior to running SMOKE. The onroad sector is unique in that emissions values are not known until after SMOKE-MOVES is run. After SMOKE-MOVES is run, an FF10-formatted inventory is developed based on reports produced by SMOKE-MOVES.

Movesmrg creates reports by county and SCC for all pollutants and species for each day, or block of days depending on the DAYS_PER_RUN setting. A Python script called the Movesmrg report post-processor reads all daily (or if DAYS_PER_RUN=7, weekly) Movesmrg reports for the year, aggregates and sums them together, and creates a set of monthly and annual reports by state, county, state/SCC, and county/SCC. This script is provided as a utility in the beta platform script package. Memory requirements for this script are even higher than that for running SMOKE-MOVES. For example, on EPA systems, RPD report processing requires up to 64 GB of memory and uses under one hour of run time per month of processing. RPV memory requirements and run time are about one-third that of RPD, while RPP and RPH do not have high memory requirements or run times.

Following completion of the Movesmrg report post-processor for both onroad and onroad_ca_adj, monthly county-SCC reports are converted to FF10 format, primarily to aid in the generation of comparison reports and summaries. This FF10 is provided in the beta platform package. As standard practice, we do not include all model species in these onroad FF10s. Instead we only include CAPs, NO_X and PM species, NONHAPTOG by mode, and certain VOC HAPs.

7. Emissions Summaries

National and state totals by pollutant for the beta platform cases are provided here, and some example plots. Additional onroad mobile plots and maps are available online through the LADCO website[6] and the Intermountain West Data Warehouse[7].

[6] https://www.ladco.org/technical/modeling-results/2016-inventory-collaborative/

Descriptions of the emissions platform cases shown in the tables and plots below are as follows:

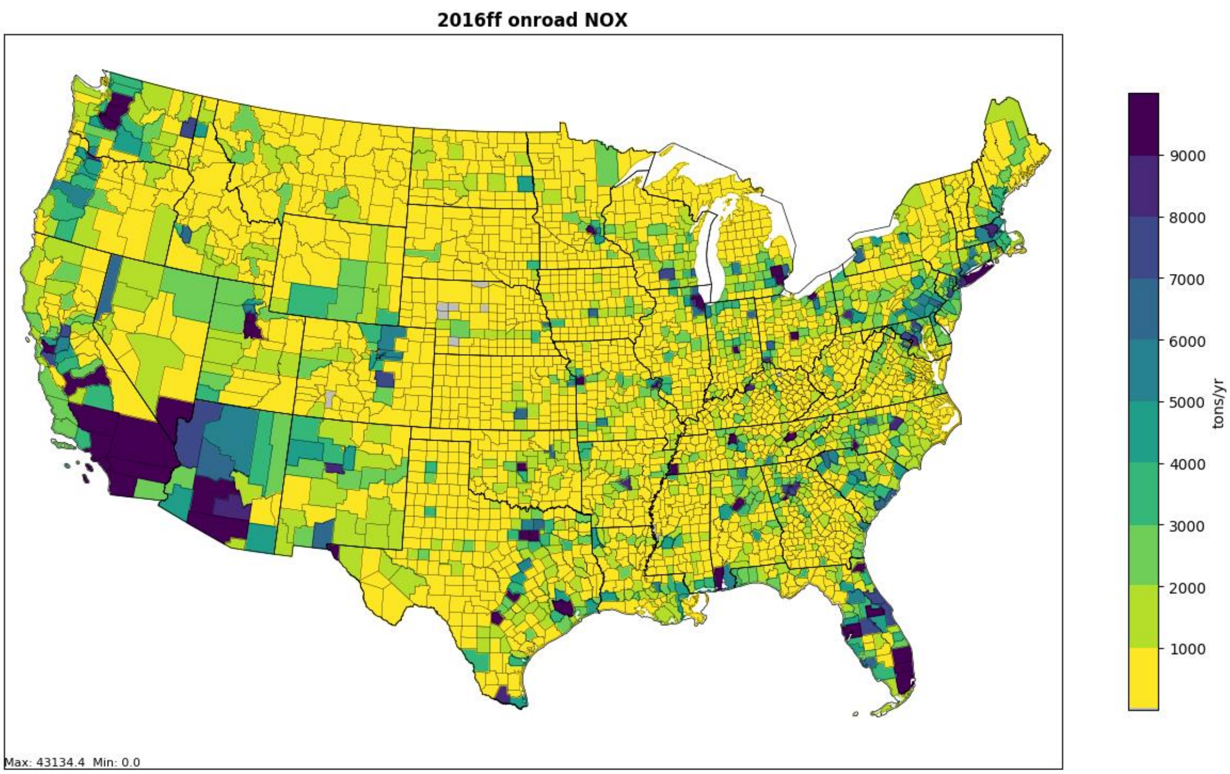
2011en, 2023en, 2028el = Final 2011, 2023, and 2028 cases from the 2011v6.3 platform

