Calculating Piston-Engine Aircraft Airport Inventories for Lead for the 2011 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 2011 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 are largely the same as those used to construct the 2008 NEI.

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.[2] Lead emissions associated with GA and AT aircraft stem from the use of one hundred octane low lead (100LL) aviation gasoline (avgas). The lead is added to the fuel in the form of tetraethyl lead (TEL), which 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.[3] Lead is not added to jet fuel, which is used in commercial aircraft, most military aircraft, or other turbine-engine powered aircraft.

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 activity. 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 the 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.

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[1] In this document '2011 NEI' refers to the 2011 NEI data, available at: http://www.epa.gov/ttn/chief/net/2011inventory.html

[2] 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.

[3] FAA General Aviation and Part 135 Activity Surveys – CY 2010, Table 5.1, '2010 General Aviation and Air Taxi Total Fuel Consumed and Average Fuel Consumption Rate by Aircraft Type.'

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 takeoff cycle at airports as well as emissions occurring in flight.[4] 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 2011.[5] 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. Prior to the 2008 NEI, EPA 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 2011 NEI to calculate the national lead inventory in order to use a consistent data source.

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 and subtract the small amount of lead that is retained in the engine, engine oil and/or exhaust system (equation 1). The volume of avgas used in the U.S. in 2011 was 217,500,000 gallons.[6] The concentration of lead in avgas 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 100LL.[7] The maximum lead concentration specified by ASTM for 100LL is 0.56 grams per liter or 2.12 grams per gallon.[8] A fraction of lead is retained in the engine, engine oil and/or exhaust system which we currently estimate at 5%.[9]

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

[5] U.S. Department of Transportation Federal Aviation Administration Aviation Policy and Plans. FAA Aerospace Forecast Fiscal Years 2013-2033. Tables 23 and 31. Available at: http://www.faa.gov/about/office_org/headquarters_offices/apl/aviation_forecasts/aerospace_forecasts/2013-2033/

[6] U.S. Department of Transportation Federal Aviation Administration Aviation Policy and Plans. FAA Aerospace Forecast Fiscal Years 2013-2033. Tables 23 and 31. Available at: http://www.faa.gov/about/office_org/headquarters_offices/apl/aviation_forecasts/aerospace_forecasts/2013-2033/

[7] FAA General Aviation and Part 135 Activity Surveys – CY 2010, Table 5.1, '2010 General Aviation and Air Taxi Total Fuel Consumed and Average Fuel Consumption Rate by Aircraft Type.'

[8] 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.

[9] 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

For the 2011 NEI, the national estimate of lead emissions from the consumption of avgas was 483 tons (see equation 1 below).

$$\frac{(217{,}500{,}000 \text{ gal})\ (2.12 \text{ g Pb/gal})\ (0.95)}{907{,}180 \text{ g/ton}} = 483 \text{ tons Pb} \qquad (1)$$

As described above, DOE's EIA also provides estimates of the annual volume of leaded avgas produced in a given year. For 2011, the volume of avgas produced in the U.S. was 5,360 thousand barrels or 225,120,000 gallons.[10] Consumption of this volume of avgas equates to a national lead emissions estimate of 500 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.[11] 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. This section provides an overview of the FAA data sources used to develop airport-specific LTO inventories; the method used to adjust older FAA 5010 activity data; and, the method used to avoid double-counting after FAA data sources were merged.

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.[12] 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.[13] 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

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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.

[10] DOE Energy Information Administration. Fuel production volume data obtained from http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MGAUPUS1&f=A, accessed August 2013.

[11] 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.

