2020 National Emissions Inventory Technical Support Document: Nonroad Mobile Sources

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4.1   Sector description

The mobile nonroad equipment data category includes all mobile source emissions that do not operate on roads, excluding commercial marine vehicles, railways, and aircraft. The emissions included in the NEI for this category are modeled using MOVES and cover nonroad equipment in 10 broad economic sectors: construction, agriculture, industrial, lawn & garden (commercial and residential), commercial, logging, railroad support (excluding locomotives), recreational vehicles, recreational marine (pleasure craft; excluding commercial marine vessels), and underground mining. Nonroad equipment emissions were computed by running the MOVES3,[1] which incorporates the NONROAD model. MOVES3 and its predecessor MOVES2014b incorporated updated nonroad engine population growth rates, nonroad Tier 4 engine emission rates, and sulfur levels of nonroad diesel fuels. MOVES3 was used for all states other than California, which developed their own emissions using their own tools.

In using MOVES to calculate GHG emissions from these sources, the NEI uses a bottom-up methodology whereby nonroad emissions are the product of an adjusted emission factor multiplied by rated engine power, engine load factor, engine population, and activity. The US GHGI reports CO_2 emissions for these nonroad sources based on top-down overall gasoline and diesel fuel use by end use/economic sector. The economic sector fuel use data used in the US GHGI do not distinguish between stationary and mobile sources, so nonroad mobile CO_2 emissions are not specifically identified in the US GHGI, with the exception of recreational marine vessels. Therefore, the bottom-up NEI approach applied nationally will lead to differences with national totals in the US GHGI and the related state-level estimates in the GHGI by State.

4.2   Computing Nonroad emissions using MOVES

MOVES3, the latest public release of EPA's Motor Vehicle Emissions Simulator (MOVES) Model, estimates daily emissions for total hydrocarbons (THC), nitrogen oxides (NOx), carbon monoxide (CO), carbon dioxide (CO_2), particulate matter 10 microns and less (PM_{10}), and sulfur dioxide (SO_2), as well as calculating fuel consumption. MOVES3 (version 3.0.3) [ref 1] uses ratios from some of these emissions to calculate emissions for particulate matter 2.5 microns and less ($PM_{2.5}$), methane, ammonia (NH_3), four more aggregate hydrocarbon groups (NMHC, NMOG, TOG, and VOC), 14 hazardous air pollutants (HAPs), 17 dioxin/furan congeners, 32 polycyclic aromatic hydrocarbons, and six metals. For a complete list of these pollutants, see Table 4-1. All the input and activity data required to run MOVES-Nonroad are contained within the MOVES default database, which is distributed with the model. However, EPA uses alternative equipment spatial allocations for some sectors that is different from the publicly distributed default database tables. State- and county-specific data can be used by creating a supplemental database known as a county database (CDB) and specifying it in the MOVES run specification (runspec). State, local and tribal (S/L/T) agencies can update the data within the CDBs to produce emissions

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[1] https://www.epa.gov/moves.

estimates that accurately reflect local conditions and equipment usage. MOVES first uses the data in the CDBs and fills in any missing data from the MOVES default database.

To develop the 2020 NEI nonroad emissions, EPA executed MOVES3, the most current public version of MOVES available at the time. Specifically, the code version was MOVES3.0.3. The default database used for the NEI nonroad runs was movesdb20220105_nrupdates, which is a copy of the database released publicly with MOVES3. The 'nrupdates' version of the MOVES default database contains alternative nonroad equipment spatial allocations by replacement of the three tables nrBaseYearEquipPopulation, nrStateSurrogate, and nrSurrogate.

The national updates made to the MOVES3 default database are the same as those made previously to the MOVES2014b default database for the 2017 NEI and 2016v1 Platform. The updated tables allocate national populations of Agricultural and Construction equipment to the state and county levels, as described in the 2016v1 Platform Nonroad Mobile Emissions Specification Sheet [ref 4].

