2024 SmartWay Air Carrier Partner Tool:

Technical Documentation

**U.S. Version 1.0
(Data Year 2023)**

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Transportation and Climate Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

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1.0   Overview

This document provides detailed background information on the data sources, calculation methods, and assumptions used within the 2024 SmartWay Air Tool, version 1.0. The SmartWay Air Tool utilizes up-to-date emission factors, in combination with detailed aircraft activity data, to estimate emissions and associated performance metrics. The primary purpose of the Tool is to help fleets calculate actual pollutant emissions for specific aircraft types and track their emissions performance over time. Shippers can, in turn, use the data that air carriers report using these Tools to develop more advanced emissions inventories associated with their freight activity and to track their emissions performance over time.

The Tool allows the user to evaluate fleet performance in terms of different mass-based performance metrics for CO_2, NO_x, and PM (PM_{10} and $PM_{2.5}$):

- Grams per mile

- Grams per average payload ton-mile

Fleet performance can be assessed on a fleet or fuel-type basis, or on an aggregated basis across all fleets and fuels. By collecting detailed information on fleet operations air carriers can compare their performance to other, similar carriers, which can help them to better manage their emissions performance.

2.0 Data Inputs and Sources

Similar to the other SmartWay tools, air carrier partners provide information concerning fuel usage and aircraft activity including landing and take-off cycles (LTOs) and hours of operation in order to estimate CO_2, NO_x and $PM_{2.5}$ emissions, and to account for performance improvements made to their fleets over time.

The approach used to estimate CO_2 emissions associated with aircraft operations focuses on total fuel usage. NO_x and $PM_{2.5}$ emissions are estimated using detailed information about fleet composition and operations. Most airlines provide aircraft-specific activity data to the Federal Aeronautics Administration (FAA). To reduce the burden to Partners, the data elements required for this Tool are similar to the data already being reported to the FAA.

2.1 AVAILABLE EMISSION FACTORS

Currently there are two types of aircraft engines used for non-military operations: aircraft equipped with turbine engines that use jet fuel, and smaller aircraft equipped with piston-driven engines that use aviation gasoline. The emission factors used for the fuel-based emission estimates are presented in Table 1.

Table 1. Fuel-based Factors (g/kg of fuel)

Fuel	g CO_2 per kg fuel
Jet Fuel	3,155
Aviation Gas	3,146

Note: Alternative fuels such as Sustainable Aviation Fuels (SAF) are currently being considered for commercial aviation applications. Only recently have these fuels received certification for aviation use at concentrations up to 50 percent. These fuels are being tested in pilot projects and have yet to be fully commercialized, which is expected to take several years as infrastructure issues related to the distribution and storage of these fuels are addressed. As results concerning the performance and associated emissions of these alternative fuels are released, these data will be evaluated for possible inclusion in future versions of the SmartWay Air Tool.

The preferred approach for estimating NO_x and $PM_{2.5}$ is based on hours of operation and LTO activity data.[1] Therefore, fuel-based emission factors are not used for these pollutants. NO_x and $PM_{2.5}$ emissions are based on aircraft-specific data obtained from the FAA's Aviation Environmental Design Tool (AEDT). The fuel usage and emission factor data in AEDT are obtained from the International Civil Aviation Organization (ICAO) Aircraft Engine Databank and adjusted to account for the airframe to which the engine is applied. The NO_x

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[1] PM_{10} is assumed to be 102.5% of $PM_{2.5}$ for jet fuel, and 145.0% of $PM_{2.5}$ for aviation gasoline, as per the EPA 2017 National Emissions Inventory. See https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data. Accessed 1-7-2024.

and PM$_{2.5}$ emission factors have been updated using the AEDT model, version 2d. All current aircraft and engines included in version 2d have been added to the Air Tool.

The ICAO testing cycle focused on airport-related emissions. As such, only data on approach, landing, taxi-in, idle, taxi-out, takeoff, and climbout modes were collected. Emission factors for cruising are not provided in the ICAO test data, nor are they calculated in AEDT. For the SmartWay Air Tool, cruising emissions are calculated based on the assumption that the aircraft engines operate at a percent of take-off engine loads (i.e., maximum thrust), as specified by the user (see Engine Load % on the Aircraft Inventory worksheet of the Tool).

Black carbon (BC) emission estimates for jet fuel are assumed to equal 13% of PM$_{2.5}$ emissions.[2] BC emissions associated with aviation gasoline are assumed to equal those of unleaded on-road gasoline, calculated by multiplying aviation gasoline gallons by 0.050 grams/gallon.[3, 4]

2.2   AIRCRAFT ACTIVITY DATA

Two types of activity data are required for the SmartWay Air Tool: data used to estimate emissions (e.g., fuel usage, hours of operation, and LTOs) and data needed to develop performance metrics (e.g., miles traveled, ton-miles, cargo payload, utilization rates). Much (though not all) of the data needed for this Tool are publicly reported, as summarized in Table 2. Some non-reported data, such as ton-miles, will also need to be provided.