[12] http://www.faa.gov/airports/airport_safety/airportdata_5010/

[13] http://aspm.faa.gov/main/taf.asp

Network (OPSNET)[14] which is publically available in the Air Traffic Activity System (ATADS) database.[15] 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 are estimates.[16] 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.[17]

The 5010 airport data report supplies the operations data date, which includes data for years prior to 2011 (Table 1).[18]

Table 1: Number of Facilities by Operations Data Year with Operations Counts for Airports not in the TAF Database that Submit Operations Data to the FAA 5010 Data Report

Year of Operations Data	**Number of Facilities by Operations Data Year**			**Sum of GA Operations by Operations Data Year**	
None	107	5%		350,487	4%
1971 – 1979	61	3%		198,475	2%
1980 – 1989	223	10%		519,898	5%
1990 – 1999	179	8%		499,226	5%
2000	16	1%		50,427	1%
2001	12	1%		9,342	<1%
2002	10	<1%		14,000	<1%
2003	8	<1%		24,805	<1%
2004	13	1%		14,975	<1%
2005	39	2%		86,583	1%
2006	34	1%		29,303	<1%
2007	35	2%		87,458	1%
2008	130	6%		533,392	6%
2009	381	16%		2,008,553	21%
2010	554	24%		2,329,070	24%
2011	509	22%		2,965,160	31%

[14] http://aspm.faa.gov/opsnet/sys/
[15] http://aspm.faa.gov/opsnet/sys/Airport.asp
[16] FAA's Terminal Area Forecast Summary (Fiscal Years 2011 – 2040), Appendix A (page 28) http://www.faa.gov/about/office_org/headquarters_offices/apl/aviation_forecasts/taf_reports/media/TAF_summary_report_FY20112040.pdf
[17] In the absence of updated information from States, local authorities or Tribes, we are using the LTO data provided in the FAA database.
[18] The 12-month ending date on which annual operations data in the report is based.

Nationally, piston-engine operations have decreased in recent years,[19] therefore EPA did not use GA operations data from years prior to 2011 as reported; we scaled the operations downward using a factor based on the decrease in national fuel production. EPA multiplied the older GA piston-engine data (Section 6 describes the method EPA used to calculate the number of piston-engine operations from total GA and AT activity data) by scaling factors that were calculated by dividing the 2011 national amount of avgas produced by the national amount of avgas produced in the year for which the operations data were reported.[20] A table with the scaling factors is provided in Appendix A. The annual data for the national volume of avgas produced comes from the DOE, EIA website and is available for 1981 – 2011.[21] For operations data older than 1981, EPA divided the 2011 national amount of avgas produced by the average of the national amount of avgas produced from 1981 – 1989.

As mentioned above, we have accounted for potential double-counting of piston-engine aircraft LTOs, which is described here: EPA 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 dataset 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.[22] 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 control for double counting. 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 2011 NEI was developed using the February 7, 2012 version of the 5010 airport data report. In that version of the report there were 19,782 airport facilities in the U.S. that submitted data to the FAA. Among these 19,782 facilities, 69 facilities were not relevant for the purposes of estimating lead emissions because they were either listed as closed (56) or they were balloonports (13).[23] Therefore, lead inventories were needed

[19] http://www.faa.gov/data_research/aviation_data_statistics/general_aviation/

[20] 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 four decades.

[21] http://www.eia.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 2011 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.

[22] 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 2011 NEI as such.

[23] Balloon craft do not use avgas

for 19,714 facilities.[24] In the February 7, 2012 version of the 5010 airport data report, the 2011 TAF, and 2011 ATADS data there were a total of 5,627 airport facilities for which operations data were provided (many of which are facilities in FAA's TAF database).[25] There were 14,087 facilities in the 5010 airport data report and the 2011 TAF data for which there were no operations data.[26] Section 4 of this document describes the method EPA used to estimate operations for the 8,430 airport facilities in the 2011 NEI that do not have reported activity data. Section 5 describes the method EPA used to estimate operations for the 5,557 heliport facilities in the 2011 NEI that do not have reported activity data.[27] Additionally, as part of the review process for the 2011 NEI, EPA received updated airport data from states.

Section 6 describes how we estimate GA and AT piston-engine LTOs at airports in the 2011 NEI, separate from GA and AT jet LTOs.

Section 4. Estimating LTOs at the 8,430 Airport Facilities with No LTO Data

In order to estimate LTOs at airports that do not report these data, we investigated the utility of data that could be used to provide reasonable estimates of LTO activity at airports. Such estimating methods have been used previously by FAA and those analyses were evaluated for possible use in the development of emission inventories.

