Calculating Piston-Engine Aircraft Airport Inventories for Lead for the 2008 National Emissions Inventory

United States Environmental Protection Agency

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Assessment and Standards Division
Office of Transportation and Air Quality
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Section 1. Introduction

The main purpose of this document is to describe the methods the Environmental Protection Agency (EPA) used to calculate airport lead (Pb) inventories for the 2008 National Emissions Inventory (NEI).[1] These methods focus on the development of approaches to estimate piston-engine aircraft activity at airports in the U.S. since the activity of this fleet is reported to the Federal Aviation Administration (FAA) as general aviation (GA) or air taxi (AT) activity – categories that also include jet-engine aircraft activity. The methods described here reflect improvements to the methods used in developing the airport-specific piston-engine aircraft inventories in the 2002 NEI and the 2005 NEI.

Background information regarding the use of leaded aviation gasoline (avgas) in piston-engine powered aircraft is available in other documents.[2,3] Briefly, most piston-engine aircraft operations fall into the categories of either GA or AT. Aircraft used in GA and AT activities include a diverse set of aircraft types and engine models and are used in a wide variety of applications.[4] Lead emissions associated with GA and AT aircraft stem from the use of one hundred octane low lead (100LL) avgas. The lead is added to the fuel in the form of tetraethyl lead (TEL). This lead additive helps boost fuel octane, prevent engine knock, and prevent valve seat recession and subsequent loss of compression for engines without hardened valves. Today, 100LL is the most commonly available type of aviation gasoline in the United States.[5] Lead is not added to jet fuel that is used in commercial aircraft, most military aircraft, or other turbine-engine powered aircraft. Lead emissions from the use of leaded avgas comprised 45% of the national inventory for emissions of lead in 2002.[6]

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[1] In this document '2008 NEI' refers to 2008 NEI version 1 (January 2011), available at http://www.epa.gov/ttn/chief/net/2008inventory.html

[2] EPA (2007) Review of the National Ambient Air Quality Standards for Lead: Policy Assessment of Scientific and Technical Information. OAQPS Staff Paper. EPA-452/R-07-013 November 2007. pp 2-8 and 2-9.

[3] FAA William J. Hughes Technical Center http://www.tc.faa.gov/act4/insidethefence/2006/0609_06_AvFuels.htm

[4] Commercial aircraft include those used for scheduled service transporting passengers, freight, or both. Air taxis fly scheduled and for-hire service carrying passengers, freight or both, but they usually are smaller aircraft than those operated by commercial air carriers. General aviation includes most other aircraft (fixed and rotary wing) used for personal transportation, business, instructional flying, and aerial application.

[5] ChevronTexaco (2005) Aviation Fuels Technical Review. FTR-3. http://www.chevronglobalaviation.com/docs/aviation_tech_review.pdf

[6] U.S. Environmental Protection Agency (2008) EPA's Report on the Environment EPA/600/R-07/045F. Available at: http://www.epa.gov/roe

This document is organized into eight sections. Section 2 describes the data we use to calculate the national inventory for the amount of lead released to the air from the combustion of leaded avgas. Section 3 describes the landing and takeoff data we use to calculate airport-specific inventories for lead. Section 4 describes how we estimate landing and takeoff data for the airport facilities that do not report it to the FAA. Section 5 describes the estimate of landing and takeoff activity occurring at heliports in the U.S. Section 6 describes the methods used to calculate the airport-specific inventories for lead. Section 7 describes data that would be needed to improve the estimates of airport-specific inventories for lead and Section 8 describes the estimates of the amount of lead emitted in-flight that are in the 2008 NEI.

In this document, units of tons (i.e., U.S. short tons) are used when discussing the national and airport-specific lead inventory in order to be consistent with the manner in which the NEI reports inventories for lead and other pollutants. The unit of grams is used in describing the concentration of lead in avgas and in describing emission factors. Conversion factors are provided for clarity.

Section 2. Calculating the National Avgas Lead Inventory

Because lead is a persistent pollutant and accumulates in the environment, we include all lead emissions from piston-engine aircraft in the NEI – emissions occurring during the landing and take-off cycle at airports as well as emissions occurring at altitude.[7] To calculate the national avgas lead inventory, we use information provided by the U.S. Department of Transportation's (DOT's) Federal Aviation Administration (FAA) regarding the volume of leaded avgas consumed in the U.S. in 2008.[8] The U.S. Department of Energy's (DOE's) Energy Information Administration (EIA) provides information regarding the volume of leaded avgas produced in a given year. EPA has historically used the DOE EIA avgas fuel volume produced to calculate national lead inventories from the consumption of leaded avgas. However, since EPA uses DOT airport activity and aircraft data, we are using the DOT fuel volume data in the 2008 NEI to calculate the national lead inventory in order to use a consistent data source. In this document, when we refer to avgas fuel volume data it is data supplied by DOT, except where noted.

As demonstrated in the equation below, to calculate the annual emission of lead from the consumption of leaded avgas, we multiply the volume of avgas used by the concentration of lead in the avgas, minus the small amount of lead that is retained in the engine, engine oil and/or exhaust system. The volume of avgas used in the U.S. in 2008

[7] U.S. EPA, 2006. Air Quality: Criteria for Lead: 2006; EPA/600/R-5/144aF; U.S. Government Printing Office, Washington, DC, October, 2006.

[8] U.S. Department of Transportation Federal Aviation Administration Aviation Policy and Plans. FAA Aerospace Forecast Fiscal Years 2010-2030. p.99. Available at: http://www.faa.gov/data_research/aviation/aerospace_forecasts/2010-2030/media/2010%20Forecast%20Doc.pdf This document provides historical data for 2000-2008 as well as forecast data.

was 248,100,000 gallons.[9] The concentration of lead in avgas ([Pb] in the equation below) can be one of four levels (ranging from 0.14 to 1.12 grams of lead per liter) as specified by the American Society for Testing and Materials (ASTM). By far the most common avgas supplied is "100 Low Lead" or 100LL.[10,11] The maximum lead concentration specified by ASTM for 100LL is 0.56 grams per liter or 2.12 grams per gallon.[12] A fraction of lead is retained in the engine, engine oil and/or exhaust system which we currently estimate at 5%.[13]

For the 2008 NEI, the national estimate of lead emissions from the consumption of avgas was 551 tons (see equation below).

$$\frac{(248{,}100{,}000 \text{ gal})(2.12 \text{ g Pb/gal})(0.95)}{907{,}180 \text{ g/ton}} = 551 \text{ tons Pb}$$

As described above, DOE's EIA also provides estimates of the annual volume of leaded avgas produced in a given year. For 2008, the volume of avgas produced in the U.S. was 5,603 thousand barrels or 235,326,000 gallons.[14] Consumption of this volume of avgas equates to a national lead emissions estimate for this source of 522 short tons.