Table 4-1: Pollutants produced by MOVES-Nonroad for 2020 NEI

Pollutant ID	Pollutant Name	Pollutant ID	Pollutant Name
1	Total Gaseous Hydrocarbons	82	Indeno(1,2,3,c,d)pyrene particle
2	Carbon Monoxide (CO)	83	Phenanthrene particle
3	Oxides of Nitrogen (NOx)	84	Pyrene particle
5	Methane (CH$_4$)	86	Total Organic Gases
20	Benzene	87	Volatile Organic Compounds
21	Ethanol	88	NonHAPTOG
23	Naphthalene particle	90	Atmospheric CO$_2$
24	1,3-Butadiene	99	Brake Specific Fuel Consumption (BSFC)
25	Formaldehyde	100	Primary Exhaust PM$_{10}$ - Total
26	Acetaldehyde	110	Primary Exhaust PM$_{2.5}$ - Total
27	Acrolein	130	1,2,3,7,8,9-Hexachlorodibenzo-p-Dioxin
30	Ammonia (NH$_3$)	131	Octachlorodibenzo-p-dioxin
31	Sulfur Dioxide (SO$_2$)	132	1,2,3,4,6,7,8-Heptachlorodibenzo-p-Dioxin
40	2,2,4-Trimethylpentane	133	Octachlorodibenzofuran
41	Ethyl Benzene	134	1,2,3,4,7,8-Hexachlorodibenzo-p-Dioxin
42	Hexane	135	1,2,3,7,8-Pentachlorodibenzo-p-Dioxin
43	Propionaldehyde	136	2,3,7,8-Tetrachlorodibenzofuran
44	Styrene	137	1,2,3,4,7,8,9-Heptachlorodibenzofuran
45	Toluene	138	2,3,4,7,8-Pentachlorodibenzofuran
46	Xylene	139	1,2,3,7,8-Pentachlorodibenzofuran
60	Mercury Elemental Gaseous	140	1,2,3,6,7,8-Hexachlorodibenzofuran
61	Mercury Divalent Gaseous	141	1,2,3,6,7,8-Hexachlorodibenzo-p-Dioxin
62	Mercury Particulate	142	2,3,7,8-Tetrachlorodibenzo-p-Dioxin
63	Arsenic Compounds	143	2,3,4,6,7,8-Hexachlorodibenzofuran
65	Chromium 6+	144	1,2,3,4,6,7,8-Heptachlorodibenzofuran
66	Manganese Compounds	145	1,2,3,4,7,8-Hexachlorodibenzofuran

Pollutant ID	Pollutant Name	Pollutant ID	Pollutant Name
67	Nickel Compounds	146	1,2,3,7,8,9-Hexachlorodibenzofuran
68	Dibenzo(a,h)anthracene particle	169	Fluoranthene gas
69	Fluoranthene particle	170	Acenaphthene gas
70	Acenaphthene particle	171	Acenaphthylene gas
71	Acenaphthylene particle	172	Anthracene gas
72	Anthracene particle	173	Benz(a)anthracene gas
73	Benz(a)anthracene particle	174	Benzo(a)pyrene gas
74	Benzo(a)pyrene particle	175	Benzo(b)fluoranthene gas
75	Benzo(b)fluoranthene particle	176	Benzo(g,h,i)perylene gas
76	Benzo(g,h,i)perylene particle	177	Benzo(k)fluoranthene gas
77	Benzo(k)fluoranthene particle	178	Chrysene gas
78	Chrysene particle	181	Fluorene gas
79	Non-Methane Hydrocarbons	183	Phenanthrene gas
80	Non-Methane Organic Gases	184	Pyrene gas
81	Fluorene particle	185	Naphthalene gas

4.3 Additional Data: Nonroad County Databases (CDBs)

MOVES uses county databases (CDBs) to provide detailed local information for estimating nonroad emissions. The EPA encouraged S/L/T agencies to submit MOVES-Nonroad CDBs to the Emission Inventory System (EIS) for the 2020 NEI. Data not provided in CDBs is automatically supplied from the modified MOVES default database. As is also true for MOVES onroad runs, even if an agency submitted fuel or meteorological data, the EPA used "EPA default" values for these data parameters. EPA developed fuel inputs for 2020 based on the extensive refinery gate batch dataset collected as a part of EPA's fuel compliance programs and incorporated this into MOVES3. The meteorological data were derived from a Weather Research and Forecasting Model (WRF) version 4.1.1[ref 5].

The modified MOVES default database for MOVES3 containing refinements to construction and agricultural sectors, (movesdb20220105_nrupdates) and state-submitted inputs in CDBs were used to run MOVES-Nonroad to produce emissions for all states other than California. California-submitted emissions were used.