Table 2. Activity Data Sources

Activity Measure	Reporting Form	TranStats Database
Fuel Consumption	P-12A e	Schedule P-12A
	F-2 d	Available on request
LTOs	T-100 and T-100(f) a	T-100 Segment (All Carriers)
Distance Between Airports	T-100 and T-100(f) a	T-100 Segment (All Carriers)
Passengers Transported	T-100 and T-100(f) a	T-100 Segment (All Carriers)
Mail Transported	T-100 and T-100(f) a	T-100 Segment (All Carriers)
Freight Transported	T-100 and T-100(f) a	T-100 Segment (All Carriers)
Operating Revenue	P-1.2 b	Schedule P-12
	P-1.1 c	Schedule P-11
	F-1 d	Available on request

[a] Forms are submitted monthly by foreign, large certificated, commuter and small certificated carriers (14 CFR Parts 217, 241, 298). Foreign T-100(f) data are held confidential for six months. Small carrier data are held confidential for two and a half months.

[b] Forms are submitted quarterly by large certificated carriers with annual operating revenues of $20 million or more. Foreign carriers are not required to report financials. Large carrier financial data (P-1.2 and P-1.1) are held confidential

[2] Eastern Research Group, North American Black Carbon Emissions Estimation Guidelines. Prepared for the Commission on Environmental Cooperation, May 2015, http://www.cec.org/files/documents/publications/11629-north-american-black-carbon-emissions-recommended-methods-estimating-black-en.pdf, accessed 1-7-2024.

[3] Ibid.

[4] Unlike today's on-road gasoline, aviation gasoline contains tetra-ethyl lead as an additive. The addition of lead increases gasoline octane ratings which in turn may decrease BC emissions. Accordingly, the BC emissions assumed for aviation gasoline may be overestimated to some extent.

for two and a half months.

^c Forms submitted semiannually by large certificated carriers with annual operating revenues of less than $20 million.

^d Forms submitted quarterly by commuter and small certificated carriers. Small carrier financials and fuel consumption data (F-1 and F-2) are held confidential for 3 years. Small certificated and commuter carriers are defined by the size of planes in their fleet and the number of trips per week.

^e Forms submitted monthly by large certificated carriers with annual operating revenues of $20 million or more. Foreign carriers are not required to report fuel usage.

For NO_x and $PM_{2.5}$, emissions at and near airports are estimated for individual aircraft by applying annual, aircraft-specific LTOs to the LTO emission factors obtained from the AEDT model (see Section 2.2.1). Because aircraft trip lengths can vary significantly, total hours of operation are required to estimate the time spent in cruising mode. The total time associated with annual LTO activities are subtracted from the reported total annual hours to avoid double counting.

2.3   AIRCRAFT CHARACTERIZATION DATA

As noted above, CO_2 emissions are simply based on the amount of fuel used by the partner annually. For NO_x and $PM_{2.5}$, the two key data elements required to estimate emissions are the aircraft make and model and the associated engine make and model. As any given aircraft model can be equipped with a wide range of engines that have different fuel consumption and emission rates, it is important that partners provide as much detailed information as possible about the engines used in their fleet. In the newest version on AEDT(2d) there are an approximate total of 2,912 aircraft and engine combinations. Many of these aircraft are not used to carry freight though (e.g., military aircraft), and have been excluded from the Air Tool. The list of the possible aircraft and engine combinations are available in the AirTool-Aircraft-Engine-Data.xlsx file, available from EPA upon request.

If partners do not know the engine for their aircraft, the Tool will identify default engines for each aircraft. For an engine to be designated as a default for a particular aircraft make and model, a valid aircraft engine combination should first be identified in the AEDT dataset. In some cases, there is only one engine listed per aircraft make/model in AEDT. For those aircraft, the one available engine is simply designated as the default engine. For other aircraft, Ascends activity data are used to determine which engines are the most common for each aircraft. If an engine listed in Ascends is not in AEDT, the next most common engine is used instead. If there is no match with the Ascends data, AEDT also has defaults listed as well as the prior generation EDMS software from FAA. Additional internet search results provided the basis for determining the default engine for some aircraft.

Default engines are designated by a "1" in the Default column in the AirTool-Aircraft-Engine-Data.xlsx file.

In addition, to accurately represent a partner's performance metrics the Air Tool estimates aircraft capacity in units of mass for 2,619 individual aircraft-engine combinations. In October 2014, using Jane's Transportation Reference Guide, Aviation Week's Aerospace & Defense Sourcebook, and other online resources, capacities for the individual aircraft were reviewed and over 125 corrections were made. Current capacities were quality checked by comparing the ratio of capacity and aircraft length, for similar sized aircraft. Capacity corrections were made calculated ratios were outside an acceptable range.

