

# **MASSACHUSETTS 2008 PERIODIC EMISSIONS INVENTORY OF VOLATILE ORGANIC COMPOUNDS NITROGEN OXIDES CARBON MONOXIDE SULFUR DIOXIDE PARTICULATE MATTER AMMONIA**

## **INTRODUCTION**

In June 2010, the Massachusetts Department of Environmental Protection (MassDEP) submitted electronically to the U.S. Environmental Protection Agency (EPA) 2008 Massachusetts emissions inventory data for the following pollutants: volatile organic compounds, nitrogen oxides, carbon monoxide, sulfur dioxide, particulate matter, and ammonia. This document provides an overview of the 2008 inventory and emissions trends.

Summaries of the 2008 data and trends are provided in separate spreadsheets. Additional information about the data and methodologies used to assemble the 2008 emissions inventory is available from Kenneth Santlal, Inventory Coordinator, MassDEP, 617-292-5776; [kenneth.santlal@state.ma.us](mailto:kenneth.santlal@state.ma.us).

## **REGULATORY REQUIREMENTS**

The federal Clean Air Act (CAA) and associated regulations require that states compile and submit to EPA estimates of certain air pollutants emitted from sources within their borders. States that do not attain one or more of the National Ambient Air Quality Standards (NAAQS)<sup>1</sup> must develop emission inventories of pollutants that contribute to non-attainment. Inventories provide estimates of the contribution of various source categories to pollution levels.

Massachusetts has developed emissions inventories since the 1980s. Pursuant to the 1990 Clean Air Act amendments, as a non-attainment area under the ozone and carbon monoxide (CO) NAAQS, Massachusetts was required to submit State Implementation Plans (SIPs) demonstrating how the NAAQS would be met. The attainment SIPs included a 1990 base year emissions inventory for a typical summer day for VOCs, NO<sub>x</sub> and CO, and for a typical winter day for CO. Massachusetts also was required to conduct triennial Periodic Emission Inventories (PEIs) to update the 1990 base year inventory for the period 1993 through 2008.

These inventories were used to meet regulatory requirements related to the ozone and CO standards to demonstrate progress in reducing emissions, to help plan for the adoption of control measures, and to track trends in emissions from various source categories. Additional information about prior inventories is available on MassDEP's web site at: [www.mass.gov/eea/agencies/massdep/air/reports/emissions-inventories.html](http://www.mass.gov/eea/agencies/massdep/air/reports/emissions-inventories.html).

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<sup>1</sup> NAAQS are set for six criteria pollutants: ozone, nitrogen dioxide, particulate matter, carbon monoxide, sulfur dioxide, and lead.

In 2002, EPA promulgated the Consolidated Emissions Reporting Rule (CERR) (67 Federal Register 39602, June 10, 2002; <http://www.epa.gov/ttn/chief/cerr/index.html>), which required states to include in emission inventories pollutants that contribute to regional haze. The CERR requires that states submit electronically to EPA every three years a single, statewide annual inventory of the following pollutants that contribute to regional haze and diminished visibility in certain federal parks and wilderness areas: volatile organic compounds (VOCs), nitrogen oxides (NO<sub>x</sub>), carbon monoxide (CO), particulate matter (PM<sub>10</sub> and PM<sub>2.5</sub>), ammonia (NH<sub>3</sub>), and sulfur dioxide (SO<sub>2</sub>). In 2008, EPA promulgated a supplemental emissions reporting rule entitled “Air Emissions Reporting Requirements” (AERR) (73 Federal Register 76539; <http://www.epa.gov/ttn/chief/aerr/>), which applies to 2011 and subsequent emissions inventories.

In 1997, EPA revised the ozone NAAQS and in 2004 designated all of Massachusetts as non-attainment of the 1997 ozone NAAQS. In January 2008, MassDEP submitted to EPA an Ozone Attainment Demonstration SIP<sup>2</sup> for the 1997 ozone NAAQS that included a 2002 inventory of the three precursors of ozone: VOCs, NO<sub>x</sub>, and CO. The 2002 PEI included for the first time annual emissions for regional haze pollutants (SO<sub>2</sub>, PM<sub>10</sub>, PM<sub>2.5</sub>, and NH<sub>3</sub>). MassDEP submitted a 2005 PEI in September 2008 as part of the triennial CERR reporting requirements to EPA. The 2005 PEI was not required for SIP purposes.

