

Massachusetts  
2011 Periodic Emissions Inventory of  
VOC, NO<sub>x</sub>, CO, SO<sub>2</sub>, PM<sub>10</sub>, PM<sub>2.5</sub> and NH<sub>3</sub>

February 2018

**SECTION 5**  
**OFF-ROAD MOBILE SOURCES**

- 5.1 AIRCRAFT
- 5.2 RAILROAD LOCOMOTIVES
- 5.3 COMMERCIAL MARINE VESSELS (CMV)
- 5.4 NON-ROAD ENGINES

# SECTION 5

## OFF-ROAD MOBILE SOURCES

### 5.1 AIRCRAFT

MassDEP accepted EPA's National Emissions Inventory (NEI) Aircraft emission estimates for Massachusetts located at:

[ftp://ftp.epa.gov/EmisInventory/2011v6/v1platform/2011emissions/point\\_by\\_state/\(MA\\_2011NEIv1\\_point\\_20130723\\_revised\\_ptnonipm\\_15aug2013\\_v3.csv\)](ftp://ftp.epa.gov/EmisInventory/2011v6/v1platform/2011emissions/point_by_state/(MA_2011NEIv1_point_20130723_revised_ptnonipm_15aug2013_v3.csv)).

Since 2008 EPA has recorded aircraft emissions as point sources in the NEI. EPA documented the 2011 Aircraft methodology in Section 4.2 of *"EPA 2011 National Emission Inventories, Version 1, Technical Support Document, June 2014, Draft"*.<sup>1</sup>

MassDEP supplemented EPA's emissions with military aircraft emissions from Westover Air Force Base in Hampden County as shown in Table 5.1-1. Table 5.1-2 summarizes aircraft emissions by county. EPA's aircraft emission estimates for Massachusetts airports are presented in 5-3.

EPA estimated emissions related to aircraft activity for all known airports (including seaplane ports and heliports) in the 50 states, Puerto Rico, and US Virgin Islands. All of the approximately 20,000 individual airports are geographically located by latitude/longitude and stored in the NEI as point sources. As part of the development process, S/L/T agencies had the opportunity to provide both activity data as well as emissions to the NEI.

The aircraft sector includes all aircraft types used for public, private, and military purposes. This includes four types of aircraft: (1) Commercial, (2) Air Taxis (AT), (3) General Aviation (GA), and (4) Military. The fraction of turbine- and piston-driven aircraft is either collected or assumed for all aircraft types by EPA, which allows the emissions estimation model to assign the fuel used (jet fuel or aviation gas, respectively).

Commercial aircraft include those used for transporting passengers, freight, or both. Commercial aircraft tend to be larger aircraft powered with jet engines. Air Taxis carry passengers, freight, or both, but usually are smaller aircraft and operate on a more limited basis than the commercial aircraft. General Aviation includes most other aircraft used for recreational flying and personal transportation. Military aircraft are associated with military purposes, and they sometimes have activity at non-military airports. Military aircraft cover a wide range of aircraft types such as training aircraft, fighter jets, helicopters, and jet-powered and piston-powered planes of varying sizes.

The national AT and GA fleet includes both jet and piston-powered aircraft. Most of the AT and GA fleet are made up of larger piston-powered aircraft, though smaller business jets can also be found in these categories.

---

<sup>1</sup> [http://www.epa.gov/ttn/chief/net/2011nei/2011\\_nei\\_tsdv1\\_draft2\\_june2014.pdf](http://www.epa.gov/ttn/chief/net/2011nei/2011_nei_tsdv1_draft2_june2014.pdf)

The 2011 NEI also includes emission estimates for aircraft auxiliary power units (APUs) and aircraft ground support equipment (GSE) typically found at airports such as aircraft refueling vehicles, baggage handling vehicles, equipment, aircraft towing vehicles, and passenger buses.