2014fd = 2014NEIv2 and 2014 NATA

2016fe = 2016 alpha platform (grown from 2014NEIv2)

2016ff, 2023ff, and 2028ff = 2016, 2023, and 2028 cases from the 2016 beta platform

Figure 3. 2016ff onroad NOX emissions by county (tons)



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[7] http://views.cira.colostate.edu/iwdw/eibrowser2016

Figure 4. 2016ff onroad VOC emissions by county (tons)

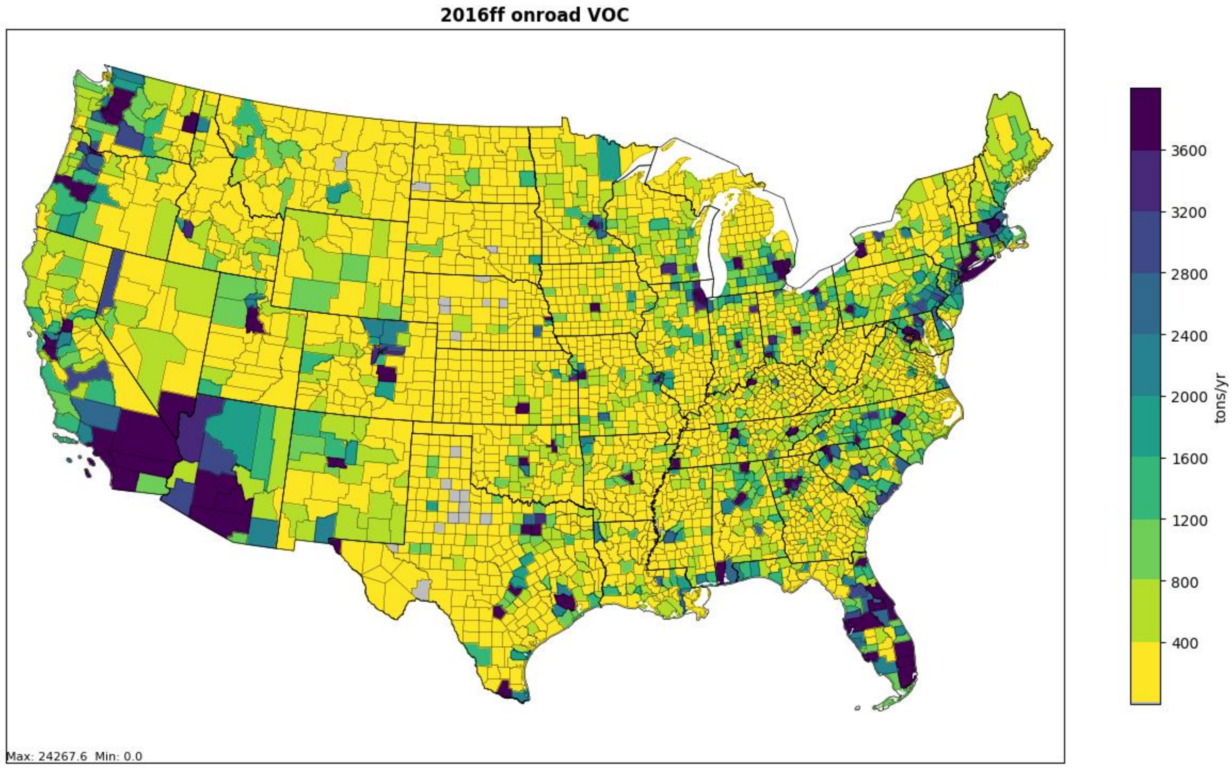

Figure 5. 2016ff Onroad NOx emissions Density for 2016 and 2023

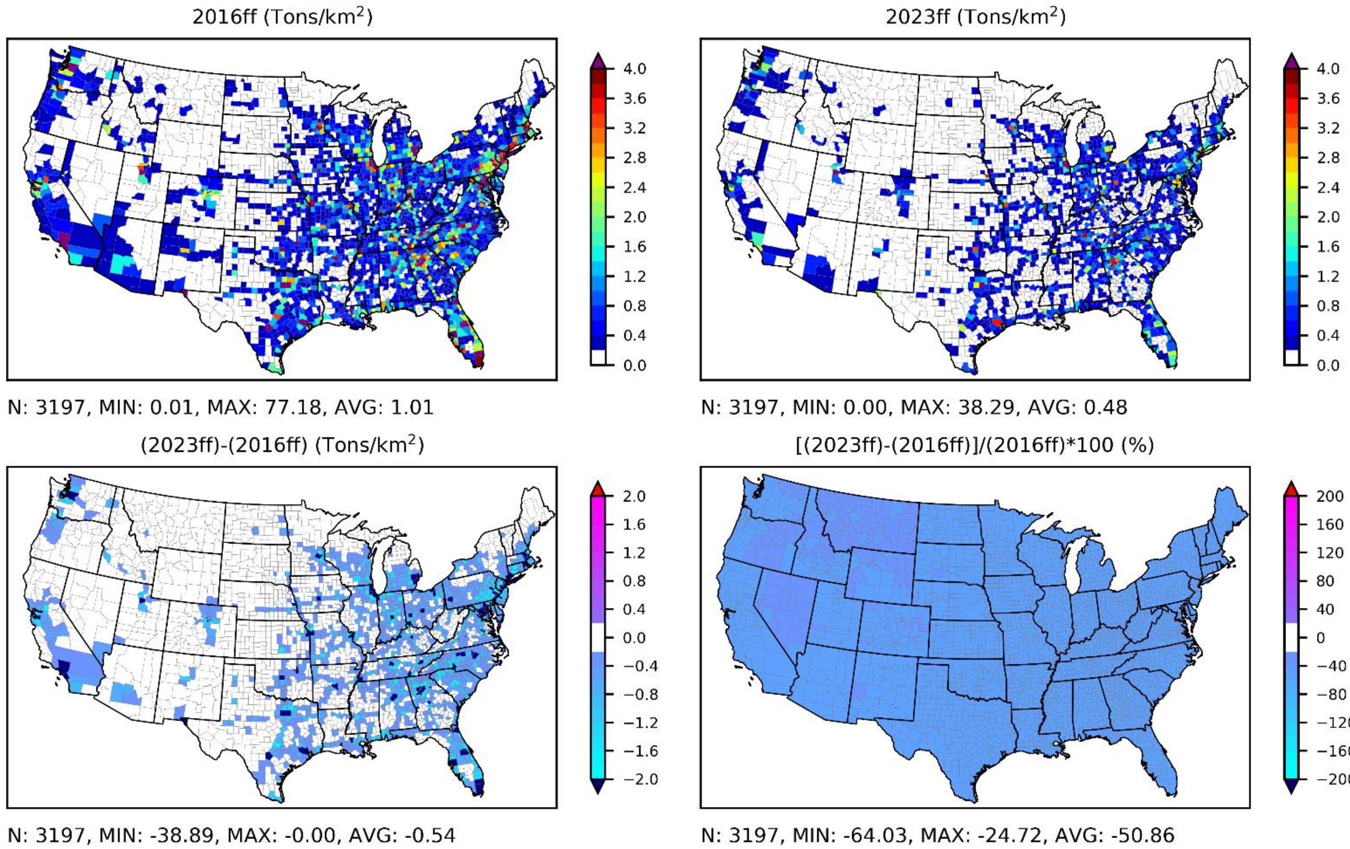

Table 6. Comparison of national total annual CAPS onroad emissions (tons/yr)

Pollutant	2011en	2014fd	2016fe	2016ff	2023en	2023ff	2028el	2028ff
CO	25,981,557	24,141,986	20,446,327	20,330,093	11,300,137	14,251,351	8,272,641	10,427,337
NH3	120,859	107,684	101,230	100,841	82,106	87,246	82,341	83,631
NOX	5,707,939	4,835,396	4,045,836	4,065,540	1,785,898	1,953,938	1,292,791	1,353,757
PM10	525,348	463,199	403,118	403,334	318,727	303,617	294,834	274,078
PM2.5	188,925	161,732	130,263	130,564	79,527	78,910	64,135	63,041
SO2	28,195	28,094	27,356	27,547	12,114	12,397	11,638	11,547
VOC	2,713,181	2,346,620	1,961,995	1,985,763	987,796	1,195,488	733,956	885,883

Table 7. Comparison of state total annual NOx onroad emissions (tons/yr)

State	2011en	2014fd	2016fe	2016ff	2023en	2023ff	2028el	2028ff
Alabama	152,732	129,445	111,108	111,934	41,856	54,390	30,113	35,057
Arizona	131,771	118,595	98,360	94,385	48,422	51,006	35,581	35,098
Arkansas	91,244	79,428	67,286	67,109	33,252	32,823	24,892	22,019
California	384,892	274,369	230,117	230,117	102,925	102,886	82,042	82,018