## **2008 EMISSIONS INVENTORY**

MassDEP developed the 2008 PEI to meet EPA’s CERR requirements (it is not required for SIP purposes). In June 2010, MassDEP submitted 2008 point and area source inventory data electronically to EPA’s National Emissions Inventory (NEI) central data repository for air emissions data. MassDEP also submitted state-specific data that EPA uses to run its onroad mobile MOVES model and NONROAD models. MassDEP does not develop emissions estimates for certain area sources, but incorporates emissions estimates developed by EPA for Massachusetts, including: Residential Wood-burning, Open Burning, Portable Fuel Containers, Construction Activity, and Paved and Unpaved Roads. MassDEP followed EPA’s inventory guidance documents, which are listed as references at the end of this document.

### **Inventoried Pollutants**

#### **Annual and Seasonal Day Emissions**

Emissions inventories generally contain estimates of annual emissions for a given year. Methodologies, including emission factors, control factors and activity levels, are developed to represent annual average conditions and are reported as tons per year (TPY). In addition to annual emissions, estimates of daily emissions during the summer are presented for ozone precursors (VOCs, NO<sub>x</sub> and CO) in tons per summer day (TPSD) and during the winter for CO in tons per winter day (TPWD).

EPA requires that states estimate ozone precursors emitted during the ozone season in ozone non-attainment areas because high ozone concentrations are generally associated with warmer weather. The peak ozone season for Massachusetts is May through September, with most ozone exceedances occurring in the months of June, July and August. Typical summer day emissions for point and area sources are estimated using seasonal activity data, if available for a source category, or by applying an adjustment factor to annual data. Temperature is an important factor in emission estimates, especially for the mobile source categories. In accordance with EPA guidance, MassDEP used the average temperatures for the ten days with the highest ozone levels in the last three years (2006-2008) to generate the temperature factor used to estimate mobile source summer day emissions.

For CO non-attainment areas, EPA requires the CO emissions inventory to reflect the conditions when peak CO concentrations occur. For most areas in the country, including Massachusetts, the peak CO season is in

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<sup>2</sup> <http://www.mass.gov/eea/agencies/massdep/air/reports/state-implementation-plans.html>  
2 2008 Emissions Inventory – June, 2010

the winter months of December, January and February. Although Massachusetts no longer has CO non-attainment areas, MassDEP continues to estimate daily winter emissions of CO in order to track emission trends as part of its 10-year CO Maintenance Plan.

### **Pollutants**

**VOC**, as defined and listed in Massachusetts regulation 310 CMR 7.00, is any compound of carbon which participates in atmospheric chemical reactions. VOCs are emitted from industrial, commercial and residential solvent and fuel combustion processes, on-road and off-road mobile sources, and biogenic sources.

**NO<sub>x</sub>** is emitted from fuel combustion by on-road mobile, off-road mobile, industrial, commercial, and residential sources. Nitrogen dioxide (NO<sub>2</sub>) is one of the major components of NO<sub>x</sub>. In addition to being a precursor to ozone, NO<sub>2</sub> is also a criteria pollutant and contributes to acid rain formation and regional haze.

**CO** is generally emitted from the same combustion processes that produce NO<sub>x</sub>. CO is a minor precursor to ozone formation and is also a criteria pollutant. CO concentrations are highest during cold weather so typical winter day emissions are inventoried.

**SO<sub>2</sub>** is a criteria pollutant as well as a contributor to regional haze and acid rain. In addition, Massachusetts estimates SO<sub>2</sub> emissions pursuant to the State Acid Rain Program requirements, 310 CMR 7.21. This state regulation requires that MassDEP report statewide annual SO<sub>2</sub> emissions to ensure levels continue to be well below the State Acid Rain cap and trigger levels.