FAA has used regression models to estimate operations at facilities where operations data are not available.[28,29] 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.[30] 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 stationed at an airport (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 FAA 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-

[24] There was one facility in FAA's TAF database (72S) that was not in the 5010 Data Report, so the sum of 19,714 plus 69 is one larger than the 19,782 in the downloaded FAA 5010 Data Report.
[25] Either GA Itinerant, GA Local, or Air Taxi operations data, as these operations can be performed by piston-engine aircraft.
[26] No GA Itinerant, GA Local, or Air Taxi operations data.
[27] There are 100 facilities in the NPIAS report that have both 0 GA and 0 AT operations; however, EPA did not estimate operations for these 100 facilities.
[28] 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.
[29] Mark Hoekstra, "Model for Estimating General Aviation Operations at Non-Towered Airports" prepared for FAA Office of Aviation Policy and Plans, April 2000.
[30] 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.

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.[31]

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,[32] ultralight); number of GA aircraft based at each airport by type (glider, helicopter, jet engine, military, multi-engine, single engine, ultralight); operations data (AT, commercial, commuter, GA itinerant, GA local, military)[33]; and operations date (12-month ending date on which annual operations data is based). We merged the 2010 U.S. Census data with the 5010 airport data report to provide 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 2 shows that for non-heliport facilities that did not have LTO data in the February 7, 2012 version of the 5010 airport data report, 6,314 had based aircraft data while 2,216 did not have based aircraft data.[34] Therefore, as described below, LTO estimates were derived using different methods depending on data availability.

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[31] The mean absolute difference between the model operations estimate and the state operations estimate was 16,940 operations.

[32] Stolport is an airport designed with STOL (Short Takeoff and Landing) operations in mind, normally having a short single runway.

[33] As explained in footnote 14, 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.

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

Table 2: Contingency table describing the numbers of non-heliport facilities that have or do not have LTO data and/or based aircraft data for facilities in the February 7, 2012 version of the 5010 airport data report

		HAVE LTO DATA		
		YES	**NO**	
HAVE BASED AIRCRAFT DATA	**YES**	4,807	6,314	**11,121**
	NO	728	2,216	**2,944**
		5,535	**8,530**	**14,065**

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

There are 6,289 facilities in the 2011 NEI (not including heliports) for which the 5010 airport data report supplies the number of based aircraft[35] but not activity data to which the regression equation (based aircraft vs. LTOs) could be applied.[36] Using the 4,807 airports for which both LTO and aircraft data is known, the initial relationship found between based aircraft and LTOs was:

$$LTOs = 2956 + 166*aircraft \quad (2)$$
$(R^2 = 0.52)$

The FAA models found population to be another significant regressor. We used the population of the county (from the 2010 U.S. Census) in which the airport is located as the population variable. Adding county population to the model gave the following relationship:

[35] Based aircraft for this purpose was limited to single- and multi-engine aircraft, helicopters, gliders, and ultralights since these aircraft types can use leaded avgas.
[36] There are 100 facilities in the NPIAS report that have both 0 GA and 0 AT operations; however, EPA did not estimate operations for these 100 facilities. 25 of the 100 facilities have based aircraft data, hence the difference between the 6,314 value in Table 1 and the 6,289 value stated in this sentence.

$$\text{LTOs} = 2706 + 156*\text{aircraft} + 0.0025*\text{county population} \quad (3)$$
($R^2 = 0.53$)

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[37] 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.[38] 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 4 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 4 (interaction of an airport being in Alaska and its sum of based aircraft).

$$\text{LTOs} = 2472 + 167*\text{aircraft} + 0.0022*\text{county population} - 162*\text{Alaska} - 98*(\text{AlaskaXaircraft}) \quad (4)$$
($R^2 = 0.55$)

After analyzing the data and plot for the data underlying equation 4, 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 to more than 200,000 LTOs/year).[39] These facilities were removed from the regression analysis. The resulting relationship was:

$$\text{LTOs} = 1974 + 168*\text{aircraft} + 0.0009*\text{county population} - 1181*\text{Alaska} - 125*(\text{AlaskaXaircraft}) \quad (5)$$
($R^2 = 0.63$)

When equation 5 was applied to the 6,289 airport facilities that report based aircraft data but not LTO activity, the resulting sum of LTOs was almost 8 million.[40]

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[37] 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).

[38] 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).