State	2011en	2014fd	2016fe	2016ff	2023en	2023ff	2028el	2028ff
Colorado	101,459	89,794	76,686	74,065	32,457	39,591	24,124	27,749
Connecticut	36,707	30,676	24,533	23,905	11,604	10,313	8,269	7,367
Delaware	13,464	12,066	10,073	10,064	4,483	4,367	3,249	2,904
D.C.	4,740	4,384	3,625	3,624	1,481	1,877	1,086	1,182
Florida	308,752	262,347	222,366	226,866	99,332	100,614	72,019	67,385
Georgia	223,223	177,000	161,423	174,018	68,445	80,892	48,973	57,859
Idaho	51,345	48,473	42,608	42,453	19,130	24,030	14,399	17,086
Illinois	176,702	168,750	131,034	130,731	72,932	60,213	56,626	41,455
Indiana	171,431	151,846	124,377	124,091	53,849	58,239	38,875	39,979
Iowa	82,761	70,842	60,834	60,553	28,315	29,654	20,912	20,355
Kansas	78,055	73,361	61,687	61,537	24,877	30,523	18,047	20,297
Kentucky	115,685	104,470	84,858	84,671	37,993	40,826	27,819	27,340
Louisiana	94,087	96,957	78,020	77,873	30,689	37,308	22,564	26,109
Maine	28,199	23,094	18,801	20,038	7,687	9,447	5,503	6,756
Maryland	81,346	73,232	62,157	60,876	26,839	28,430	19,303	18,945
Massachusetts	60,860	44,729	37,421	38,353	18,003	17,058	13,003	12,058
Michigan	194,617	134,323	105,775	106,444	58,622	48,067	42,028	32,766
Minnesota	123,515	94,172	75,377	74,943	38,063	35,575	27,405	23,916
Mississippi	91,026	79,571	65,701	65,597	25,482	30,586	17,788	20,258
Missouri	177,866	158,130	132,173	131,701	53,566	66,702	38,725	45,862
Montana	35,906	38,230	33,481	33,366	11,157	20,622	8,247	14,857
Nebraska	57,303	49,178	42,709	42,519	19,968	22,148	14,983	15,321
Nevada	55,930	44,313	37,559	37,306	16,453	20,132	11,690	14,391
New Hampshire	18,412	16,292	13,492	13,347	6,355	6,403	4,539	4,626
New Jersey	103,012	71,433	57,508	57,291	34,554	25,309	24,878	18,972
New Mexico	77,345	72,181	66,252	65,469	26,068	34,712	19,259	24,586
New York	162,230	143,495	110,222	111,115	56,101	56,797	40,707	40,330
North Carolina	204,008	159,301	136,660	134,247	47,108	58,732	30,968	37,208
North Dakota	26,407	36,073	27,418	27,424	8,647	13,917	6,265	9,657
Ohio	250,423	156,663	126,024	125,836	71,354	56,925	49,227	39,713
Oklahoma	115,094	92,071	76,481	76,320	37,673	38,859	27,448	27,014
Oregon	80,954	71,134	61,737	61,751	21,802	34,830	15,338	24,158
Pennsylvania	203,995	174,231	140,272	140,093	57,180	64,743	39,768	44,171
Rhode Island	10,199	12,581	10,318	10,306	3,245	4,426	2,429	3,083
South Carolina	109,374	87,847	76,897	92,111	32,926	42,629	23,263	28,056
South Dakota	26,506	27,734	23,643	23,565	8,722	12,532	6,448	8,746
Tennessee	182,796	147,638	126,845	126,339	61,100	61,048	44,927	40,954
Texas	422,030	413,729	353,642	353,009	116,997	164,949	77,883	115,390
Utah	65,240	74,618	66,996	66,719	28,911	34,882	20,675	25,771
Vermont	10,809	7,619	6,179	6,172	4,009	3,045	3,010	2,142
Virginia	145,507	132,762	109,391	107,200	49,776	48,433	35,427	31,110

State	2011en	2014fd	2016fe	2016ff	2023en	2023ff	2028el	2028ff
Washington	163,925	129,267	110,435	110,245	52,726	58,973	38,196	39,146
West Virginia	41,840	40,880	33,501	32,879	13,833	15,721	10,124	10,469
Wisconsin	127,169	104,025	85,353	88,652	45,066	42,193	33,156	30,127
Wyoming	35,047	32,045	26,421	26,312	13,861	15,561	10,590	11,937

Table 8. Comparison of state total annual VOC onroad emissions (tons/yr)