**PM** (particulate matter) is the mixture of tiny airborne particles in the air, including dust, dirt, soot, smoke, and liquid droplets. In this inventory, PM refers to “primary” PM -- particles that enter the atmosphere as direct emissions from a stack or other source. Secondary PM refers to particles that form through chemical reactions in the ambient air; secondary PM is not inventoried. Sources of primary PM include industrial processes, solvent operations, fuel combustion, incinerators, power plants, and motor vehicles. Particulate matter is both a criteria pollutant and a contributor to regional haze. **PM<sub>10</sub>** refers to coarse particles equal to or smaller than 10 micrometers in diameter. **PM<sub>2.5</sub>** particles are less than or equal to 2.5 micrometers in diameter (or about one-thirtieth the diameter of an average human hair). PM<sub>10</sub> and PM<sub>2.5</sub> are both criteria pollutants and contributors to regional haze.

**NH<sub>3</sub> (ammonia)** is a precursor of PM<sub>2.5</sub> and contributes to regional haze and is inventoried as required by EPA’s CERR. NH<sub>3</sub> is emitted from large industries, waste treatment facilities, wood-burning, animal wastes, fertilizers, soils, and mobile sources.

### **Inventory Categories and Methodology**

The general methodology used to develop the emission inventory for stationary point, stationary area, on-road mobile, off-road mobile, and biogenic sources involves the application of activity factors and emission factors to source categories. An emission factor is a representative value that relates the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., pound of particulate matter emitted per ton of coal burned or grams of a pollutant per mile travelled). Such factors facilitate estimation of emissions from various sources of air pollution. In most cases, these factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages of activities or operations in the source category.

**Stationary Point Sources** include categories of stationary facilities with actual emissions over 1 ton per year (TPY) of a criteria air pollutant or NH<sub>3</sub>. The stationary point source data is derived from a source registration form submitted to MassDEP by Massachusetts factories, power plants, and other large business facilities in

which the facilities report emissions to the ambient air of the inventoried pollutants. The facility data is recorded in MassDEP's Air Quality Reporting System (AQRS). The most common method for calculating point source emissions is to apply emission factors to facility activities, such as the quantity and type of material or fuel used. The AQRS has a built-in table of EPA AP-42 emission factors that are based on source classification codes (SCC) related to specific source processes. A single facility may report emissions for multiple source processes. MassDEP factors in a facility's control equipment and its effectiveness when estimating emissions for these sources.

Data from source-specific emissions tests and continuous emissions monitors (CEMs) are usually preferred for estimating a stationary source's emissions because they provide the best representation of the tested source's emissions. However, test data from individual sources are not always available and may not reflect the variability of actual emissions over time. Thus, emission factors are frequently the best or only method available for estimating emissions, in spite of their limitations.

**Stationary Area Sources** collectively represent individual sources that are too small and numerous to be inventoried as specific point sources. The Stationary Area Source section is comprised of six categories: 1. Waste Management practices; 2. Gasoline Distribution; 3. Solvent Use; 4. Combustion Processes; 5. Agricultural Activities; and 6. Fugitive Dust - Construction and Paved/Unpaved Roads.

These individual sources are grouped with other like sources into an area source category. Their emissions can be estimated collectively using one methodology. For example, gasoline stations and dry cleaning establishments are treated as area sources. The main reason not to treat them as point sources is that the effort required to gather data and estimate emissions for each individual facility is great while emissions per facility are generally small. Point source activity or emissions are subtracted from the corresponding area source categories in order to prevent double counting. MassDEP applies a rule effectiveness formula<sup>3</sup> to those area source categories that are subject to state regulatory controls (e.g., Gasoline Station Stage I Tank Truck Unloading, Architectural and Industrial Maintenance Coatings).

There also are categories of sources, such as Pesticides, Commercial/Consumer Products, and Architectural Coating, which generate significant emissions but are not emitted from a facility. These types of non-facility area sources also are included within the Stationary Area Source categories.