[39] 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

[40] The accuracy of the based aircraft data on which equation 5 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. See: National Based Aircraft Inventory Program: http://www.basedaircraft.com/public/FrequentlyAskedQuestions.aspx, accessed 2/17/2009

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 GA 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 ~82 LTOs/year. Multiplying 82 by the number of airports that do not report activity data equals 687,045 LTOs.[41] Therefore, EPA used equation 5 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 0.08 to those LTOs to obtain the LTOs that are reported in the 2011 NEI.[42] 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 687,045 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 5 and the scaling factor were used to estimate LTO activity for the 2011 NEI at the 6,289 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 2,141 facilities (not including heliports) for which the 5010 airport data report supplies neither the number of based aircraft nor activity data. EPA investigated 100 of these facilities using on-line searches and Google Earth satellite images to ascertain whether these facilities exist and if so, whether aircraft activity appeared to be occurring. Because the majority of these facilities appeared to be active, we elected to assign 1 LTO to each facility.

Section 5. Calculating LTOs at Heliports:

There were 5,649 heliport facilities in the February 7, 2012 FAA 5010 data report that were operational. Of those, only 92 (or 2%) reported LTO data, and of those, only 29 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.[43, 44]

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[41] This number is calculated by multiplying 81.5 LTOs/year by 8,430, which is the number of airports that don't report activity data (6,289 don't report activity data and 2,141 facilities don't report activity or based aircraft data).

[42] The scaling factor was calculated by dividing 684,904 LTOs by 8,608,829 LTOS; the 684,904 LTOs are equal to 687,045 LTOs minus 2,141 LTOs (2,141 LTOs represent the sum of LTOs assigned to the 2,141 facilities that don't report either activity data or based aircraft data - the derivation of LTO estimates for these facilities is described in Section 3 *(b)*). The 8,608,829 LTOs are the sum of LTOs that result from applying equation 4 to the 6,289 facilities with based aircraft data but no activity data.

[43] Executive Summary: Regional Helicopter System Plan, Metropolitan Washington Area, prepared by Edwards and Kelcey for the Metropolitan Washington Council of Governments, 2005.

The summary statistics for LTO data provided at the 92 operational heliports is presented in Table 3. These facilities report a wide range in activity from 1 LTO/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 51 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 51 LTOs, resulting in 18 LTOs assigned to the GA, piston-engine category and 33 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 3: Heliport LTO Data for those Reporting LTO Data in the February 7, 2012 Version of the 5010 Airport Data Report

18,200	Maximum GA LTOs
1	Minimum GA LTOs
793	Average GA LTOs
51	Median GA LTOs
50	Mode GA LTOs

Section 6. Methodology for Estimating Airport-Specific Lead Emissions

In 2008, EPA developed a method to calculate lead emissions at airports where piston-engine aircraft operate.[45] 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 and applied in developing airport lead inventories for the 2011 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: piston-engine LTOs, the emission factor for lead emitted during the LTO cycle, and the estimated fraction of lead retained in the engine and oil.

Typically aircraft emission inventories for gaseous and particulate matter (PM) pollutants are calculated using FAA's EDMS.[46] Currently, EDMS does not calculate lead emissions and thus, it is not a readily available tool for determining airport lead inventories related to aircraft operations. To determine piston-engine aircraft lead emissions, EPA relied upon the basic methodology employed in EDMS. This requires as

[44] Alaska Aviation Emission Inventory, prepared by Sierra Research, Inc. for Western Regional Air Partnership, 2005.
[45] 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..
[46] EDMS available from http://www.faa.gov/about/office_org/headquarters_offices/apl/research/models/edms_model/

input the activity of piston-engine aircraft at a facility, fuel consumption rates by these aircraft during the various modes of the LTO cycle, 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.

$$\text{LTO Pb (tons)} = \frac{\text{(piston-engine LTO) (avgas Pb g/LTO) (1-Pb retention)}}{\text{907,180 g/ton}} \qquad (6)$$

(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 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 2011 NEI is to identify airports that have inventories of 0.50 tons per year or more since this is one of the criteria for identifying airports where lead monitoring may need to be considered 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 0.50 tons per year, we used a more airport-specific surrogate for piston-engine aircraft conducting GA activity at this subset of airports than the remainder of the airports where we applied national default averages described below. We used this approach because GA activity is dominated by piston-engine activity and similar data are not available to allow airport-specific estimates of AT activity conducted by piston-engine aircraft. In some cases, airport master plans, airport layout plans, noise abatement studies and/or land use compatibility plans provide information regarding the fraction of AT and GA activity conducted by piston-engine aircraft and in those cases, we use these data sources.