Table 4-2 shows the selection hierarchy for the nonroad data category. CDBs were used to run MOVES-Nonroad to produce emissions for all states other than California. California-submitted emissions were used.

Table 4-2: Selection hierarchy for the Nonroad Mobile data category

Priority	Dataset	Notes
1	S/L/T-supplied emissions	Three tribes submitted nonroad emissions: Kootenai Tribe of Idaho, Nez Perce Tribe, and Shoshone-Bannock Tribes of the Fort Hall Reservation of Idaho. California submitted emissions calculated with their own model (EMFAC).
2	S/L/T-supplied input data through 2020 NEI process	
3	2020EPA_NONROAD	All data from MOVES3

EPA asked S/L/T agencies to provide model inputs in the form of MOVES CDBs for 2020. Table 4-3 shows the S/L/T agencies that submitted nonroad model inputs for the 2020 NEI via the EIS Gateway.

Table 4-3: Submitted MOVES-Nonroad input tables, by agency

State Code	State or County(ies) in the Agency	nrbaseyearequippopulation (source populations)	nrdayallocation (allocation to day type)	nrgrowthindex (population growth)	nrhourallocation (allocation to diurnal pattern)	nrmonthallocation (seasonal allocation)	nrsourceusetype (yearly activity)	nrstatesurrogate (allocation to counties)	county (barometric pressure)	countyyear (stage II information)	nrequipmenttype (surrogate selection)	nrsurrogate (surrogate identification)	nrscc (SCCs)
4	Arizona - Maricopa Co.	A					B	A			B	B	
9	Connecticut	C											
13	Georgia							B					
17	Illinois					D							
18	Indiana		D			D							
26	Michigan		D			D							
27	Minnesota		D			D							
39	Ohio		C			C							
41	Oregon						B						
48	Texas	B	B			B	B	B	B	B	B	B	B
49	Utah	D		D		D		D					
53	Washington							E			E	E	
55	Wisconsin					D							

A Submitted data with modification: deleted records not associated with Commercial Lawn & Garden equipment.
B Submitted data.
C Submitted data with modification: deleted records not associated with Recreational Marine source type IDs 2113 to 2159.
D Data carried forward from the 2017 NEI.
E Submitted data with modification: deleted records not associated with WA's recreational marine surrogate IDs.

The 1,264 submitted CDBs used for the MOVES-Nonroad run are packaged together in '2020_NonroadCDBs.zip' available at the 2020 NEI Supplemental nonroad mobile data FTP site. The rest were run using the modified MOVES default database, which does not require CDBs. A list of all 3,225 U.S. counties and their corresponding CDBs, if any, is available in '2020_nonroad_counties_FinalList.xlsx'. These supplemental nonroad mobile data contents are listed in Table 4-4 and are all available on the 2020 NEI Supplemental nonroad mobile data FTP site.

Table 4-4: Contents of the Nonroad Mobile supplemental inputs folder

	File or Folder	Description
1	2020_NonroadCDBs.zip	Submitted nonroad CDBs used to run MOVES3 and EPA CDBs.
2	2020_nonroad_counties_FinalList.xlsx	List of all counties and their CDBs.
3	2020_zonemonthhour.zip	Zonemonthhour table (meteorology data).
4	2020_NonroadRunspecs.zip	Runspecs for all counties.
5	2020_Modified_MOVES_Default_DB.zip	Modified version of the MOVES3 database containing alternative tables for Construction and Agricultural equipment spatial allocation.
6	2020_postprocess_nraq_nrvoc.zip	Post-processing scripts for MOVES runs.
7	Nonroad CARB SCC Xwalk.xlsx	File mapping California emission inventory codes (EICs) to EPA SCCs.

4.4 MOVES runs and Postprocessing Steps

In the 2020 NEI Supplemental nonroad mobile data FTP site, the Excel file '2020_nonroad_counties_FinalList.xlsx' lists all 3,225 counties and their corresponding CDBs if one was used for the county. The CDBs that were used are in '2020_NonroadCDBs.zip' in the online NRSupplemental Data folder. If no CDB was listed for a county, that county was run with the modified MOVES default database for MOVES3 (movesdb20220105_nrupdates).