When weight capacity was clearly defined, values were chosen that reflected total passenger and luggage weight (military aircraft totals included munitions). Note that there are often inconsistencies in how capacities are defined, however, leading to uncertainty in these assignments. For this reason, partners are encouraged to input their own estimates for weight capacity if available.

3.0　Emission Estimation

Within the SmartWay Air Tool a fuel-based approach is used for the calculation of CO_2 while an operations-based approach is used for calculating NO_x and $PM_{2.5}$.

3.1　EMISSION CALCULATIONS BASED ON FUEL CONSUMPTION DATA

CO_2 emissions are estimated using the following equation:

$$EM = FU_a \times FC \times EF_a$$

Where:

EM	=	Emission estimate for CO_2 (grams per year)
FU_a	=	Reported fuel use (gallons/year or tons/year) for fuel type a
FC	=	Fuel conversion factor for gallons to kilograms (Jet Fuel = 3.07 kilogram/gallon; aviation gasoline 2.73 kilogram/gallon); tons of fuel to kilograms (1 ton = 907.18 kilograms)
EF_a	=	Emission factor for fuel type a (grams/kilogram of fuel) - Table 1
a	=	Fuel type (e.g., jet fuel or aviation gasoline)

3.2　EMISSION CALCULATIONS BASED ON AIRCRAFT-SPECIFIC DATA

The operations-based approach allows for NO_x and $PM_{2.5}$ emissions to account for individual aircraft in the partner's fleet. The emissions calculation is developed using two types of aircraft operations: 1) airport-related activities (i.e., approach, landing, taxi-in, idle, taxi-out, take-off, and climbout), which are quantified in terms of LTO cycles, and 2) cruising operations between airports, measured in hours.

Airport-related Activities

LTO data can be applied to aircraft-specific fuel-consumption and emission factors, which were developed from data extracted from the FAA's AEDT database. Within the Air Tool, aircraft engine emissions data are applied to time-in-mode data for each segment of the LTO cycle, providing aircraft-specific LTO-based emission factors.

AEDT uses fuel-based indexes to estimate emissions, which means the time-in mode values are linked to fuel usage rates, which in turn vary based on aircraft model/engine combinations. These fuel usage rates are built into the AEDT model, which then calculates the emissions based on fuel usage. A detailed description of the methodology for modeling mode-specific emission factors can be found in Appendix A.

User-provided aircraft-specific LTO activity data (under Total Annual LTOs on the Aircraft Operations screen) is applied to the LTO emission factors using the following equation:

$$EA_{xp} = LTO_x \times EF_{LXp}$$

Where:

EA_{XP}	=	Airport-related aircraft emissions for specific aircraft model and engine combination (x) and pollutant (p) (grams per year)
LTO_x	=	Annual LTO activity for specific aircraft (x) (LTOs/year)
EF_{LXP}	=	LTO emission factor for specific aircraft (x) and pollutant (p) (grams/LTO)
X	=	Specific aircraft make/model/engine combination
P	=	Pollutant (NO_x or $PM_{2.5}$)

Additional information on the emission factors used for the LTO emission calculations can be found in the AirTool-Aircraft-Engine-Data.xlsx file.

Cruising Operations

Reported aircraft hours of operation include time spent in airport-related activities as well as cruising. For this reason, it is necessary to adjust the total hours value to estimate the time spent in the cruising mode. As noted, the time an aircraft spends in an LTO cycle varies by aircraft make and model, and time-in-mode values are included in the AEDT model for all modes except idling. The EPA default value used in the latest National Emission Inventory (NEI) for the idling time-in-mode is used in the Air Tool.

The time spent in the cruising mode is estimated using the following equation:

$$TO_x = TH_x - (LTO_x \times LM_x / 60)$$

Where:

TO_x	=	Total cruising hours of operation for specific aircraft x (hours/year)
TH_x	=	Total hours of operation for specific aircraft (x)
LTO_x	=	Annual LTOs for specific aircraft (x)
LM_x	=	Total time spent per LTO cycle, minutes (from AEDT, EPA)
60	=	Conversion - minutes per hour
x	=	Aircraft make and model

To estimate cruising emissions, the cruising hours of operation are applied to the cruising emission factors. These emission factors assume that aircraft in cruising mode operate at the fraction of power specified in the Engine Load % field. Cruising emissions are estimated using the following equation:

$$EC_{xp} = TO_x \times (EF_{cXp} X\ 3,600) \times LF_x/70$$

Where:

EC_{XP}	=	Cruising aircraft emissions for specific aircraft model (x) and pollutant (p) (grams per year)

TO_x	=	Total cruising hours of operation for specific aircraft x (hours/year)
EF_{cXP}	=	Cruising emission factor for specific aircraft (x) and pollutant (p) (grams / second)
3,600	=	Conversion seconds per hour
LF_x	=	Load factor specified for each aircraft make/model (x), in percent
70	=	Default engine load factor percent for cruising operations from AEDT
x	=	Specific aircraft make and model
p	=	Pollutant

Additional information on the emission factors used for the cruising mode can be found in the AirTool-Aircraft-Engine-Data.xlsx file.