We used the fraction of based aircraft that are reported as single- or multi-engine to calculate the number of GA LTOs that were conducted by piston-engine aircraft at that airport.[47] The data regarding the population of based aircraft at an airport is available for

[47] These categories are reported separately from jet aircraft so they allow the closest estimate of piston-engine powered aircraft. However, some turbojet and turbofan aircraft may be reported as single- or multi-

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 GA LTOs.

We evaluated this surrogate by comparing the results obtained from using the based aircraft data 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.[48]

For the majority of airports in the 2011 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[49] Activity Surveys – CY 2010 (GAATA).[50] Table 2.4 in the 2010 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 percent (34%) are turboprop and turbojet powered which use jet fuel, such as Jet A. The LTO data in Table 2.4 in the 2010 GAATA Survey does not distinguish LTOs as GA or AT, and thus does not provide the information needed to separate jet from piston-engine activity for GA and AT.

In order to estimate the fraction of GA activity conducted by piston-engine aircraft and the fraction of AT activity conducted by piston-engine aircraft, we used the number of hours flown by piston-engine versus turboprop or turbojet aircraft that are reported in Table 1.4 in the 2010 GAATA Survey. We chose this approach since the overall (i.e., for GA and AT combined) piston-engine percent of hours flown (65.8%) is very close to the percent of LTOs that are conducted by piston-engine aircraft (65.7%). The 2010 GAATA Survey reports that for GA activity, seventy-two percent (72%) of the hours are flown by piston-engine aircraft while twenty-eight percent (28%) of the hours

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engine aircraft in which case the use of these data would slightly overestimate actual piston-engine aircraft activity (as noted later in this section).

[48] 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

[49] On-demand (air taxi) and commuter operations not covered by Part 121

[50] 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 2010 GAATA, see Appendix A at http://www.faa.gov/data_research/aviation_data_statistics/general_aviation/CY2010/

are flown by turboprop and turbojet powered aircraft.[51] Twenty-two percent (22%) of all AT hours flown are by piston-engine aircraft while seventy-eight percent (78%) 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 (rotorcraft) operate. Therefore, EPA also calculated the percent of rotorcraft hours flown that are conducted by piston-engine aircraft. Thirty-six percent (36%) of all GA rotorcraft hours flown are by piston-engine rotorcraft while sixty-four percent (64%) of all GA rotorcraft hours flown are by turboprop and turbojet powered rotorcraft. Two percent (2%) of all AT rotorcraft hours flown are by piston-engine rotorcraft while ninety-eight percent (98%) of all AT rotorcraft hours flown are by turboprop and turbojet powered rotorcraft. Table 4 identifies the piston-engine and turbine fractions that were used in the absence of airport-specific information to calculate piston-engine aircraft operations at airports and heliports in the 2011 NEI.

Table 4: Piston-Engine and Turbine Activity Fractions used in the 2011 NEI

	Airports		**Heliports**	
	GA	**AT**	**GA**	**AT**
Piston-Engine	72.1%	21.8%	35.8%	2%
Turbine Powered	27.9%	78.2%	64.2%	98%

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

The vast majority of piston-engine aircraft have either one or two engines. EDMS version 5.0.2 contains information on the amount of avgas consumed per LTO for some single and twin-engine aircraft. For the single-engine aircraft, we averaged the amount of fuel consumed per LTO using the six types of single piston-engine aircraft in EDMS that best represent the in-use fleet.[52] The EDMS scenario property used to calculate fuel consumption per LTO was the 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.[53] The average fuel consumption for a single-engine piston aircraft is 16.96 pounds of fuel per LTO (lbs/LTO) or 2.83 gallons per LTO (gal/LTO) (applying the average density of 100LL avgas of 6 pounds per