Section 3. Landing and Takeoff Data Sources and Uses

Airport-specific inventories require information regarding landing and takeoff (LTO) activity by aircraft type.[15] According to FAA records, there are approximately 20,000 airport facilities in the U.S., the vast majority of which are expected to have activity by piston-engine aircraft that operate on leaded avgas. Of these facilities, EPA's NEI has in the past, reported emissions of lead (and other criteria pollutants and

[9] U.S. Department of Transportation Federal Aviation Administration Aviation Policy and Plans. FAA Aerospace Forecast Fiscal Years 2010-2030. p.99. Available at: http://www.faa.gov/data_research/aviation/aerospace_forecasts/2010-2030/media/2010%20Forecast%20Doc.pdf This document provides historical data for 2000-2008 as well as forecast data.
[10] ChevronTexaco (2005) Aviation Fuels Technical Review. FTR-3.
[11] The 2008 General Aviation Statistical Databook & Industry Outlook report by General Aviation Manufactures Association (GAMA) found that over 90% of avgas is 100LL.
[12] ASTM International (2005) Annual Book of ASTM Standards Section 5: Petroleum Products, Lubricants, and Fossil Fuels Volume 05.01 Petroleum Products and Lubricants (I): D 56 – D 3230.
[13] The information used to develop this estimate is from the following references: (a) Todd L. Petersen, Petersen Aviation, Inc, *Aviation Oil Lead Content Analysis*, Report # EPA 1-2008, January 2, 2008, available at William J. Hughes Technical Center Technical Reference and Research Library at http://actlibrary.tc.faa.gov/ and (b) E-mail from Theo Rindlisbacher of Switzerland Federal Office of Civil Aviation to Bryan Manning of U.S. EPA, regarding lead retained in engine, September 28, 2007.
[14] DOE Energy Information Administration. Fuel production volume data obtained from http://tonto.eia.doe.gov/dnav/pet/hist/mgaupus1A.htm accessed November 2006.
[15] An aircraft operation is defined as any landing or takeoff event, therefore, to calculate LTOs, operations are divided by two. Most data sources from FAA report aircraft activity in numbers of operations which, for the purposes of calculating lead emissions using the method described in this document, need to be converted to LTO events.

hazardous air pollutants) at 3,410 airports.[16] While the 3,410 airport facilities are among the most active in the U.S., they comprise only a small fraction of the total airport facilities where leaded avgas is used.

FAA's Office of Air Traffic provides a complete listing of operational airport facilities in the National Airspace System Resources (NASR) database. The electronic NASR data report, referred to here as the 5010 airport data report, can be generated from the NASR database and is available for download from the FAA website.[17] This report is updated every 56 days. EPA obtains airport information (including operations) for a subset of the facilities in the NASR database from FAA's Terminal Area Forecast (TAF) database that is prepared by FAA's Office of Aviation Policy and Plans.[18] The TAF database currently includes information for airports in FAA's National Plan of Integrated Airport Systems (NPIAS), which identifies airports that are significant to national air transportation. Approximately 500 of the airports that are in the TAF database have either an FAA air traffic control tower or an FAA contract tower where controllers count operations. The operations data from the control towers is reported to The Operations Network (OPSNET)[19] which is publically available in the Air Traffic Activity System (ATADS) database.[20] The operations data for the towered airports that is reported in OPSNET and ATADS is then reported to the TAF database. The operations data for the airports in the TAF database that do not have control towers represent estimates.[21] The operations supplied in the 5010 airport data report for facilities not reported in the TAF may be self-reported by airport operators through data collection accomplished by airport inspectors who work for the State Aviation Agency, or operations data can be obtained through other means.[22]

The 5010 airport data report supplies the date that the associated operations data represents.[23] Because airports that are not in the TAF database submit data voluntarily to FAA for the 5010 data report, many of the airports have operations data that represent data for years earlier than 2008. Nationally, GA and AT piston-engine operations have decreased in recent years,[24] therefore EPA did not use operations data from years prior to 2008 as it is reported. Instead, EPA multiplied the older GA and AT piston-engine data (Section 6 describes the method EPA used to calculate the number of piston-engine

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[16] These 3,410 facilities are the facilities for which the FAA's Terminal Area Forecast (TAF) database provides information regarding aircraft activity. The TAF database is prepared by FAA's Office of Aviation Policy and Plans and includes information for the airports in FAA's National Plan of Integrated Airport Systems (NPIAS). One of the goals of the NPIAS is to identify airports that are significant to national air transportation.
[17] http://www.faa.gov/airports_airtraffic/airports/airport_safety/airportdata_5010/
[18] http://aspm.faa.gov/main/taf.asp
[19] http://aspm.faa.gov/opsnet/sys/
[20] http://aspm.faa.gov/opsnet/sys/Airport.asp
[21] FAA's Terminal Area Forecast Summary (Fiscal Years 2009 – 2030), Appendix A (page 28) http://www.faa.gov/data_research/aviation/taf_reports/media/TAF%20Summary%20Report%20FY%202009%20-%202030.pdf
[22] In the absence of updated information from States, local authorities or Tribes, we are using the LTO data provided in the FAA database.
[23] The 12-month ending date on which annual operations data in the report is based.
[24] http://www.faa.gov/data_research/aviation_data_statistics/general_aviation/

operations from total GA and AT activity data) by scaling factors that were calculated by dividing the 2008 national amount of avgas produced by the national amount of avgas produced in the year the operations data represents.[25] A table with the scaling factors is provided in Appendix A. The national volume of avgas produced data comes from the DOE, EIA website and is available for 1981 – 2009.[26] For operations data older than 1981, EPA divided the 2008 national amount of avgas produced by the average of the national amount of avgas produced from 1981 – 1989. Jet engines do not use avgas, therefore EPA did not apply scaling factors to the turbine operations for data from years prior to 2008.

EPA also obtains operations data from the T-100 segment data from the Bureau of Transportation Statistics (BTS). The aircraft in the T-100 data are matched to aircraft in the FAA's Emission and Dispersion Modeling System (EDMS) using the crosswalk table developed for earlier versions of the NEI. Generally the T-100 data covers commercial air carrier operations, but some AT activities are included in the data set that would double count with the TAF data at the same airport. To correct for possible double counting, first the AT LTOs included in the T-100 data were compiled using the aircraft type data included in the aircraft make/models crosswalk.[27] The resulting aggregated LTOs were compared with the reported TAF LTOs for airports where there were overlaps. The T-100 AT LTOs were then subtracted from the TAF AT data to ensure that double counting was minimized. Note that if the T-100 AT value was larger than the TAF value, the TAF value was set to zero to eliminate the possibility of negative LTOs in the dataset.