Unlike point sources that are inventoried individually, area sources are inventoried collectively based on an estimated level of activity related to a particular area source category. The activity factors for these area sources include material sales records, state registration records, fuel/material usage, default employment, and per capita data. MassDEP obtained emission factors from EPA's *Compilation of Air Pollution Emission Factors*<sup>4</sup> ("AP-42"), the Emissions Inventory Improvement Project (EIIP) and Eastern Regional Technical Advisory Committee (ERTAC) guidance documents. MassDEP apportions area source emissions to counties based on available fuel/material used, employment, state registration, and population data.

EPA and its contractor EH Pechan<sup>5</sup> developed emissions estimates for several area source categories that MassDEP has adopted: Agricultural Production –Livestock, Agricultural Tilling, Commercial Cooking, Construction Dust, Residential Open Burning, Wood-Burning, Paved and Unpaved roads, Ammonia from livestock and animals, and Biogenics.

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<sup>3</sup> Rule effectiveness reflects the ability of a regulatory program to achieve some percentage of all the emission reductions that could be achieved with full compliance by all sources at all times.

<sup>4</sup> *Compilation of Air Pollutant Emission Factors, Volume 1, Stationary Point and Area Sources, AP-42, Fifth Edition and Supplements*, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1997. ([www.epa.gov/ttn/chieff/publications.html#factor](http://www.epa.gov/ttn/chieff/publications.html#factor))

<sup>5</sup> <http://cert.pechan.com/epa/npee2008/index.html>

<sup>4</sup> 2008 Emissions Inventory – June, 2010

**On-Road Mobile Sources** include emissions from roadway and highway vehicles, such as cars, trucks, and buses. EPA has transitioned from MOBILE6.2 to the MOVES model for estimating onroad mobile emissions. MassDEP has not fully transitioned to MOVES and is adopting EPA's latest MOVES annual emissions by county as reported in NEI. MassDEP provided several 2008 input factors and files to EPA in order to run the MOVES model for Massachusetts. MassDEP obtained the activity factor, which is daily vehicle miles traveled (DVMT) from the Massachusetts Department of Transportation (MassDOT). MOVES requires a wide range of state input parameters such as vehicle Inspection and Maintenance program (I/M) data, temperature, vehicle mix, vehicle age distribution, and mileage accumulation rates. I/M inputs include start year, anti-tampering rates, and emission failure rates. MOVES calculates emission factors for all vehicle types for speeds up to 65 mph. EPA estimated annual on-road and non-road model emissions for all states but not for a typical summer day. MassDEP estimated a typical summer day by using the ratio between the 2008 MOBILE6.2 annual and summer/winter day emissions and applied it to the MOVES annual emissions.

**Off-Road Mobile Sources** include emission estimates from various types of engines used in recreational boating, construction equipment, locomotives, lawn and garden equipment, and numerous other types of off-road mobile operations. The basic activity factor is the number of various engines and the quantity of different types of fuel multiplied by appropriate emission factors. MassDEP used the latest version NONROAD2008a computer model developed by EPA's Office of Mobile Sources to generate off-road emissions. MassDEP input the appropriate temperatures, seasonal Reid Vapor Pressure and fuel characteristics to run the NONROAD model for a typical summer day for ozone precursors and a typical winter day for CO. MassDEP ran the NONROAD model for all four seasons in order to estimate annual emissions for 2008.

**Biogenic Sources** are natural, biological sources of ozone precursor emissions such as trees, agricultural crops, and microbial activity in soils and water. MassDEP adopted EPA's 2008 biogenic emissions estimated by the latest Biogenic Estimation Inventory System (BEIS3.14) model and reported in the National Emission Inventory (NEI).<sup>6</sup> The BEIS3.14 model incorporates EPA's default land use, crop acreage, and forest type by county, and assigns emission rates to different land use types. It applies meteorological data inputs, including temperature and insolation, for a typical summer day. Earlier biogenic emission models estimated VOC emissions only, whereas BEIS3.14 now estimates a small amount of NO<sub>x</sub> and CO. MassDEP accepted EPA's estimate for this category because it does not have better quality emissions data than what EPA has developed.

