

Preparation of Fine Particulate Emissions Inventories

Chapter 4 – Nonroad Mobile Sources



What Sources are Included?

SCCs (4-digit SCC denotes engine type)

2260xxxxxx	2-Stroke Gasoline
2265xxxxxx	4-Stroke Gasoline
2267xxxxxx	Liquefied Petroleum Gasoline (LPG)
2268xxxxxx	Compressed Natural Gas (CNG)
2270xxxxxx	Diesel

Two exceptions:

2282xxxxxx	Recreational Marine
2285xxxxxx	Railroad Maintenance

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What Sources are Included? (cont.)

Equipment Category (7-digit SCC denotes equipment)

- Airport ground support
- Agricultural
- Construction
- Industrial
- Commercial
- Residential/commercial Lawn and garden
- Logging
- Recreational marine vessels
- Recreational equipment
- Oil field
- Underground mining
- Railway maintenance

10-digit SCC generally denotes specific application within equipment category

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What Sources are Included? (cont.)

■ Pollutants

- PM10-PRI, PM2.5-PRI, CO, NO_x, VOC, SO₂, and CO₂
 - PM₁₀ and PM_{2.5} emission factors represent Primary PM
 - NH₃ not a direct output of NONROAD, can be estimated based on fuel consumption and EPA emission factors derived from light-duty onroad vehicle emission measurements
 - Model estimates exhaust and evaporative VOC components

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NONROAD Model Emission Equation

$$I_{\text{exh}} = E_{\text{exh}} * A * L * P * N$$

- where:
- I_{exh} = Exhaust emissions, (ton/year)
 - E_{exh} = Exhaust emission factor, (ton/hp-hr)
 - A = Equipment activity, (hours/year)
 - L = Load factor, (proportion of rated power used on average basis)
 - P = Average rated power for modeled engines, (hp)
 - N = Equipment population

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NONROAD Model Emission Equation (cont.)

■ Emission Factors

- Dependent on engine type and engine size (horsepower)
 - Future year emission controls or standards reflected in emission factor value
- SO₂, CO₂, and evaporative VOC emissions based on fuel consumption
- PM₁₀ assumed to be equivalent to total PM
 - For gasoline and diesel-fueled engines, PM_{2.5} = 0.92 * PM₁₀
 - For LPG and CNG-fueled engines, PM_{2.5} = PM₁₀

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Geographic Allocation

- County-level allocation of equipment population
 - National or state-level equipment populations from PSR or alternate sources, reported by equipment type (SCC) and horsepower range
 - Allocates populations to counties using surrogate indicators that correlate with nonroad activity for specific equipment types

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Temporal Allocation

- NONROAD accounts for temporal variations in activity
 - Monthly activity profiles by equipment category according to 10 geographic regions
 - Typical weekday and weekend day activity profiles by equipment category; do not vary by region

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Improving Inputs

- Specify local fuel characteristics and ambient temperatures
- Replace NONROAD model default activity inputs with State or local inputs
 - Perform local survey
- Obtain local information to improve geographic allocation indicators and temporal profiles

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Improving Inputs (cont.)

- Significant PM Fine Equipment Categories include:
 - Diesel construction
 - Diesel farm
 - Diesel industrial
 - Gasoline lawn and garden
 - Gasoline recreational marine

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Resources

<http://www.epa.gov/otaq/nonrdmdl.htm>

- From this web site, there are links to:
 - Downloadable version of NONROAD2002a model
 - Documentation
 - User's Guide
 - Technical Reports to describe the sources and development of all model default input values

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AIRCRAFT - Overview

- SCCs
 - 2275020000 – Commercial Aircraft
 - 2275050000 – General Aviation
 - 2275060000 – Air Taxis
 - 2275001000 – Military Aircraft
- Activity Data – landing and take-off operations (LTOs)
- Emission Factors – aircraft/engine-specific or fleet average

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AIRCRAFT - Overview (cont.)

- Definitions of Aircraft Categories:
 - Commercial - Aircraft used for scheduled service to transport passengers, freight, or both
 - Air taxis - Smaller aircraft operating on a more limited basis to transport passengers and freight
 - General aviation - aircraft used on an unscheduled basis for recreational flying, personal transportation, and other activities, including business travel
 - Military aircraft - aircraft used to support military operations

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AIRCRAFT - Overview (cont.)

- Aircraft operations are defined by landing and take-off operation (LTO) cycles, consisting of five specific modes:
 - Approach
 - Taxi/idle-in
 - Taxi/idle-out
 - Take-off
 - Climb-out
- The operation time in each of these modes (TIM) is dependent on the aircraft category, local meteorological conditions, and airport operational considerations

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**COMMERCIAL AIRCRAFT
NEI Method**

- Activity/Emissions Developed at National Level
 - Commercial Aircraft Emissions
 - Calculated using national-level FAA LTO data by aircraft type and emission rates from Emissions and Dispersion Modeling System (EDMS) Version 4.0.
 - Used default engines for each aircraft type and default time-in-mode values.