The 2008 draft NEI was developed using the January 15, 2009 version of the 5010 airport data report. In that version of the report there were 19,925 airport facilities in the U.S. that had submitted data to the FAA. Among these 19,925 facilities, 99 facilities were not relevant for the purposes of estimating lead emissions because they were either listed as closed (85) or they were balloonports (14).[28] Therefore, lead inventories were needed for 19,826 facilities. In the January 15, 2009 version of the 5010 airport data report there were 5,654 airport facilities for which operations data were provided (many of which are facilities in FAA's TAF database).[29] There were 14,172 facilities in the 5010 airport data report for which there were no operations data.[30] As a

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[25] The FAA General Aviation and Air Taxi (Part 135) Activity Surveys (source of national level piston-engine operations data) are only available annually, starting in 1999. Because there are airports with operations data older than 1999, EPA used avgas product supplied data as a surrogate for piston-engine operations to estimate the change in piston-engine activity over the last three decades.

[26] http://tonto.eia.doe.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=mgaupus1&f=A. DOT recently changed the way they estimate fuel consumption data, so while EPA used DOT data to determine the 2008 national avgas lead inventory, for the purpose of calculating these scaling factors EPA used DOE's data in order to have historical fuel data that is calculated in a consistent manner.

[27] The T-100 data does not specify that the operations data is air taxi in nature; however, in discussions with FAA, EPA determined that these flights are air taxi in nature and has assigned them in the 2008 NEI as such.

[28] Balloon craft do not use avgas

[29] Either Commuter, GA Itinerant, GA Local, or Air Taxi operations data, as these operations can be performed by piston-engine aircraft.

[30] No Commuter, GA Itinerant, GA Local, or Air Taxi operations data.

part of the review process for the draft 2008 NEI, EPA received updated airport data from states and also looked at more recent versions of the 5010 airport data report to update the status of airports, so the number of airports for which EPA estimated activity is slightly lower in the 2008 NEI than in the draft 2008 NEI. The following section of this document describes the method EPA used to estimate operations for the 14,132 airport facilities in the 2008 NEI that do not have reported activity data.

As described in Section 1, most piston-engine aircraft fall into the categories of either GA or AT. Some GA and AT activity is conducted by turboprop and turbojet aircraft which do not used leaded avgas. There are no national databases that provide airport-specific LTO activity data for piston-engine aircraft separately from turbojet and turboprop aircraft. The databases described above report total GA and AT activity conducted by both piston-engine and jet-engine aircraft. Part *(a)* in Section 6 describes how we estimate piston-engine LTOs at airports in the 2008 NEI.

Section 4. Estimating LTOs at the 14,132 Airport Facilities with No LTO Data

FAA has used regression models to estimate operations at facilities where operations data are not available.[31,32] In this work and other work, FAA identified characteristics of small towered airports for which there were statistically significant relationships with operations at these airports.[33] Regression models based on the airport characteristics were then used to estimate general aviation operations for a set of non-towered airports. The airport characteristics identified by FAA and used to estimate general aviation operations at small airports include: the number of aircraft based at a facility (termed 'based aircraft'), population in the vicinity of the airport, airport regional prominence, per capita income, region, and the presence of certificated flight schools.

In the 2000 report titled 'Model for Estimating General Aviation Operations at Non-towered Airports,' a model of GA annual activity was developed using information from small towered airports to explain GA activity at towered and non-towered airports. The model explained GA activity at the towered airports well (R^2 of 0.75) but produced higher estimates than state-supplied estimates for non-towered airports.[34]

The relevant data available in the 5010 airport data report for the purposes of estimating airport operations include: facility type (airport, balloonport, seaplane base, gliderport, heliport, stolport,[35] ultralight); number of GA aircraft based at each airport by

[31] Federal Aviation Administration, Office of Aviation Policy and Plans, Statistics and Forecast Branch. July 2001. Model for Estimating General Aviation Operations at Non-towered Airports Using Towered and Non-towered Airport Data. Prepared by GRA, Inc.
[32] Mark Hoekstra, "Model for Estimating General Aviation Operations at Non-Towered Airports" prepared for FAA Office of Aviation Policy and Plans, April 2000.
[33] GRA, Inc. "Review of TAF Methods," Final Report, prepared for FAA Office of Aviation Policy and Plans under Work Order 45, Contract No. DTFA01-93-C-00066, February 25, 1998.
[34] The mean absolute difference between the model operations estimate and the state operations estimate was 16,940 operations.
[35] Stolport is an airport designed with STOL (Short Take-Off and Landing) operations in mind, normally having a short single runway.

type (glider, helicopter, jet engine, military, multi-engine, single engine, ultralight); operations data (air taxi, commercial, commuter, GA itinerant, GA local, military)[36]; and operations date (12-month ending date on which annual operations data is based). Census data was also merged with the 5010 airport data report to give population data for each airport's county.

Using the FAA work referenced above, we explored relationships among the airport data variables that best predicted aircraft activity (LTOs). We found that based aircraft was a highly significant and positive regressor to LTOs. Table 1 shows that for facilities that did not have LTO data in the January 15, 2009 version of the 5010 airport data report, 7,856 had based aircraft data while 6,316 did not have based aircraft data.[37, 38] Therefore, as described below, LTO estimates were derived using different methods depending on data availability.

Table 1: Contingency table describing the numbers of airport facilities that have or do not have LTO data and/or based aircraft data for airport facilities in the January 15, 2009 version of the 5010 airport data report

		HAVE LTO DATA		
		YES	**NO**	
HAVE BASED AIRCRAFT DATA	**YES**	4,872	7,856	**12,728**
	NO	782	6,316	**7,098**
		5,654	**14,172**	**19,826**

[36] As explained in footnote 15, an aircraft operation is defined as any landing or takeoff event, therefore, to calculate LTOs, operations are divided by two. The 5010 airport data report from FAA reports aircraft activity in numbers of operations which, for the purposes of calculating Pb emissions using the method described in the TSD, are converted to LTO events.

[37] As described in Section 3, the number of facilities with no LTO data changed slightly from the draft 2008 NEI to the 2008 NEI. In the 2008 NEI, of the facilities that did not have reported activity data, 7,837 facilities reported based aircraft data and 6,295 did not report based aircraft data.

[38] These numbers include data for the following types of facilities: airports, balloonports, seaplane bases, gliderports, heliports, stolports, and ultralights.