MOVES was run for each county in a single, separate run specification file (runspec). All the runspecs are in the '2020_NonroadRunspecs.zip' file in the online NRSupplemental Data folder. The MOVES-Nonroad runs were checked for completeness and absence of error messages in the run logs. The output was post-processed to consolidate each county into a single database and to produce SMOKE-ready input. The scripts that performed these processes are in '2020_postprocess_nraq_nrvoc.zip' in the 2020 NEI Supplemental nonroad mobile data FTP site. The MOVES runs created monthly, day type (weekday and weekend) total inventories for every U.S. county, and post-processing scaled the day totals to monthly and annual values.

The following additional steps were taken on the monthly MOVES nonroad outputs to prepare data for loading into EIS:

1. The gas and particle components of PAHs (e.g., Chrysene, Fluorene) were combined.
2. The individual mercury species were combined into total mercury (i.e., pollutant 7439976).
3. Emissions were aggregated from the more detailed SCCs modeled in MOVES to the SCCs modeled in SMOKE. Information about this aggregation is contained in the '2020NonroadSCCaggregation.xlsx' file posted on the 2020 NEI Supplemental data ftp site.

4. Pollutants produced by MOVES but not accepted in the NEI were removed (e.g., ethanol, NONHAPTOG, and total hydrocarbons).
5. Five speciated $PM_{2.5}$ species were added based on speciation profiles (i.e., elemental carbon, organic carbon, nitrate, sulfate and other $PM_{2.5}$).
6. DIESEL-PM10 and DIESEL-PM25 were added by copying the PM_{10} and $PM_{2.5}$ pollutants (respectively) as DIESEL-PM pollutants for all diesel SCCs.
7. Airport ground support equipment emissions were removed.
8. Oil and gas field equipment emissions were removed.
9. Incorporated California-submitted nonroad emissions.

Note that starting in 2020, the Alaska county 02-261 (Valdez-Cordova) split into two counties: 02-063 (Chugach Census Area) and 02-066 (Copper River Census Area). This change was not incorporated in MOVES3, so the 2020 NEI emissions for these counties were processed in MOVES3 under Valdez-Cordova county, and then split into separate totals for Chugach Census Area and Copper River Census Area based on census population data in the two census areas.

Following the completion of the MOVES runs, railway maintenance emissions were removed from specific counties / census areas in Alaska because Alaska DEC specified that this type of activity does not happen in those areas. Specifically, emissions from SCCs 2285002015, 2285004015, and 2285006015 were removed from the following counties / census areas: 02013, 02016, 02050, 02060, 02070, 02100, 02105, 02110, 02130, 02150, 02158, 02164, 02180, 02185, 02188, 02195, 02198, 02220, 02240, 02261, 02275, and 02282. Alaska DEC also specified some counties / census areas in which logging and agricultural emissions do not happen, but the emissions for the specified SCCs were already zero in the specified areas.

4.5   Use of California Submitted Emissions

California submitted criteria and HAP nonroad emissions for EPA's use in the NEI. California estimates emissions with a California-specific model and converts them from their EIC codes to SCC codes via a crosswalk (Nonroad CARB SCC Xwalk.xlsx). The California criteria emissions and most HAP emissions were used directly. For PAHs, due to differences in pollutants included in MOVES and those provided by CARB, PAH emissions were taken from MOVES rather than from CARB. A list of the PAHs which are based on MOVES data rather than CARB data in California is in Table 4-5.

Table 4-5: PAHs calculated using MOVES for California Nonroad SCCs

Pollutant	Pollutant Code
Acenaphthene	83329
Acenaphthylene	208968
Anthracene	120127
Benz[a]Anthracene	56553
Benzo[a]Pyrene	50328
Benzo[b]Fluoranthene	205992
Benzo[g,h,i,]Perylene	191242
Benzo[k]Fluoranthene	207089
Chrysene	218019
Dibenzo[a,h]Anthracene	53703
Fluoranthene	206440

Pollutant	Pollutant Code
Fluorene	86737
Indeno[1,2,3-c,d]Pyrene	193395
Phenanthrene	85018
Pyrene	129000

In addition, CO_2 data were added to the California nonroad inventory based on EPA estimates, because CO_2 emissions were not provided in the submission. EPA also speciated CARB total $PM_{2.5}$ and PM_{10} using the same approach as for other states and copied the $PM_{2.5}$ and PM_{10} to DIESEL-PM "pollutants" for all diesel SCCs. Table 4-6 illustrates pollutants and data source in the 2020 NEI.