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General Aviation, Air Taxi and Military Aircraft – NEI Method

- National Emissions for General Aviation, Air Taxi, and Military Aircraft calculated using equation:

$$\text{National Emissions}_{c,p} = \text{National LTOs}_c * EF_{c,p}$$

where: LTOs = landing and take-off operations;
 EF = emission factor;
 c = aircraft category; and
 p = criteria pollutant.

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General Aviation, Air Taxi and Military Aircraft – NEI Method (cont.)

- LTO-based PM Emission Factors
 - General Aviation
 - PM10-PRI: 0.2367 lbs/LTO
 - Air Taxi and Military Aircraft
 - PM10-PRI: 0.60333 lbs/LTO
 - PM2.5-PRI Emissions
 - Estimated by applying particle size multiplier developed for related engines to PM₁₀ emissions estimate
 - PM2.5-PRI = 0.92 * PM10-PRI

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AIRCRAFT - NEI Method

- National Emissions Allocation for Each Aircraft Category

$$\text{Airport Emissions}_{c,p,x} = \text{National Emissions}_{c,p} * AF_{c,p,x}$$

where: AF = allocation factor; and
 x = airport (e.g. La Guardia)
 c = aircraft category; and
 p = criteria pollutant.

$$AF_{c,x} = \text{LTOs}_{c,x} / \text{National LTOs}_c$$

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AIRCRAFT - NEI Method (cont.)

- Documentation on the procedures used to develop criteria pollutant (as well as HAP) aircraft emission estimates is available at:

ftp://ftp.epa.gov/EmisInventory/finalnei99ver3/criteria/documentation/nonroad/99nonroad_voli_oct2003.pdf

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AIRCRAFT - General Approach

- Determine the mixing height to be used to define the LTO cycle
- Define the fleet make-up for each airport
- Determine airport activity in terms of the number of LTOs by aircraft/engine type
- Select emission factors for each engine model associated with the aircraft fleet

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AIRCRAFT - General Approach (cont.)

- Estimate the time-in-mode (TIM) for the aircraft fleet at each airport
- Calculate emissions based on aircraft LTOs, emission factors for each aircraft engine model, and estimated aircraft TIM
- Aggregate the emissions across aircraft

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COMMERCIAL AIRCRAFT
Improvements to NEI

- Determine engine types associated with local aircraft types, to replace default aircraft/engine assignments in EDMS
- Obtain information on climb-out, takeoff, approach times, as well as taxi/idle times

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COMMERCIAL AIRCRAFT
Improvements to NEI (cont.)

- For PM₁₀ and PM_{2.5}, match few emission factors from EPA's 1992 Volume IV, Mobile Sources Procedures document, to the aircraft engines in their fleet as best as possible
- EPA OTAQ working with FAA to develop updated aircraft PM emission factors
- Regional inventories have used PM-10/NO_x emission factor ratios for air taxi applied to commercial aircraft NO_x emissions

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GA, AT and Military Aircraft
Improvements to NEI

- Obtain local estimates of LTOs for these categories (to obtain LTOs not covered by FAA data)
- Obtain information on the aircraft/engine types that comprise the aircraft fleet for these categories. Apply EPA engine-specific emission factors or EDMS, if available

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COMMERCIAL MARINE VESSELS
Overview

- Commercial Marine Vessel SCCs
 - 2280002100 – Diesel, In Port
 - 2280002200 – Diesel, Underway
 - 2280003100 – Residual, In Port
 - 2280003200 – Residual, Underway

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COMMERCIAL MARINE VESSELS
NEI Method

- National Diesel and Residual Emissions split into port and underway components
- Port and underway activity allocated separately, assigned to counties
- Port emissions assigned to a single county in port area

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COMMERCIAL MARINE VESSELS
NEI Method (cont.)

- Documentation on the procedures used to develop criteria pollutant (as well as HAP) commercial marine emission estimates is available at:

ftp://ftp.epa.gov/EmisInventory/finalnei99ver3/criteria/documentation/nonroad/99nonroadvoli_oct2003.pdf

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COMMERCIAL MARINE VESSELS
Improvements to NEI

- Review 1999 NEI emission estimates for representativeness
- Allocate port emissions to ports other than 150 largest
- Allocate port emissions to appropriate counties, since port emissions assigned to a single county in port area

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COMMERCIAL MARINE VESSELS
Improvements to NEI (cont.)