## 5.2 RAILROAD LOCOMOTIVES

Railroad locomotives are usually the most important source of NO<sub>x</sub>, PM, and SO<sub>2</sub> emissions from off-road engines. Rail activity is typically broken into the five subcategories below each with its own SCC as determined by EPA's 2011 National Emissions Inventory, Version 1 Technical Support Document.<sup>2,3</sup>

1. Class I Line Haul (22-85-002-006) – large interstate freight carrier (e.g., CSX, formerly Conrail) and AMTRAK
2. Class II/III Line Haul (22-85-002-007) – smaller regional (some interstate) and local railroads
3. Passenger Trains (22-85-002-008) – interstate
4. Commuter Trains (22-85-002-009) – Massachusetts Bay Transit Authority (MBTA)
5. Switch-yard Operations (22-85-002-010) – switching locomotives for Class I & II/III

Class I railroads represent the largest railroad systems in the country and operate over a large geographic area carrying most of the interstate freight and passenger service nationwide. According to the Interstate Commerce Commission (ICC), railroads with operating budgets over \$250 million are classified as Class I.<sup>4</sup>

The smaller rail operations include Class II/III, passenger trains, commuter rail lines, and switchyard locomotives. Switchyard locomotives perform yard operations moving both Class I and Class II/III railroad cars to different lines within a railway yard.

Railroad locomotives are primarily of two types: electric and diesel-electric powered. Electric locomotives are powered by electricity generated at stationary power plants which are inventoried as point sources. Diesel-electric locomotives use diesel engines and generators to produce the required electrical power. In addition to the pollutants mentioned above, railroad diesel engines also emit CO and NH<sub>3</sub>.

**Methodology.** This is the second PEI inventory that MassDEP is accepting EPA NEI locomotive emissions. The 2008 emissions were estimated from the Eastern Regional Technical Advisory Committee (ERTAC) and were grown to 2011 by Eastern Research Group (ERG) under EPA contract.<sup>5</sup> ERTAC has also improved on the EPA Volume IV emission factors for locomotive emissions. ERTAC was able to obtain detailed Class I, II/III and switchyard railroad data from most railroad companies which is unavailable to states. ERTAC used an averaging methodology to apportion diesel fuel to railroads that did not report to them. MassDEP collected data from these non-reporting local railroads in order to correct and supplement the ERTAC diesel fuel data. ERG allocated emissions according to line haul shape IDs and yard locations based on 2008 locations. Railroad freight traffic data were obtained by ERG from a variety of sources including U.S.DOT Bureau of Transportation Statistics (BTS), U.S.DOE's

<sup>2</sup> [http://www.epa.gov/ttn/chief/net/2011nei/2011\\_nei\\_tsdv1\\_draft2\\_june2014\\_Section4.4\\_Locomotives](http://www.epa.gov/ttn/chief/net/2011nei/2011_nei_tsdv1_draft2_june2014_Section4.4_Locomotives).

<sup>3</sup> EPA contractor ERG No 0245.03.402.001 Contract No EP-D-07-097 'Documentation for Locomotive Component of the NEI Methodology. Submitted to Laurel Driver at EPA May 3, 2011. [ftp://ftp.epa.gov/EmisInventory/2011/doc/2008nei\\_locomotive\\_report.pdf](ftp://ftp.epa.gov/EmisInventory/2011/doc/2008nei_locomotive_report.pdf)

<sup>4</sup> [http://en.wikipedia.org/wiki/Railroad\\_classes#Class\\_I](http://en.wikipedia.org/wiki/Railroad_classes#Class_I)

<sup>5</sup> Eastern Research Group (ERG) September 5, 2012 correspondence to Laurel Driver at EPA "Development of 2011 Railroad Component for NEI. Contract # EP-D-07-097 'Mobile Source Inventories' [ftp://ftp.epa.gov/EmisInventory/2011/doc/2011nei\\_Locomotive.pdf](ftp://ftp.epa.gov/EmisInventory/2011/doc/2011nei_Locomotive.pdf)  
[ftp://ftp.epa.gov/EmisInventory/2011v6/v1platform/2011emissions/nonpoint\\_by\\_state/](ftp://ftp.epa.gov/EmisInventory/2011v6/v1platform/2011emissions/nonpoint_by_state/)

Annual Energy Outlook (AEO), the American Association of Railroads (AAR), and the American Short Lines and Regional Railroad Association. Growth rates were based on the difference in billions of ton miles travelled from 2008 to 2011.

MassDEP obtained system-wide diesel fuel use from Massachusetts Bay Transit Authority (MBTA)<sup>6</sup> and apportioned it to counties based on daily scheduled stops in the cities and towns served. MassDEP estimated the emissions from MBTA in Table 5.2-1 using ERTAC/ENVIRON<sup>7</sup> post 1999 controlled emission factors. Here is an example of the NOx emissions estimation of the MBTA commuter trains for Bristol County.