State	2011en	2014fd	2016fe	2016ff	2023en	2023ff	2028el	2028ff
Alabama	75,523	67,278	57,501	59,409	20,819	36,494	15,013	24,854
Arizona	56,167	55,882	49,152	49,587	22,447	31,438	16,844	22,958
Arkansas	34,779	33,171	27,857	28,381	13,250	17,102	9,926	12,265
California	166,559	124,804	104,935	104,935	63,118	62,769	52,202	51,830
Colorado	52,808	47,417	40,199	40,918	19,677	26,699	15,058	20,473
Connecticut	21,636	20,593	16,398	16,278	9,137	9,766	6,875	7,771
Delaware	6,896	7,249	6,094	6,092	3,097	3,770	2,404	2,854
D.C.	2,147	3,194	2,677	2,677	921	1,852	713	1,252
Florida	183,609	146,389	125,411	131,637	70,418	79,001	51,019	57,891
Georgia	109,005	83,824	80,530	79,742	36,041	47,411	25,629	35,472
Idaho	23,812	22,188	19,112	19,457	8,886	12,590	6,824	9,293
Illinois	67,386	90,736	69,891	69,915	30,200	40,478	23,773	30,020
Indiana	83,362	72,127	58,715	59,541	28,006	33,943	20,251	24,813
Iowa	40,970	37,319	31,059	31,445	14,635	18,921	10,920	13,765
Kansas	38,708	34,632	28,794	29,311	13,022	17,962	9,492	12,928
Kentucky	50,326	47,420	38,682	39,294	17,779	23,008	12,938	16,416
Louisiana	48,164	40,103	32,920	33,690	17,202	19,601	12,663	14,173
Maine	13,808	11,096	8,819	9,112	4,523	5,432	3,436	4,199
Maryland	36,508	33,808	28,585	27,977	16,190	17,568	12,290	12,910
Massachusetts	34,238	29,365	24,642	23,909	14,297	14,796	10,832	11,473
Michigan	106,140	84,777	65,938	66,921	37,412	38,136	27,716	28,471
Minnesota	68,356	58,386	44,941	45,463	24,501	27,453	18,409	20,627
Mississippi	46,084	37,107	30,691	31,491	13,565	18,136	9,317	12,684
Missouri	61,135	68,063	56,344	56,940	22,981	35,273	17,056	25,139
Montana	18,537	19,836	16,416	16,668	5,767	11,602	4,336	8,734
Nebraska	27,669	24,666	20,865	21,199	9,208	13,170	6,904	9,452
Nevada	24,212	20,006	17,234	18,060	8,741	11,579	6,535	8,718
New Hampshire	10,064	9,168	7,454	7,334	4,846	4,922	3,716	4,009
New Jersey	43,302	31,234	26,190	25,887	18,833	15,759	14,639	12,620
New Mexico	30,777	24,625	22,090	22,671	10,538	14,254	7,804	10,546
New York	91,192	78,344	58,463	58,987	38,415	38,367	28,875	29,078
North Carolina	112,173	84,601	72,350	71,697	31,454	40,054	21,709	28,753
North Dakota	11,548	11,496	8,203	8,292	3,987	5,223	3,002	3,922

State	2011en	2014fd	2016fe	2016ff	2023en	2023ff	2028el	2028ff
Ohio	129,619	86,184	70,103	71,245	41,806	41,606	29,479	31,885
Oklahoma	54,315	42,735	35,246	36,019	19,585	21,894	14,412	15,936
Oregon	44,974	40,291	34,498	34,879	13,294	22,123	9,515	15,953
Pennsylvania	100,184	80,517	63,954	64,409	32,456	38,036	23,280	28,017
Rhode Island	6,816	6,042	4,890	4,888	2,920	2,908	2,285	2,258
South Carolina	51,164	46,580	40,944	42,580	17,462	24,631	12,546	17,589
South Dakota	13,781	12,516	10,238	10,411	4,539	6,670	3,343	4,940
Tennessee	80,463	69,074	58,953	60,121	28,073	35,170	20,483	25,039
Texas	168,172	152,522	136,105	137,732	70,770	79,975	51,589	58,849
Utah	28,049	27,964	25,180	25,566	13,517	16,141	10,113	12,533
Vermont	5,297	4,523	3,590	3,628	2,276	2,304	1,808	1,769
Virginia	63,152	65,140	54,718	54,637	25,130	32,849	18,550	23,663
Washington	77,507	70,567	59,503	60,265	26,658	38,040	20,490	27,650
West Virginia	20,493	17,353	14,133	14,248	7,097	8,315	5,208	5,942
Wisconsin	60,066	53,313	42,620	41,930	24,161	24,765	18,531	19,208
Wyoming	11,527	10,392	8,168	8,291	4,139	5,530	3,205	4,287