## **2008 Emissions Summaries**

2008 pollutant emissions are summarized in Tables 1 - 6 and Figures 1 - 13 according to the five source categories: Point, Area, On-road Mobile, Off-road Mobile and Biogenics. VOC, NO<sub>x</sub> and CO emissions are shown with and without biogenic emissions. Table 2 lists statewide emissions by detailed source types and Source Classification Code (SCC) within the five major source categories. Table 3 presents the same emissions but estimated for Eastern and Western MA.

### **Emission Trends 1990 To 2008**

Table 4 and Figures 9 - 12 present annual emission trends from 1990 through 2008 for each of the years for which an inventory was completed.<sup>7</sup> Trends are shown for VOC, NO<sub>x</sub>, CO and SO<sub>2</sub> which MassDEP has

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<sup>6</sup> EPA's National Emissions Inventory (NEI) is a database that incorporates emissions data received from a variety of sources into a comprehensive national inventory for the 6 criteria pollutants and 188 hazardous air pollutants. It is updated every three years. The NEI can be accessed at: <http://www.epa.gov/ttn/chief/net/2008inventory.html>

<sup>7</sup> Note that 2008 On-road emissions were estimated by EPA's MOVES model but previous years were estimated by the MOBILE6.2 model.

inventoried since 1990. (Emissions of PM10, PM2.5 and NH3 have only appeared in three inventories (2002, 2005, 2008) so data is insufficient to present a trend.)

The 1990 - 2008 emissions trends demonstrate the success of various control strategies implemented as part of Massachusetts' ozone attainment plans and to meet Massachusetts Acid Rain Program requirements. For example, emissions from point sources have declined significantly as a result of emissions control requirements at large facilities such as power plants and factories. Emissions from on-road mobile sources also have declined significantly despite an increase in vehicle miles traveled during this period.

**Table 4 shows that total VOC emissions were reduced by 52%, or 532 TPSD, from 1990 to 2008.** Of these reductions, 245 tons were from on-road mobile sources. The on-road mobile source emission reductions for this period, in spite of increased vehicle miles traveled, are due to numerous ongoing programs to reduce emissions from motor vehicles, including: the Federal Motor Vehicle Control Program (FMVCP), Massachusetts Low Emission Vehicle program (LEV), Massachusetts Enhanced Inspection and Maintenance (I/M) program, Stage II Vapor Recovery for gasoline stations, and Reformulated Gasoline (RFG). Emissions from stationary and area sources are the result of new VOC control measures and some decreases in manufacturing.

**Total NOx emissions were reduced by 50%, or 466 TPSD, from 1990 to 2008.** Point source reductions of 80%, or 254 TPSD, are attributable to Reasonably Available Control Technology (RACT) requirements and reductions from power plant emissions. The 42% onroad mobile reduction is attributable to the I/M and LEV programs. Further reductions are expected after 2008 as older, higher emitting cars are replaced with cleaner vehicles. Off-road emissions decreased by 10% from 1990 to 2008 and newly adopted control programs are expected to further reduce NOx emissions from this category.

**Total CO emissions were reduced by 66%, or 4,434 TPSD, from 1990 to 2008.** Most of the reduction is attributable to an estimated 3,848 TPSD (82%) reduction in on-road mobile emissions. Future reductions from off-road engines are expected as programs to control emissions from these sources are implemented.

**Total SO2 emissions were reduced by 79%, or 289,049 TPY, from 1990 to 2008.** Of these reductions, 217,872 TPY are due to controls on point sources, mainly power plants. Table 5 shows that because of substantial emission reductions since 1982, SO2 emissions for 2008 are now less than half of the Massachusetts Acid Rain statutory cap.

## QUALITY ASSURANCE PROCEDURES

MassDEP has used consistent quality assurance (QA) procedures for all its emissions inventories that were developed by an independent contractor for the Massachusetts 1990 base year inventory. The QA procedures have two levels of review. Level I is a checklist that includes minimum requirements of EPA's inventory guidance such as establishment of non-attainment areas and classification, pollutants covered and their source categories, and use of the latest EPA emission models such as MOVES and NONROAD2008a. Level II is a more detailed checklist that includes ensuring that point sources are reported down to appropriate thresholds, "reality checks" such as converting category emissions on a per capita basis compared to EPA national expected ranges, proper application of control efficiency/rule effectiveness/rule penetration, and prevention of double counting between point and area sources. All of these procedures were employed in development of the 2008 inventory.