(a) Estimating LTOs at Facilities with Based Aircraft Data, but No LTO Data:

There are 6,414 facilities in the 2008 NEI (not including heliports) for which the 5010 airport data report supplies the number of based aircraft[39] but not activity data to which the regression equation (based aircraft vs. LTOs) could be applied. Using the 4,872 airports for which both LTO and aircraft data is known, the initial relationship found between based aircraft and LTOs was:

Equation 1:
LTOs = 2494 + 208*aircraft $R^2 = 0.55$

The FAA models found population to be another significant regressor. We used the population of the county in which the airport is located as the population variable. Adding county population to the model gave the following relationship:

Equation 2:
LTOs = 2204 + 194*aircraft + 0.0038*county population $R^2 = 0.56$

EPA received numerous comments to the docket on its Advance Notice of Proposed Rulemaking on Lead Emissions from Piston-Engine Aircraft Using Leaded Aviation Gasoline[40] indicating that aviation in Alaska is different than it is in the continental U.S. Commenters pointed out that in Alaska, 82% of communities are not accessible by road and rely on air transport for life sustaining goods and services.[41] Commenters also noted that Alaskans travel by air eight times more often per capita than those in the continental U.S. For those reasons, we added a dummy variable in equation 3 to identify whether or not an airport is located in Alaska. Because the relationship between based aircraft and LTOs is likely different for Alaskan airports than it is for airports that aren't in Alaska, we also added an interaction term to equation 3 (interaction of an airport being in Alaska and its sum of based aircraft).

Equation 3:
LTOs = 1937 + 205*aircraft + 0.0038*county population + 566*Alaska – 108*(AlaskaXaircraft)
$R^2 = 0.58$

After analyzing the data and plot for the data underlying equation 3, we found many airport facilities identified as commercial airports for which based aircraft was extremely low (i.e., less than 10), yet LTOs were quite high (i.e., anywhere from 100,000

[39] Based aircraft for this purpose was limited to single- and multi-engine aircraft, helicopters, and ultralights since these aircraft types can use leaded avgas.
[40] U.S. Environmental Protection Agency (2010) Advance Notice of Proposed Rulemaking on Lead Emissions From Piston-Engine Aircraft Using Leaded Aviation Gasoline. 75 FR 22440 (April 28, 2010).
[41] Comments to the docket on EPA's Advance Notice of Proposed Rulemaking on Lead Emissions from Piston-Engine Aircraft Using Leaded Aviation Gasoline from the Alaska Air Carriers Association (dated 18 June 2010; comment number OAR-2007-0294-0323.1) and Alaska Governor Parnell (dated 25 August 2010; comment number OAR-2007-0294-0403.1).

to more than 200,000 LTOs/year).[42] These facilities were removed from the regression analysis. Additionally, for reasons described below, heliports were also removed from the regression. The resulting relationship was:

Equation 4:
LTOs = 1293 + 203*aircraft + 0.0019*county population - 473*Alaska – 144*(AlaskaXaircraft)

$R^2 = 0.65$

When equation 4 was applied to the 6,414 airport facilities that report based aircraft data but not LTO activity, the resulting sum of LTOs was almost 15 million. EPA estimates that the number of LTOs at the airports that do not report activity data should approximate the number of LTOs from the bottom of the distribution of the set of airports that report activity data to the 5010 airport data report but that are not in the TAF database. The average number of LTOs per year from airports in the bottom 30% of the set of airports that report activity data to the 5010 airport data report but that are not in the TAF database is ~63 LTOs/year. Multiplying 63 by the number of airports that do not report activity data equals 549,050 LTOs.[43] Therefore, EPA used equation 4 to generate the distribution of LTOs at the individual airports that report based aircraft data but not activity data and then applied a scaling factor of 0.0356 to those LTOs to obtain the LTOs that are reported in the 2008 NEI.[44] The sum of the LTOs from this set of airports plus the sum of the LTOs at the airports that do not report either based aircraft or activity data (described below in section *(b)*) sum to 549,050 LTOs. These LTOs are all assigned to the GA, piston-engine category since they are assigned to smaller general aviation airports that are assumed to have little to no air taxi or jet aircraft activity.

Equation 4 and the scaling factor were used to estimate LTO activity for the 2008 NEI at airport facilities that report based aircraft data but not activity data.

(b) Estimating LTOs at Facilities with Neither Based-Aircraft Data nor LTO Data:

There are 2,260 facilities (not including heliports) for which the 5010 airport data report supplies neither the number of based aircraft nor activity data. In the absence of data to establish a relationship to airport activity, we assign a default value of LTOs to the GA, piston-engine category for each of these facilities.

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[42] From FAA's website, "Addresses for Commercial Service Airports", available at: http://www.faa.gov/airports_airtraffic/airports/planning_capacity/passenger_allcargo_stats/addresses/media/commercial_service_airports_addresses.xls

[43] This rounded number is calculated by multiplying 63.298 LTOs/year by 8,674, which is the number of airports that don't report activity data (6,414 don't report activity data and 2,260 facilities don't report activity or based aircraft data).

[44] The scaling factor was calculated by dividing 528,710 LTOs by 14,862,767 LTOS; the 528,710 LTOs are equal to 549,050 LTOs minus 20,340 LTOs (20,340 LTOs represent the sum of LTOs assigned to the 2,260 facilities that don't report either activity data or based aircraft data - the derivation of LTO estimates for these facilities is described in Section 4 *(b)*). The 14,862,767 LTOs are the sum of LTOs that result from applying equation 4 to the 6,414 facilities with based aircraft data but no activity data.

The default value was determined by evaluating GA LTOs that are reported at the set of 2,471 facilities that report activity data to the 5010 airport data report but that are not in the TAF set of airports. The average number of LTOs reported to the bottom ten percent of these facilities (when sorted by total GA LTOs) was 9. These facilities are assumed to most closely approximate the set of 2,260 facilities that do not report any based aircraft or LTO data; therefore, we assigned 9 LTOs to the GA, piston-engine category for these airport facilities for purposes of developing inventory estimates.