Table 4-6: Pollutant and data source in nonroad for the 2020 NEI

CAS	poll desc	poll category	data source for California
100414	Ethylbenzene	VOC HAP	CARB
100425	Styrene	VOC HAP	CARB
106423	Xylenes (mixed isomers)	VOC HAP	CARB
106990	Butadiene, 1,3-	VOC HAP	CARB
107028	Acrolein	VOC HAP	CARB
108383	Xylenes (mixed isomers)	VOC HAP	CARB
108883	Toluene	VOC HAP	CARB
110543	Hexane	VOC HAP	CARB
120127	Anthracene	PAH	MOVES
123386	Propionaldehyde	VOC HAP	CARB
129000	Pyrene	PAH	MOVES
1330207	Xylenes (mixed isomers)	VOC HAP	CARB
18540299	Chromium VI	metal	CARB
191242	Benzo[g,h,i,]Perylene	PAH	MOVES
193395	Indeno[1,2,3-c,d]Pyrene	PAH	MOVES
205992	Benzo[b]Fluoranthene	PAH	MOVES
206440	Fluoranthene	PAH	MOVES
207089	Benzo[k]Fluoranthene	PAH	MOVES
208968	Acenaphthylene	PAH	MOVES
218019	Chrysene	PAH	MOVES
50000	Formaldehyde	VOC HAP	CARB
50328	Benzo[a]Pyrene	PAH	MOVES
53703	Dibenzo[a,h]Anthracene	PAH	MOVES
540841	Trimethylpentane, 2,2,4-	VOC HAP	CARB
56553	Benz[a]Anthracene	PAH	MOVES
71432	Benzene	VOC HAP	CARB
7439965	Manganese	metal	CARB
7439976	Mercury, Unspeciated	metal	CARB

CAS	poll desc	poll category	data source for California
7440020	Nickel	metal	CARB
7440382	Arsenic	metal	CARB
75070	Acetaldehyde	VOC HAP	CARB
83329	Acenaphthene	PAH	MOVES
85018	Phenanthrene	PAH	MOVES
86737	Fluorene	PAH	MOVES
91203	Naphthalene	VOC HAP	CARB
95476	O-xylene	VOC HAP	CARB
CH4	Methane	GHG	MOVES CH4 * CARB VOC/MOVES VOC
CO	Carbon Monoxide	CAP	CARB
CO2	Carbon Dioxide	GHG	MOVES state total, allocated to county-SCC by CARB SO2
DIESEL-PM10	Diesel PM10	HAP	CARB
DIESEL-PM25	Diesel PM2.5	HAP	CARB
EC	elemental carbon	speciated PM	CARB w/MOVES speciation
N2O	Nitrous Oxide	GHG	MOVES state total, allocated to county-SCC by CARB SO2
NH3	Ammonia	CAP	MOVES state total, allocated to county-SCC by CARB SO2
NO3	particulate nitrate	speciated PM	CARB w/MOVES speciation
NOX	Nitrogen oxides	CAP	CARB
OC	organic carbon	speciated PM	CARB w/MOVES speciation
PM10-PRI	Particulate matter, 10 microns and less	CAP	CARB
PM25-PRI	Particulate matter, 2.5 microns and less	CAP	CARB
PMFINE	pmfine	speciated PM	CARB w/MOVES speciation
SO2	Sulfur Dioxide	CAP	CARB
SO4	particulate sulfate	speciated PM	CARB w/MOVES speciation
VOC	Volatile organic compounds	CAP	CARB

4.6 References for nonroad mobile

1. MOVES-Nonroad, its documentation and technical reports can be found here: [Nonroad Technical Reports.](#)

2. CARB's group of models for off-road equipment may be linked to from this site: Mobile Source Emissions Inventory.

3. MOVES3, its default database, documentation and technical reports.

4. National Emissions Inventory Collaborative (2019). Specification Sheet – 2016v1 Platform Nonroad Mobile Emissions. Retrieved from the Specification Sheet: Mobile Nonroad.

5. Detailed information on The Weather Research & Forecasting Model (WRF) may be found here: Weather Research and Forecasting Model and here: Skamarock, W.C., et al., National Center for Atmospheric Research, Mesoscale and Microscale Meteorology Division, Boulder CO, June 2008, NCAR/TN-475+STR, A Description of the Advanced Research WRF Version 3.