- Obtain activity estimates at the local or State-level from Department of Transportation, Port Authority
 - Fuel consumption
 - Categories of vessels
 - Number and size (hp) of vessels in each category
 - Number of hours at each time-in-mode
 - Cruising
 - Reduced speed zone
 - Maneuvering
 - Hotelling

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COMMERCIAL MARINE VESSELS
Emission Calculation

$$\text{Emissions} = \text{Pop} * \text{HP} * \text{LF} * \text{ACT} * \text{EF}$$

where:

- Pop = Vessel Population or Ship Calls
- HP = Average Power (hp)
- LF = Load Factor (fraction of available power)
- ACT = Activity (hrs)
- EF = Emission Factor (g/hp-hr)

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COMMERCIAL MARINE VESSELS
Activity

- 1999 EPA studies:
 - *Commercial Marine Activity for Deep Sea Ports in the United States*
 - *Commercial Marine Activity for Great Lake and Inland River Ports in the United States*
- Studies provide activity profiles for select ports, and present method for an inventory preparer to allocate detailed time-in-mode activity data from a typical port to another similar port

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COMMERCIAL MARINE VESSELS
Activity (cont.)

- Activity profiles for typical port include:
 - Number of vessels in each category
 - Vessel Characterization, including propulsion size (horsepower), capacity tonnage, and engine age
 - Number of hours at each time-in-mode associated with cruising, reduced speed zone, maneuvering, and hotelling

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COMMERCIAL MARINE VESSELS
Activity (cont.)

- Data on the number of trips and the tons of cargo handled by vessel type are provided for the top 95 Deep Sea Ports and top 60 Great Lake and Inland River Ports
- More detailed activity for these ports can then be estimated based on the data calculated for a typical port

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COMMERCIAL MARINE VESSELS
Emission Factors

- Depending on activity data obtained:
 - Horsepower-based emission factors
 - Fuel-based emission factors
- EPA performing studies to develop updated emission rates
 - Category 3 Engine Final Rulemaking, January 2003

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COMMERCIAL MARINE VESSELS
Emission Factors (cont.)

- PM10-PRI EFs for Category 1 and Category 2 Engines:

Engine Category	PM10 [g/kW-hr]
Category 1: 37-75 kW	0.90
Category 1: 75-225 kW	0.40
Category 1: 225+ kW	0.30
Category 2 (5-30 l/cylinder)	0.32

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COMMERCIAL MARINE VESSELS
Emission Factors (cont.)

- PM10-PRI EFs for Category 3 Engines (> 30 l/cylinder):

Mode: Engine	PM10 [g/kW-hr]
Cruise and Reduced Speed Zone: 2-stroke	1.73
Cruise and Reduced Speed Zone: 4-stroke	1.76
Maneuvering: 2-stroke	2.91
Maneuvering: 4-stroke	2.98
Hotelling: 2-stroke	0.32
Hotelling: 4-stroke	0.32
All Modes: Steam Generators	2.49

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COMMERCIAL MARINE VESSELS
Emission Factors (cont.)

- Emission factors in grams per gallon fuel consumed also available from *Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources*, EPA-450/4-81-026d (Revised), U.S. EPA, OAQPS, July 1989
- $PM_{2.5}\text{-PRI} = 0.92 * PM_{10}\text{-PRI}$ emissions

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LOCOMOTIVES
Overview

SCCs:

- 2285002006 – Diesel Class I Line Haul
- 2285002007 – Diesel Class II/III Line Haul
- 2285002008 – Diesel Passenger (Amtrak)
- 2285002009 – Diesel Commuter
- 2285002010 – Diesel Switchyard Locomotives

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LOCOMOTIVES
NEI Methods

- PM Emission Factors (represent Primary PM)
 - Line-Haul
 - PM_{10} : 6.7 g/gallon
 - $PM_{2.5}$: 6.03 g/gallon
 - Yard
 - PM_{10} : 9.2 g/gallon
 - $PM_{2.5}$: 8.28 g/gallon

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LOCOMOTIVES
NEI Methods (cont.)

- Activity Data (Gallons of distillate fuel oil consumed)
- National Activity
 - 1999 year U.S. distillate consumption by railroads
 - Class I
 - Class II/III
 - Passenger
 - Commuter
- Class I Line-Haul versus Yard (Switch) Operation Activity
 - Multiplied National Class I consumption by estimated line-haul percentage of total fuel consumption

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LOCOMOTIVES
NEI Methods (cont.)

- County-level emissions allocation
 - National emissions allocated to counties based on ratio of county to national rail activity
 - Rail activity measured as product of density (gross ton miles per mile) on each rail line and mileage for the associated rail line in county determined through GIS analysis

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LOCOMOTIVES
NEI Methods (cont.)

- Detailed documentation on the procedures used to develop criteria pollutant locomotive emission estimates for the 1999 NEI are available at:

ftp://ftp.epa.gov/EmisInventory/finalnei99ver3/criteria/documentation/nonroad/99nonroad_voli_oct2003.pdf

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LOCOMOTIVES
Improving the NEI

- Review NEI emission estimates for representativeness
- Obtain more representative fuel consumption estimates at the local or State-level
- Determine relative contribution of line-haul versus yard activity at local or State-level

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LOCOMOTIVES
Case Study - Overview

- Case Study: County-level Locomotive Inventory for Sedgwick County, KS
 - See Case Study Number 4-1

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LOCOMOTIVES
Case Study – Solution

- Case Study: County-level Locomotive Inventory for Sedgwick County, KS
 - See Handout 4-1

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