Section 5. Calculating LTOs at Heliports:

There were 5,559 heliport facilities in the January 15, 2009 FAA 5010 data report that were operational. Of those, only 92 (or 2%) reported LTO data, and of those, only 31 reported both based aircraft and LTO data. Because of the limited information regarding activity at heliports, some municipalities have hired contractors to survey activity in their local area.[45, 46]

The summary statistics for LTO data provided at the 92 operational heliports is presented in Table 2. These facilities report a wide range in activity from 3 LTOs/year to more than 18,000 LTOs/year. Some facilities clearly have significant helicopter traffic (i.e., thousands of LTOs/year) which is supported by the contractor summaries of heliport activity in the Washington Metropolitan area. The little data available to us suggests that the median helicopter activity is less than 200 LTOs/year. In the absence of more information on which to base estimates of LTO activity, we assigned 141 LTOs (the median of the reported heliport LTOs) to the GA category at all of the heliports which do not report LTO data. The piston-engine fraction developed in Section 6 is applied to the 141 LTOs resulting in 51 LTOs assigned to the GA, piston-engine category and 90 assigned to the GA, turbine-engine category. This is an area of significant uncertainty in the inventory and one for which EPA is seeking information from local agencies.

Table 2: Heliport LTO Data for those Reporting LTO Data in the January 15, 2009 Version of the 5010 Airport Data Report

18,250	Maximum LTOs
3	Minimum LTOs
1,123	Average LTOs
141	Median LTOs
50	Mode LTOs

[45] Executive Summary: Regional Helicopter System Plan, Metropolitan Washington Area, prepared by Edwards and Kelcey for the Metropolitan Washington Council of Governments, 2005.
[46] Alaska Aviation Emission Inventory, prepared by Sierra Research, Inc. for Western Regional Air Partnership, 2005.

Section 6. Methodology for Estimating Airport-Specific Lead Emissions

In 2008, EPA developed a method to calculate lead emissions at airports where piston-engine powered aircraft operate. [47] This method brings lead inventories into alignment with the manner in which other criteria pollutants emitted by aircraft are calculated. This method is described here with changes that were made from previous methods (i.e., the method used to develop the 2002 inventory) and applied in developing airport lead inventories for the 2008 NEI. In this section we first present the equation used to calculate lead emitted during the LTO cycle then we describe each of the components of the input data: we describe how we calculate piston-engine LTOs from data available in FAA databases, we describe the derivation of the emission factor for the amount of lead emitted during the LTO cycle, and we describe the estimate of the amount of lead retained in the engine and oil that we do not include in the amount of lead released to the air.

Historically, where aircraft specific activity data are available (such as T-100), aircraft gaseous and particulate matter (PM) emissions have been calculated through the FAA's EDMS.[48] This modeling system was designed to develop emission inventories for the purpose of assessing potential air quality impacts of airport operations and proposed airport development projects. However, EDMS has a limited number of piston-engine aircraft in its aircraft data and is currently not set up to calculate metal emissions and thus, it is not a readily available tool for determining airport lead inventories related to aircraft operations. In developing this approach to determine piston-engine aircraft lead emissions, EPA relied upon the basic methodology employed in EDMS. This requires as input the activity of piston-engine aircraft at a facility, fuel consumption rates by these aircraft during the various modes of the LTO cycle and time in each mode (taxi/idle-out, takeoff, climb-out, approach, and taxi/idle-in), the concentration of lead in the fuel and the retention of lead in the engine and oil. The equation used to calculate airport-specific lead emissions during the LTO cycle is below, followed by a description of each of the input parameters.

$$\text{LTO Pb (tons)} = \frac{\text{(piston-engine LTO)(avgas Pb g/LTO)(1-Pb retention)}}{\text{907,180 g/ton}}$$

(a) Calculating Piston-engine LTO:

Piston-engine LTOs are used to calculate emissions of lead that are assigned to the airport facility where the aircraft operations occur. An aircraft operation is defined as any landing or takeoff event, therefore, to calculate LTOs, operations are divided by two. Most data sources from FAA report aircraft activity in numbers of operations which, for the purposes of calculating lead emissions, need to be converted to LTO events. We

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[47] U.S. EPA (2008) Lead Emissions from the Use of Leaded Aviation Gasoline in the United States, Technical Support Document. EPA420-R-08-020. Available at: www.epa.gov/otaq/aviation.htm.

[48] EDMS available from http://www.faa.gov/about/office_org/headquarters_offices/aep/models/edms_model/

describe here the method used to estimate the fraction of GA and AT LTOs at an airport that are conducted by piston-engine aircraft. These fractions are calculated separately (one fraction for GA and one for AT). These fractions are multiplied by total LTOs reported separately for GA and AT and then summed to arrive at the total LTOs conducted by piston-engine aircraft at an airport.

One use of the 2008 NEI is to identify sources of lead, including airports, that have inventories of 0.50 tons per year or more for the purposes of identifying locations where lead monitoring may be required to evaluate compliance with the National Ambient Air Quality Standard for Lead. To calculate the most airport-specific inventories for airports that may potentially exceed this inventory threshold, we used a more airport-specific surrogate for this subset of airports than the remainder of the airports where we applied national default averages described below.

We used the fraction of based aircraft at an airport that are single- or multi-engine to calculate the number of GA LTOs at an airport that were conducted by piston-engine aircraft. The data regarding the population of based aircraft at an airport is available for a subset of airports in the FAA 5010 master records data report described in Section 3. For example, if an airport reports 150 single-engine aircraft, 20 multi-engine aircraft and a total of 180 aircraft based at that facility, then the fraction of based aircraft we would use as a surrogate for piston-engine aircraft is 94% ((150+20)/180). We then multiply the total GA LTOs for that facility by 0.94 to calculate piston-engine LTOs.

We evaluated this surrogate by comparing the results of using it with piston-engine aircraft operations reported for airports that supply this information in master plans, airport layout plans, noise abatement studies and/or land use compatibility plans. We could rarely find data from the same year for comparison purposes; however, for the majority of airports, based aircraft and actual observed piston-engine aircraft activity agreed within ten percent.[49]

For the majority of airports in the 2008 NEI we used national average fractions of GA and AT LTOs conducted by piston-engine aircraft that were derived using FAA's General Aviation and Part 135[50] Activity Surveys – CY 2008 (GAATA).[51] Table 2.4 in the 2008 GAATA Survey reports that approximately sixty-six percent (66%) of all GA and AT LTOs are from piston-engine aircraft which use avgas, and about thirty-four

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[49] Documents used to evaluate the use of based aircraft include the following:
Airport Master Plan Update Prescott Municipal Airport (Ernest A Love Field) (2009) Available at: www.cityof**prescott**.net/_d/amp_tablecontents.pdf
Gillespie field Airport Layout Plan Update Narrative Report (2005) Available at: www.co.san-diego.ca.us/dpw/**airport**s/powerpoints/pdalp.pdf
Land Use Compatibility Plan for the Grand Forks International Airport (2006) Available at: www.gfk**airport**.com/authority/pdf/**land_use**.pdf
McClellan-Palomar Land Use Compatibility Plan (Amended March 4, 2010) Available at: www.ci.oceanside.ca.us/.../**McClellan-Palomar**_ALUCP_03-4-10_amendment.pdf
[50] On-demand (air taxi) and commuter operations not covered by Part 121
[51] The FAA GAATA is a database collected from surveys of pilots flying aircraft used for general aviation and air taxi activity. For more information on the 2008 GAATA, see Appendix A at http://www.faa.gov/data_research/aviation_data_statistics/general_aviation/CY2008/

percent (34%) are turboprop and turbojet powered which use jet fuel, such as Jet A. The LTO data in Table 2.4 in the 2008 GAATA Survey does not distinguish LTOs as GA or AT, and thus does not allow us derive separate piston activity fractions for GA and AT.