[51] Numbers in the text may not add to 100% due to rounding; the percentages in Table 4 are the values we used to calculate the 2011 NEI.
[52] EPA understands that EDMS 5.0.2 has a limited list of piston-engines, but these are currently the best data available.
[53] U.S. EPA, *Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources*, EPA-450/4-81026d (Revised), 1992.

gallon). This same calculation was performed for the two twin-engine piston aircraft within EDMS, producing an average LTO fuel consumption rate for twin-engine piston aircraft of 9.12 gal/LTO. 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. To weight fuel consumption by aircraft population prevalence in the fleet, 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).[54, 55]

Using these single- and twin-engine piston aircraft fuel consumption rates and population fractions, a weighted average fuel usage rate per LTO was computed by multiplying the average fuel consumption 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 consumption 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 fuel consumption rates, the overall weighted-average fuel usage rate per LTO of 3.46 gal/LTO was obtained.

To calculate the average lead 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 of lead per liter or 2.12 grams of lead per gallon. Multiplying this lead concentration in avgas by the weighted average fuel usage rate produces an overall average emission factor of 7.34 grams of lead per LTO (g Pb/LTO) for piston-engine aircraft: 3.46 gal/LTO x 2.12 g Pb/gal = 7.34 g Pb/LTO.

(c) Retention of Lead in Engine and Oil:

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 of lead is 0.95.

Applying these parameters to equation 6 above yields the following:

$$\text{Pb (tons)} = \frac{\text{(piston-engine LTO) (7.34 g Pb/LTO) (0.95)}}{\text{907,180 g/ton}} \qquad (7)$$

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[54] The LTOs from the categories of 1-engine fixed wing piston, piston rotorcraft, experimental total, and light sport were summed to determine the total number of single-engine piston aircraft LTOs.

[55] Over time this fraction could be re-evaluated as the national aircraft fleet composition changes.

[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.

which simplifies to:

$$\text{Pb (tons)} = (\text{piston-engine LTO})\ (7.7 \times 10^{-6}) \quad (8)$$

Where piston-engine LTO[57] = (GA LTO x 0.721) + (AT LTO x 0.218)

(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 helicopters separately from turbine-engine helicopters. The 2010 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 not contain lead).[59] The 2010 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 rotorcraft. We expect the fraction of helicopter activity conducted by piston-engine rotorcraft to vary by heliport with some facilities having no piston-engine helicopter activity and some hosting mainly or only piston-engine 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 each heliport facility was calculated for the 2011 NEI with equation 9, using either the LTO data provided in FAA databases or the estimate LTO activity (i.e., 51 GA LTOs):

$$\text{Pb (tons)} = \frac{(\text{piston-engine helicopter LTO})\ (6.60 \text{ g Pb/LTO})\ (0.95)}{907{,}180 \text{ g/ton}} \quad (9)$$

[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.
[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/

which simplifies to:

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

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 agencies, in collaboration with airport sponsors, may be able to collect airport-specific data that could be used to replace national average or default values. EPA requests and receives state and local authority review and data updates with each NEI. The key data inputs that states and local authorities could provide that would improve airport-specific lead inventories are:

1) Airport-specific LTO activity for piston-engine aircraft, including the fraction of piston-engine activity conducted by single- versus twin-engine aircraft. 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-engine aircraft, the applicability of these times in mode will vary by airport. EPA has learned that one of the important factors in piston-engine aircraft operation that is currently not included in NEI inventory estimates is the time and fuel consumption during the pre-flight run-up checks conducted by piston-engine aircraft prior to takeoff.
3) The concentration of lead in the avgas supplied at the airport (including variation in this concentration among the fixed-based operators supplying fuel at the airfield and seasonal variation in concentration), 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 for the airport.

Section 8. Lead emitted in flight:

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.[60]

The mass of lead emitted in-flight is calculated as the difference between the total amount of lead emitted by piston-engine aircraft nationwide (obtained in equation 1) and the sum of all the lead emitted at airports (as described in sections 3 through 6). In 2011, the total amount of lead emitted in-flight was 238 tons. For inventory purposes, lead emitted in flight occurs during aircraft cruise mode and portions of the climb-out and approach modes above the mixing height (typically 3,000 ft[61]). 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 assigns these emissions to states.