All emissions were developed using Excel spreadsheets from previous inventories with built-in QA mechanisms and emissions were checked using manual calculations. A preliminary draft was reviewed internally and revisions were made based on comments received to enhance the accuracy of emissions.

Some emissions data used in the 2008 inventory for a number of categories were developed by several external parties such as EPA, Carnegie-Mellon University (CMU) and E.H. Pechan. MassDEP checked these data for accuracy before including it in the inventory. In addition, many of the categories have been reviewed by all the states in the Mid-Atlantic/Northeast Visibility Union (MANE-VU) as part of the MANE-VU inventory development process for accuracy and consistency within the MANE-VU region.

MassDEP adopted biogenic emissions from EPA's NEI that were developed from the BEIS-3.14 model. CMU prepared the Ammonia emissions from livestock and other animals. MANE-VU contractor E.H. Pechan developed emissions using multi-state surveys for categories such as Open Burning and Wood Burning. Pechan also developed annual emissions for On-Road Mobile and Paved/Unpaved Roads and several area sources such as Portable Fuel Containers. Emissions were prepared for and reviewed by Massachusetts and other MANE-VU states ensuring consistent and accurate emissions among other states.

## GENERAL REFERENCES

*2002 Base Year Emission Inventory SIP Planning: 8-hr Ozone, PM<sub>2.5</sub> and Regional Haze Programs*, U.S. Environmental Protection Agency, Research Triangle Park, NC, November 18, 2002. [http://www.epa.gov/ttn/chief/eidocs/2002baseinven\\_102502new.pdf](http://www.epa.gov/ttn/chief/eidocs/2002baseinven_102502new.pdf)

*Emissions Inventory Guidance for Implementation of Ozone and Particulate Matter National Ambient Air Quality Standards (NAAQS) and Regional Haze Regulations*. EPA-454/R-99-006.

*Emission Inventory Improvement Program, Volumes 1-7*, U.S. Environmental Protection Agency, Research Triangle Park, NC, July 1997. <http://www.epa.gov/ttn/chief/eiip/techreport/volume01/index.html>

*Compilation of Air Pollutant Emission Factors, Volume 1, Stationary Point and Area Sources*, AP-42, Fifth Edition and Supplements, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1997. <http://www.epa.gov/ttn/chief/publications.html#factor>

*Emission Inventory Requirements for Ozone State Implementation Plans*" (EPA-4504-91-010), February, 1992.

*Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources*, U.S. Environmental Protection Agency, Office of Mobile Sources and Office of Air Quality Planning and Standards, EPA 420/R-92-009. December 1992. <http://www.epa.gov/otaq/invntory/r92009.pdf>

*Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone - Volume I; General Guidance for Stationary Sources*. EPA-450/4-91-016, U.S. Environmental Protection Agency, Research Triangle Park, NC, May 1991.

*Guidelines for Estimating and Applying Rule Effectiveness for Ozone/CO State Implementation Plan Base Year Inventories*, EPA-452/R-92-010, U.S. Environmental Protection Agency, Research Triangle Park, NC, November 1992. [http://www.epa.gov/ttn/chief/old/eidocs/454r92010\\_nov1992.pdf](http://www.epa.gov/ttn/chief/old/eidocs/454r92010_nov1992.pdf)

*Consolidated Emissions Reporting Rule* (EPA CERR) <http://www.epa.gov/ttn/chief/cerr/index.html> (67 Federal Register 39602 No.111) June 10, 2002.

*Air Emissions Reporting Requirements* (EPA AERR) <http://www.epa.gov/ttn/chief/aerr/>. Federal Register Vol.73, No 243 p.76539 Dec 17 2008, 40CFR Part 51.