We are using the number of hours flown by piston versus turboprop or turbojet aircraft (reported in Table 1.4 in the 2008 GAATA Survey) to allow us to make separate estimates of the fraction of GA activity conducted by piston aircraft and the fraction of AT activity conducted by piston aircraft. We chose to use the fraction of hours flown by piston-engine aircraft as a surrogate to calculate the fraction of LTOs flown by piston aircraft since the overall (i.e., for GA and AT combined) piston percent of hours flown (66.4%) is very close to the percent of LTOs that are piston (65.7%). Table 1.4 of the 2008 GAATA presents the total hours flown by aircraft type and separates GA from AT. Seventy-three percent (73%) of all GA hours flown are by piston-engine aircraft while twenty-eight percent (28%) of all GA hours flown are by turboprop and turbojet powered aircraft.[52] Twenty-three percent (23%) of all AT hours flown are by piston-engine aircraft while seventy-seven percent (77%) of all AT hours flown are by turboprop and turbojet powered aircraft. Approximately 5,000 of the total 20,000 airport facilities in the U.S. are heliports at which only helicopters (rotocraft) operate. Therefore, EPA also calculated the percent of rotocraft hours flown that are conducted by piston-engine aircraft. Thirty-six percent (36%) of all GA rotocraft hours flown are by piston-engine rotocraft while sixty-four percent (64%) of all GA rotocraft hours flown are by turboprop and turbojet powered rotocraft. Two percent (2%) of all AT rotocraft hours flown are by piston-engine rotocraft while ninety-eight percent (98%) of all AT rotocraft hours flown are by turboprop and turbojet powered rotocraft. Table 3 identifies the piston and turbine fractions that were used in the absence of airport-specific information to calculate piston-engine operations at airports and heliports in the 2008 NEI.

Table 3: Piston and Turbine Activity Fractions used in the 2008 NEI

	Airports		**Heliports**	
	GA	**AT**	**GA**	**AT**
Piston Powered	72.5%	23.1%	36.1%	2%
Turbine Powered	27.5%	76.9%	63.9%	98%

[52] Numbers in the text may not add to 100% due to rounding; the percentages in Table 3 are the values we used to calculate the 2008 NEI.

(b) Calculating the Piston-engine Aircraft Emission Factor: Grams of Lead Emitted per LTO:

Piston-engine aircraft can have either one or two engines. EDMS version 5.0.2 contains information on the amount of avgas used per LTO for some single and twin-engine aircraft. The proportion of piston-engine LTOs conducted by single- versus twin-engine aircraft was taken from the FAA's GAATA Survey for 2008 (90% of LTOs are conducted by aircraft having one engine and 10% of LTOs by aircraft having two engines).[53] Since twin-engine aircraft have higher fuel consumption rates than those with single engines, a weighted-average LTO fuel usage rate was calculated to apply to the population of piston-engine aircraft as a whole. For the single-engine aircraft, the average amount of fuel consumed per LTO was determined from the six types of single piston-engine aircraft within EDMS.[54] This was calculated by averaging the single-engine EDMS outputs for fuel consumed per LTO using the EDMS scenario property of ICAO/USEPA Default - Times in Mode (TIM), with a 16 minute taxi-in/taxi-out time according to EPA's *Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources*, 1992.[55] This gives a value of 16.96 pounds of fuel per LTO (lbs/LTO). The average single-engine fuel consumption rate was divided by the average density of 100LL avgas, 6 pounds per gallon (lbs/gal), producing an average fuel usage rate for single-engine piston aircraft of 2.83 gallons per LTO (gal/LTO). This same calculation was performed for the two twin-engine piston aircraft within EDMS, producing an average LTO fuel usage rate for twin-engine piston aircraft of 9.12 gal/LTO.

Using these single- and twin-engine piston aircraft fuel consumption rates, a weighted average fuel usage rate per LTO was computed by multiplying the average fuel usage rate for single-engine aircraft (2.83 gal/LTO) by the fleet percentage of single-engine aircraft LTOs (90%). Next, the twin-engine piston aircraft average fuel usage rate (9.12 gal/LTO) was multiplied by the fleet percentage of twin-engine aircraft LTOs (10%). By summing the results of the single- and twin-engine aircraft usage rates, the overall weighted-average fuel usage rate per LTO of 3.46 gal/LTO was obtained.

To calculate the emission factor, the concentration of lead in fuel is multiplied by the fuel consumption per LTO. The maximum lead concentration specified by ASTM for 100LL is 0.56 grams per liter or 2.12 grams per gallon. This amount of lead is normally added to assure that the required lean and rich mixture knock values are achieved. Multiplying this lead concentration in avgas by the weighted average fuel usage rate produces an overall average value of 7.34 grams of lead per LTO (g Pb/LTO) for piston-engines: 3.46 gal/LTO x 2.12 g Pb/gal = 7.34 g Pb/LTO.

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[53] The LTOs from the categories of 1-engine fixed wing piston, piston rotocraft, experimental total, and light sport were summed to determine the total number of single-engine piston aircraft LTOs.
[54] EPA understands that EDMS 5.0.2 has a limited list of piston-engines, but these are currently the best data available.
[55] U.S. EPA, *Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources*, EPA-450/4-81026d (Revised), 1992.

(c) Retention of Lead in Engine and Oil (1-Pb Retention):

Data collected from aircraft piston-engines operating on leaded avgas suggests that about 5% of the lead from the fuel is retained in the engine and engine oil.[56] Thus the emitted fraction is 0.95. This information is used in calculating airport-specific lead inventories and will be used to develop future national estimates of lead emitted from the consumption of leaded avgas.