MBTA diesel fuel: 12,459,503 gallons \* 0.979 (MA portion: excluding Providence RI)  
= 12,197,853 gallons \* 2.5546% (apportionment to Bristol County)  
= 311,600 gallons \* 0.44269 lb NOx/gal (ERTAC/ENVIRON emission factor)  
= 137,942 lbs/2000 = 68.97 TPY NOx.  
Weekdays accounted for 71.3% of operations: 68.97 TPY NOx \* 0.713/260 days = 0.189 TPSD.

Table 5.2-2 is the emissions estimate for switchyard locomotives using EPA Volume IV emission factors for each engine.

ERTAC/ERG apportioned the system-wide annual fuel used by Class I railroads to states and counties based on county level track length and annual traffic density. ERTAC used EPA's national average line-haul emission factors based on all engine types. ERTAC also estimated emissions from switch-yard engines based on total number of engines submitted by railroads. ERTAC used an EPA national average switch-yard engine annual fuel use and emission factors. ERTAC's class I and II/III emissions for MA are reported in Tables 5.2-3.

A spokesman for AMTRAK reported no diesel fuel use in Massachusetts because their passenger line haul trains are electrified but reported a total of four switchyard locomotives operating in MA.<sup>8</sup>

Table 5.2-4 is a summary of all the railroad type emissions combined for all counties and pollutants.

### 5.3 COMMERCIAL MARINE VESSELS (CMV)

MassDEP is adopting EPA NEI 2011 estimates for commercial marine vessels. Their emissions are summarized by county in this section. The documentation here is a summary of EPA's and the full documentation can be accessed at Section 4.3 of the report "*2011 National Emissions Inventory V.1 Technical Support Document, June 2014, Draft.*"<sup>9</sup> and <ftp://ftp.epa.gov/EmisInventory/2011/doc>.

This CMV sector includes boats and ships used either directly or indirectly in the conduct of commerce or military activity. They are split into 3 subcategories: C1, C2, and C3 based on size.

The majority of vessels in this category are powered by reciprocating engines that are either fueled with distillate or residual fuel oil blends.

---

<sup>6</sup> Paul Joy MBTA Railroad Operations Directorate.

<sup>7</sup> Draft "LADCO 2005 Locomotive Emissions" prepared by Christian Lindhjem, ENVIRON International Corp. February 2007.

<sup>8</sup> Telephone conversation with John Griffin at AMTRAK Dec.8, 2009.

<sup>9</sup> [http://www.epa.gov/ttn/chief/net/2011nei/2011\\_nei\\_tsdv1\\_draft2\\_june2014.pdf](http://www.epa.gov/ttn/chief/net/2011nei/2011_nei_tsdv1_draft2_june2014.pdf)

The C3 inventory includes vessels which use C3 engines for propulsion. C3 engines are defined as having displacement above 30 liters per cylinder. The resulting inventory includes emissions from both propulsion and auxiliary engines used on these vessels as well as those on gas and steam turbine vessels. Geographically, the inventories include port and inter-port emissions that occur within the area that extends 200 nautical miles from the official U.S. shoreline, which is roughly equivalent to the border of the U.S. Exclusive Economic Zone. Only some of these emissions are allocated to states based on official state boundaries that typically extend 3 miles offshore. See section 4.3-4 of reference 12 for further explanation.

The C1 and C2 vessels tend to be smaller ships that operate closer to shore, and along inland and inter-coastal waterways. Naval vessels are not included in this inventory, though Coast Guard vessels are included as part of the C1 and C2 vessels.

The Commercial Marine Vessel source category does not include recreational marine vessels, which are generally less than 100 feet in length, most being less than 30 feet, and powered by either inboard or outboard. Recreational marine vessel emissions are included in the NONROAD model emissions in Section 5.4 of this report.

For the purpose of this inventory, we assume that the largest Category 3 (C3) vessels primarily use residual blends while the smaller Category 1 and 2 (C1 and C2) vessels typically used distillate fuels.

Each of the commercial marine Source Classification Codes (SCCs) requires an appropriate emissions type (maneuvering, hoteling, cruise, or reduced speed zone) because emission factors vary by movement type. Each SCC and movement type combination was allocated to a shape file identifier in the nonpoint inventory. The default values are those assumed when the actual movement type may be unknown. For example, emissions that occur in shipping lanes are assumed to be ‘cruising’ and cannot be ‘hoteling’, which only occurs at ports.