In the 2011 NEI, EPA allocated in-flight lead emissions 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 238 tons (the amount of lead we estimate was emitted in-flight in 2011). Table 5 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 in-flight lead emissions assigned to each state.

[60] U.S. EPA, 2006. Air Quality: Criteria for Lead: 2006; EPA/600/R-5/144aF; U.S. Government Printing Office, Washington, DC, October, 2006.
[61] According to EPA's *Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources, 1992*.

Table 5: In Flight Lead Emissions by State

State	Total GA and AT Piston-Engine LTOs	Percent of National GA and AT Piston-Engine LTOs (by state)	Pb Emissions in Flight (tons)
AK	629,006	2.0%	4.70
AL	734,038	2.3%	5.49
AR	697,003	2.2%	5.21
AZ	1,174,215	3.7%	8.77
CA	3,429,597	10.8%	25.63
CO	742,024	2.3%	5.54
CT	199,414	0.6%	1.49
DC	330	0.001%	0.00
DE	79,825	0.3%	0.60
FL	2,519,221	7.9%	18.83
GA	676,310	2.1%	5.05
HI	141,849	0.4%	1.06
IA	341,285	1.1%	2.55
ID	486,059	1.5%	3.63
IL	909,758	2.9%	6.80
IN	537,510	1.7%	4.02
KS	588,003	1.8%	4.39
KY	289,393	0.9%	2.16
LA	643,217	2.0%	4.81
MA	588,864	1.8%	4.40
MD	414,238	1.3%	3.10
ME	224,202	0.7%	1.68
MI	724,730	2.3%	5.42
MN	701,245	2.2%	5.24
MO	411,676	1.3%	3.08
MS	439,636	1.4%	3.29
MT	279,156	0.9%	2.09
NC	769,909	2.4%	5.75
ND	304,287	1.0%	2.27
NE	297,604	0.9%	2.22
NH	152,060	0.5%	1.14
NJ	419,007	1.3%	3.13
NM	228,784	0.7%	1.71
NV	312,672	1.0%	2.34

NY	949,455	3.0%	7.09
OH	1,237,154	3.9%	9.24
OK	435,141	1.4%	3.25
OR	551,685	1.7%	4.12
PA	847,858	2.7%	6.34
PR	80,788	0.3%	0.60
RI	49,965	0.2%	0.37
SC	464,252	1.5%	3.47
SD	218,646	0.7%	1.63
TN	524,272	1.6%	3.92
TX	2,256,065	7.1%	16.86
UT	293,692	0.9%	2.19
VA	573,055	1.8%	4.28
VI	23,743	0.1%	0.18
VT	72,202	0.2%	0.54
WA	1,168,777	3.7%	8.73
WI	775,600	2.4%	5.80
WV	133,037	0.4%	0.99
WY	107,779	0.3%	0.81

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)[62]	Ratio of 2011 to Year X
Before 1981[63]		0.55
1981	11,147	0.48
1982	9,307	0.58
1983	9,444	0.57
1984	8,692	0.62
1985	9,969	0.54
1986	11,673	0.46
1987	9,041	0.59
1988	9,705	0.55
1989	9,427	0.57
1990	8,910	0.60
1991	8,265	0.65
1992	8,133	0.66
1993	7,606	0.70
1994	7,555	0.71
1995	7,841	0.68
1996	7,400	0.72
1997	7,864	0.68
1998	7,032	0.76
1999	7,760	0.69
2000	7,188	0.75
2001	6,921	0.77
2002	6,682	0.80
2003	5,987	0.90
2004	6,189	0.87
2005	7,006	0.77
2006	6,626	0.81
2007	6,258	0.86
2008	5,603	0.96
2009	5,261	1.02
2010	5,358	1.00
2011	5,362	1.00

[62] Data from the Energy Information Administration's (EIA's) table, "U.S. Product Supplied of Aviation Gasoline (Thousand Barrels)." Available at: http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=mgaupus1&f=A Accessed March 28, 2012.

[63] 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 2011 avgas volume product supplied to the average avgas volume supplied from 1981 to 1989.