Applying these parameters in the equation above yields the following equation:

$$Pb(tons) = \frac{(\text{piston-engine LTO})\ (7.34\ g\ Pb/LTO)\ (0.95)}{907{,}180\ g/ton}$$

which simplifies to:

$$Pb(tons) = (\text{piston-engine LTO})\ (7.7 \times 10^{-6})$$

Where piston-engine LTO[57] = (GA LTO x 0.725) + (AT LTO x 0.231)

(d) Estimating Lead Emissions from Piston-Engine Helicopters:

The emission factor for helicopters (g Pb/LTO) was determined in the same manner as described above for piston-engine fixed-wing aircraft. The concentration of lead in avgas (2.12 g/gal) was multiplied by the weighted average fuel usage rate for four types of Robinson helicopter engines.[58] This produced an overall average emission factor of 6.60 grams of lead per LTO (g Pb/LTO) for piston-engine powered helicopters.

There are no national databases that provide heliport-specific LTO activity data for piston-engine powered helicopters separately from turbine-engine powered helicopters. The 2008 FAA GA and Part 135 Activity (GAATA) Survey reports that approximately 36% of all GA helicopter hours flown are by piston-engine aircraft which use avgas, and about 64% are by turbine-engine powered which use jet fuel (which does

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[56] The information used to develop this estimate is from the following references: (a) Todd L. Petersen, Petersen Aviation, Inc, *Aviation Oil Lead Content Analysis*, Report # EPA 1-2008, January 2, 2008, available at William J. Hughes Technical Center Technical Reference and Research Library at http://actlibrary.tc.faa.gov/ and (b) E-mail from Theo Rindlisbacher of Switzerland Federal Office of Civil Aviation to Bryan Manning of U.S. EPA, regarding lead retained in engine, September 28, 2007.

[57] This equation for piston-engine LTOs only applies to non-heliport facilities. See the text immediately below for equations for calculating piston-engine LTOs and Pb emissions at heliports.

[58] This was done using the following 4 engine types in EDMS 5.1: Robinson R22 IO-320-D1AD; Robinson R22 IO-360-B; Robinson R22 O-320; Robinson R22 TSIO-360C. The fuel consumption rates were: Robinson R22 IO-320-D1AD – 5.546 g Pb/LTO; Robinson R22 IO-360-B – 5.973 g Pb/LTO; Robinson R22 O-320 – 6.276 g Pb/LTO; Robinson R22 TSIO-360C – 8.604 g Pb/LTO.

not contain lead).[59] The 2008 FAA GAATA Survey reports that approximately 2% of all AT helicopter hours flown are by piston-engine aircraft which use avgas, and about 98% are by turbine-engine powered rotocraft. We expect the fraction of helicopter activity conducted by piston-engines to vary by heliport with some facilities having no piston-engine powered helicopter activity and some hosting mainly or only piston-engine powered helicopters. However, in the absence of heliport-specific data, the national default estimates of 36% for GA and 2% for AT from the GAATA Survey were used. Therefore, to calculate piston-engine aircraft LTO as input for this equation, the helicopter GA LTOs were multiplied by 0.36 and helicopter AT LTOs were multiplied by 0.02.

Lead emitted at the heliport facility was calculated for the 2008 NEI using either the LTO data provided in FAA databases or the estimate LTO activity in the following equation (i.e., 141 LTOs):

$$\text{Pb(tons)} = \frac{\text{(piston-engine helicopter LTO) (6.60 g Pb/LTO) (0.95)}}{\text{907,180 g/ton}}$$

which simplifies to:

$$\text{Pb(tons)} = \text{(piston-engine helicopter LTO) } (6.9 \text{ X } 10^{-6})$$

Where piston-engine helicopter LTO = (Helicopter GA LTO x 0.36) + (Helicopter AT LTO x 0.02)

Section 7. Improving Airport-specific Lead Emissions Estimates

There are refinements to the methods described here that would improve airport-specific inventories, most of which involve acquiring airport- and aircraft-specific input data. The following information describes data inputs that could be used to generate airport lead inventories tailored to specific airports or otherwise improve the estimates using currently available data. State and local authorities might have, or be able to collect, better information for some of these key data inputs.

State and local agencies might have access to airport-specific data that would improve the national estimates of lead emissions per LTO. These improvements largely involve replacing national average or default values with airport-specific data on the activity of piston-engine aircraft. Three key data inputs are:

[59] The FAA GAATA is a database collected from surveys of pilots flying aircraft used for general aviation and air taxi activity. For more information on the GAATA, see Appendix A at http://www.faa.gov/data_statistics/aviation_data_statistics/general_aviation/

1) Airport-specific LTO activity for piston-powered aircraft, including the fraction of piston-engine activity conducted by single- versus twin-engine aircraft. Some airport facilities collect this information and states may use these data to calculate airport-specific lead inventories. The activity data should be current and updated on a regular schedule so that the data represents the inventory year as closely as possible.
2) The time spent in each mode of the LTO cycle. EPA uses the EDMS scenario property of ICAO/USEPA Default - Times in Mode, with a 16 minute taxi-in/taxi-out time according to EPA's Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources, 1992. While some local authorities have confirmed that these are the relevant times in mode at their airports for piston aircraft, the applicability of these times in mode will vary by airport. EPA has learned that one of the important factors in piston aircraft operation that is currently not included in the time in mode or emissions estimates is the time and fuel consumption during the pre-flight run-up checks conducted by piston-engine aircraft prior to takeoff.
3) Other data inputs for the airport-specific lead inventory calculation for which states or local authorities may provide airport-specific information include the concentration of lead in the avgas supplied at an airport, and the fraction of lead in fuel that is retained in the engine and oil, and aircraft-specific fuel consumption rates by the piston-engine aircraft in specific modes of operation.

The accuracy of the based aircraft data on which equation 4 is modeled can be improved. FAA recognizes the need to improve the integrity of the 5010 data report based-aircraft counts for all of the GA airports and reliever airports in the NPIAS and is currently in the process of improving the data collection and submission methods to accomplish this task.[60]

Section 8. Lead emitted in flight (i.e., outside the LTO cycle):

Lead emissions, especially those at altitude, undergo dispersion and eventually deposit to surfaces, and lead deposited to soil and water can remain available for uptake by plants, animals and humans for long periods of time. Because lead is a persistent pollutant, we are including all lead emissions – at airports and in-flight – in the NEI.[61]

For inventory purposes, lead emitted outside the LTO cycle occurs during aircraft cruise mode and portions of the climb-out and approach modes above the mixing height (typically 3,000 ft[62]). This part of an aircraft operation emits lead at various altitudes as well as close to and away from airports. Because the precise area of lead emission and deposition is not known for these flights, EPA is using a simplistic approach to allocate

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[60] National Based Aircraft Inventory Program: http://www.basedaircraft.com/public/FrequentlyAskedQuestions.aspx, accessed 2/17/2009

[61] U.S. EPA, 2006. Air Quality: Criteria for Lead: 2006; EPA/600/R-5/144aF; U.S. Government Printing Office, Washington, DC, October, 2006.