**EPA-Developed Commercial Marine Vessel Emissions Data.** EPA estimated CMV emissions as a collaborative effort between EPA’s Office of Transportation and Air Quality (OTAQ) and Office of Air Quality Planning and Standards (OAQPS). EPA developed the Category 3 commercial marine inventories for a base year of 2002 and then projected to 2011 by applying regional adjustment factors to account for growth. In addition, EPA developed and applied NOX adjustment factors to account for implementation of the NOX Tier 1 standard. The C3 growth factors, NOX adjustment factors by tier and calendar year, and NOX adjustment factors by engine type and speed are defined in Appendix A of the project report *Documentation for the Commercial Marine Vessel Component of the National Emissions Inventory Methodology*, March 30, 2010.<sup>10</sup> For Category 1 and 2 marine diesel engines, the emissions estimates were consistent with the 2011 Locomotive and Marine federal rule making.<sup>11</sup>

EPA then allocated these emissions to individual GIS polygons using methods that varied by operating mode (i.e., hoteling, maneuvering, reduced speed zone, and underway). EPA allocated emissions estimates based on activity to GIS polygons representing port and waterway. Use of GIS polygons allowed the estimation/allocation of emissions to defined port, waterway, and coastal areas.

**Allocation of Port and Underway Emissions.** EPA developed port boundaries using a variety of resources to identify the most accurate port boundaries. First, GIS data or maps provided directly from the port were used. Next, maps or port descriptions from local port authorities, port districts, etc. were

---

<sup>10</sup> <http://www.epa.gov/ttn/chief/net/2008inventory.html#inventorydoc>

<sup>11</sup> U.S. Environmental Protection Agency (US EPA), 2003. Final Regulatory Support Document: *Control of Emissions from New Marine Compression-Ignition Engines at or above 30 Liters per Cylinder*, EPA420-R03-004, January 2003. <http://www.epa.gov/otaq/oceanvessels.htm>

used in combination with existing GIS data to identify port boundaries. Finally, satellite imagery from tools such as Google Earth and street layers from StreetMap USA were used to delineate port areas.

In all cases, polygons were created on land, bordering waterways and coastal areas, and were split by county boundary such that no shape file crosses county lines and county total emissions can be easily summed. Each polygon was identified by the port name and state and county FIPS code in addition to a unique ShapeID. Smaller ports with Category 1 and 2 activities were mapped as small circles, such that the port is much like a point source, but without the complication of emissions appearing in both point and nonpoint inventories. The final shapefile for 2011 NEI contained 237 ports (including 76 additional ports from 2008 NEI) and 275 polygons – a single port can cross county boundaries and thus be included in multiple polygons. The set of port shapefile GIS data is posted at: [http://www.epa.gov/ttn/chief/eis/2011nei/2011\\_ports\\_shapefile.zip](http://www.epa.gov/ttn/chief/eis/2011nei/2011_ports_shapefile.zip).

The shapefiles used for the underway emissions were unchanged from those used in the 2008 NEI and are available in the file: [http://www.epa.gov/ttn/chief/eis/2011nei/shippinglanes\\_112812\\_shapefile.zip](http://www.epa.gov/ttn/chief/eis/2011nei/shippinglanes_112812_shapefile.zip).

EPA's CMV emissions for Massachusetts by county are presented in Table 5.3-1. Monthly activity was obtained from Massport to apportion annual emissions to a summer/winter weekday.  
<https://massport.com/port-of-boston/conley-terminal/>

## 5.4 NON-ROAD ENGINES

This section covers emission estimates from non-road engines. These engines include off-highway agricultural, construction, industrial, commercial, lawn and garden, railway maintenance equipment, and recreational marine vessels. All the engine and fuel types (including 2-stroke, 4-stroke gasoline/diesel, and the CNG/LPG engines) are included. The NONROAD model estimates emissions from over 260 specific engine types in non-road equipment using state and local data input parameters. The following is the breakdown of the equipment categories and examples of engines covered by the NONROAD model.