[62] According to EPA's *Proceduree s for Emission Inventory Preparation, Volume IV: Mobile Sources, 1992*.

these emissions for the purposes of the 2008 NEI. A brief explanation of the nature of GA flights is provided here for context regarding emissions of lead in-flight.

FAA categorizes GA flights as either local area or itinerant operations and this distinction plays a role in the area over which lead is emitted. Local operations are those activities performed by aircraft operating in the local traffic pattern or within sight of the airport, aircraft executing simulated instrument approaches or low passes at the airport, and/or aircraft operating to or from the airport in a designated practice area located within a 20-mile radius of the airport. Local operations are common for GA aircraft. This includes applications such as recreational, proficiency and instructional flying as well as many common general aerial support tasks. Emissions during local flying are more likely to influence air and soil concentrations of lead in the vicinity of the airport because they occur near the airport, often at altitudes below the mixing height.

Itinerant operations are all operations other than those described above as local operations. An itinerant aircraft operation usually is one in which the aircraft departs from one airport and lands at a different airport. Depending on air time and distance, an itinerant flight is much more likely to involve departing the local flying area of the originating airport and climbing to altitudes above the mixing height. It is reasonable then, to generally expect that lead emitted outside the LTO cycle during itinerant operations, in contrast with local operations, will be more widely dispersed and at greater distances from the airport.

The portion of the national avgas lead emitted in flight (i.e., outside the LTO cycle) is calculated by subtracting the sum of airport facility lead inventories from the national avgas lead inventory. Even though FAA collects and reports information regarding the fraction of GA operations that are local and itinerant, there is no practical method to assign in-flight lead emissions to small geographic areas such as airports or census tracts. And similar data is not available for AT operations, a portion of which are conducted by piston-engine aircraft. Since the average duration of a piston-engine aircraft flight is approximately an hour, an itinerant flight can traverse county lines. Therefore, given the current data available, the best approach is to assign the out-of-LTO cycle lead to the state where the flight originated.

In the 2008 NEI EPA allocated lead emissions that are calculated as being outside the LTO cycle to states based on the state-specific fraction of national GA and AT piston-engine LTO activity. The state-specific fractions were calculated by multiplying the percent of GA and AT piston-engine LTO activity in each state by 296 tons, which is the amount of lead we currently estimate is emitted outside of the LTO cycle nationwide. Table 4 presents the total GA and AT piston-engine LTOs by state, the state-specific faction of national GA and AT piston-engine LTO activity, and the out-of-LTO lead emissions assigned to each state.

Table 4: Out-of-LTO Lead Emissions by State

STATE	Total GA and AT Piston LTOs	Percent of National GA and AT Piston LTOs (by state)	Out of LTO Pb emissions (tons)
AK	660,133	2.0%	5.86
AL	671,026	2.0%	5.96
AR	638,875	1.9%	5.68
AZ	1,430,302	4.3%	12.71
CA	3,881,357	11.6%	34.48
CO	780,426	2.3%	6.93
CT	226,807	0.7%	2.01
DC	28,833	0.1%	0.26
DE	84,617	0.3%	0.75
FL	2,751,015	8.3%	24.44
GA	750,876	2.3%	6.67
HI	138,432	0.4%	1.23
IA	281,961	0.8%	2.50
ID	430,812	1.3%	3.83
IL	920,908	2.8%	8.18
IN	566,583	1.7%	5.03
KS	459,720	1.4%	4.08
KY	280,378	0.8%	2.49
LA	622,011	1.9%	5.53
MA	714,159	2.1%	6.34
MD	436,861	1.3%	3.88
ME	228,302	0.7%	2.03
MI	880,818	2.6%	7.82
MN	647,876	1.9%	5.76
MO	389,551	1.2%	3.46
MS	461,383	1.4%	4.10
MT	270,311	0.8%	2.40
NC	743,004	2.2%	6.60
ND	214,139	0.6%	1.90
NE	221,681	0.7%	1.97
NH	173,355	0.5%	1.54
NJ	466,961	1.4%	4.15
NM	309,657	0.9%	2.75
NV	298,712	0.9%	2.65
NY	999,738	3.0%	8.88
OH	1,180,583	3.5%	10.49
OK	575,402	1.7%	5.11
OR	596,730	1.8%	5.30
PA	954,839	2.9%	8.48

PR	80,728	0.2%	0.72
RI	45,348	0.1%	0.40
SC	506,650	1.5%	4.50
SD	228,198	0.7%	2.03
TN	535,913	1.6%	4.76
TX	2,422,722	7.3%	21.52
UT	299,471	0.9%	2.66
VA	502,559	1.5%	4.46
VI	25,763	0.1%	0.23
VT	88,318	0.3%	0.78
WA	1,189,142	3.6%	10.56
WI	778,320	2.3%	6.91
WV	143,393	0.4%	1.27
WY	106,190	0.3%	0.94

For additional information or if you have questions regarding the methods described in this document, please contact Meredith Pedde (pedde.meredith@epa.gov) or Marion Hoyer (hoyer.marion@epa.gov).

APPENDIX A

Table A-1: Scaling factors

Year	U.S. Product Supplied of Aviation Gasoline (Thousand Barrels)[63]	Ratio of 2008 to Year X
Before 1981[64]		0.57
1981	11,147	0.50
1982	9,307	0.60
1983	9,444	0.59
1984	8,692	0.64
1985	9,969	0.56
1986	11,673	0.48
1987	9,041	0.62
1988	9,705	0.58
1989	9,427	0.59
1990	8,910	0.63
1991	8,265	0.68
1992	8,133	0.69
1993	7,606	0.74
1994	7,555	0.74
1995	7,841	0.71
1996	7,400	0.76
1997	7,864	0.71
1998	7,032	0.80
1999	7,760	0.72
2000	7,188	0.78
2001	6,921	0.81
2002	6,682	0.84
2003	5,987	0.94
2004	6,189	0.91
2005	7,006	0.80
2006	6,626	0.85
2007	6,258	0.90
2008	5,603	1.00

[63] Data from the Energy Information Administration's (EIA's) table, "U.S. Product Supplied of Aviation Gasoline (Thousand Barrels)." Available at: http://tonto.eia.doe.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=mgaupus1&f=A Accessed August 25, 2010.

[64] EIA does not have data for volumes of avgas product supplied for years earlier than 1981. To calculate the scaling factor to use for activity data from years before 1981, we used the ratio of 2008 avgas volume product supplied to the average avgas volume supplied from 1981 to 1989.