- Agricultural Equipment – tractors, combines, balers, tillers and sprayers
- Airport Equipment – ground support equipment, terminal tractors
- Commercial Equipment – compressors, pumps, pumps and welders
- Construction /Mining Equipment – graders, backhoes, dozers, tractors, trucks, rollers
- Industrial Equipment – forklifts, sweepers/scrubbers, and tractors
- Commercial Lawn & Garden – lawnmowers, leaf & snow-blowers, and compressors
- Residential Lawn & Garden – lawnmowers, chain saws, leaf-blowers/vacuum, tillers
- Logging Equipment – shredders & chainsaws, skidders, and tractors
- Pleasure Craft – inboard & outboard engines, power boats, jet skis
- Railroad Equipment – railway maintenance equipment,
- Recreational Equipment – ATV's, off-road motorcycles, golf carts, and snowmobiles

**Annual Emissions (by EPA).** MassDEP adopted EPA's 2011 annual NONROAD NEI Version 1<sup>12</sup> estimates for MA by county. EPA used its latest NONROAD model to estimate 2011 annual emissions for every county in the US (<http://www.epa.gov/otaq/nonrdmdl.htm>). MassDEP submitted electronically

---

<sup>12</sup> [ftp://ftp.epa.gov/EmisInventory/2011v6/v1platform/2011emissions/nonroad\\_by\\_state/](ftp://ftp.epa.gov/EmisInventory/2011v6/v1platform/2011emissions/nonroad_by_state/)  
EPA/ <http://www.epa.gov/ttn/chief/eiinformation.html> . <http://www.epa.gov/ttnchie1/ceerr/index.html> . <http://www.epa.gov/otaq/nmim.htm>

the National Mobile Inventory Model (NMIM)<sup>13</sup> input files for MOVES electronically through the EIS process, which EPA also used for running the NONROAD model to estimate annual emissions for all counties nationwide. The input files (as described in Section 4) cover variables such as fuel characteristics like state RVP, diesel sulfur %, and fuel blend. EPA's annual estimates for MA by county are presented in Table 5.4-1. MassDEP however, did one NONROAD run each in order to estimate emissions for a typical summer and winter day as described below.

MassDEP's submittal of the MOVES model inputs for 2011 satisfied the requirements of EPA's Consolidated Emissions Reporting Rule (CERR)<sup>14</sup> and the Air Emissions Reporting Requirements (AERR)<sup>15</sup> for the On-road and Non-road Mobile categories.

Structurally, the model is made up of three components: a graphical user interface (GUI) for the input of state parameters, the core model which contains all the algorithms and a reporting utility for viewing and summarizing modeled emission estimates.

The activity factor for Non-Road engines is the 2011 equipment population developed by an EPA contractor, Power Systems Research (PSR). PSR distributed the national equipment population data by age, application, power and fuel type. PSR estimated the base year equipment population by tracking sales, manufacturers' estimates of engine life and usage, and other equipment surveys (these estimates may be found at <http://www.epa.gov/otaq/models/nonrdmdl/nonrdmdl2010/420r10017.pdf>). The emission factors were time-weighted to account for age distribution based on the Onroad MOVES model.

**Summer/Winter Day Emissions (by MassDEP).** The minimum, maximum, and average temperatures are the same as those used for the 2011 MOVES inputs and are taken from Tables 4.1 and 4.2 of the On-Road Mobile Section 4 of this report. MassDEP ran the NONROAD model for 2011 to estimate emissions for a typical summer day for the Ozone SIP inventory and a typical winter day for the CO SIP inventory. The following are the NONROAD input parameters for both typical summer and winter days.

Fuel RVP (psi):	6.7	(winter: 13.5 psi)
Fuel Oxygen Weight %:	2.44	
Gasoline Sulfur %:	0.0041	
Diesel Sulfur %:	0.1218	
Marine Diesel Sulfur:	0.1389	
LPG/CNG/ Sulfur:	0.0030	
Minimum Temperature:	70.80	(winter: 23.7)
Maximum Temperature:	92.60	(winter: 39.5)
Average Ambient Temp:	85.30	(winter 31.6)
Stage II Control %:	84.00	
EtOH Blend % Mkt %:	75.10	
EtOH Vol %:	9.3	

NONROAD emissions results for a typical summer day for Eastern and Western MA counties are presented in Tables 5.4-2 and 5.4-3.

<sup>13</sup>EPA's National Inventory Model (NMIM), A Consolidated Emissions Modeling System for MOBILE6 and NONROAD <http://www.epa.gov/oms/models/nmim/420r05024.pdf>. Office of Transportation EPA420-R-05-024 and Air Quality December 2005 Regulations p.39602-39616

<sup>15</sup> EPA "Air Emissions Reporting Requirements" (AERR) <http://www.epa.gov/ttn/chief/aerr/> (73 Federal Register 76539). December 2008.