Once LTO and cruising emissions are calculated they are summed to determine total emissions for each aircraft.

3.3   AIRCRAFT UPLOAD FUNCTION

The Air Tool provides an upload function which allows the user to import hundreds or thousands of records for individual aircraft, including the engine characteristic and activity data needed to estimate emissions and performance metrics. The Air Tool aggregates the import file to the aircraft/engine level. To perform this aggregation, the Tool weights the reported engine loads by total fuel consumption for the given aircraft/engine category. Similarly, individual weight capacity values (in pounds) are weighted by the relative fraction of ton-miles for the category. Note that this approach only impacts the reported performance metrics, not the calculated mass emissions.

The SmartWay Air Tool is provided with an Excel file named "starter file.xls" which should be populated with aircraft-specific data for upload.[5] Users can provide one record for each aircraft make/model/engine make/model combination. Each record should include data for the following columns:

- # aircraft
- Fuel Type
- Fuel Units
- fuel usage
- total miles
- total ton-miles
- LTOs
- operating hours
- weight capacity

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[5] Users may export a starter file template from the Tool's Import Aircraft screen.

The first rows of the starter file contain example inputs for user reference. These rows should be over-written with actual data before importing into the Air Tool. Please be sure to save the updated file using the same name and Excel file format as the original starter file.

4.0 Performance Metrics

SmartWay Air Tool is designed to apply calculated emissions to different operational metrics. These metrics can be used as reference points to evaluate a partner's environmental performance relative to others. The equations used to estimate the different performance metrics are shown below.

4.1 GRAMS PER MILE

$$PM_p = \sum EM_{PO} / M$$

Where:

PM_p	=	Grams of pollutant per mile (grams/mile)
EM_{PO}	=	Total annual emissions summed by pollutant (P) for both operation types (O) (grams per year)
M	=	Total annual statute miles flown
P	=	Pollutant
O	=	Operation types (airport and cruising)

4.2 GRAMS PER TON-MILE

$$PTM_p = \sum E_{PTO} / TM$$

Where:

PTM_p	=	Grams of pollutant per ton-mile (grams/ton-mile)
E_{PO}	=	Annual emissions summed over operation type (O) by pollutant (P) (grams/year)
TM	=	Total annual ton-miles
P	=	Pollutant
O	=	Operations (airport and cruising)

4.3 PUBLIC DISCLOSURE REPORTS

The Air Tool provides a report summarizing Scope 1 emissions for public disclosure purposes. Mass emissions are presented in metric tons for CO_2, NO_x, and $PM_{2.5}$[6] for all fleets.

CO2 equivalent (CO_2e) emissions are also provided in the tool's Public Disclosure report and are calculated by multiplying CO_2 values by a scaling factor of 1.0083. The scaling factor was based on data from Table 2-13 in the most recent EPA Emissions and Sinks Report. The factor was derived by dividing the medium and

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[6] Emissions from CH_4, N_2O, HFC's, PFC's, SF_6 and NF_3 have been deemed immaterial, comprising less than 5% of overall GHG emissions and are therefore EXCLUDED for reporting purposes.

commercial aircraft emissions for each greenhouse gas excluding CO_2 (CH_4, N_2O, and HFCs) by the total emissions including CO_2, and then summing the ratios to obtain the total scaling factor.

Data Validation

Validation checks are performed for air carrier average payload entries. First, payloads that are more than twice the value reported for a given aircraft make/model/series elicit a warning from the tool, although these values do not have to be changed. In addition, the maximum average payload is set to 58 tons for all carriers, corresponding to the maximum payload capacity for the largest aircraft make/model specified by SmartWay partners. Payloads above this amount trigger an out of range error that must be addressed by the partner in order to proceed. Payloads between 29 and 58 tons will receive a warning which do not have to be addressed if the partner so chooses.

Range checks are also performed to ensure the relationship between miles per hour (mph), hours per LTO, and miles per LTO are reasonable for each make/model/series combination. Values outside the following ranges result in a warning message requesting the user check and confirm their data entries.

- 200 <= mph <= 700

- 0.5 <= hours/LTO <= 12.5

- 100 <= miles/LTO <= 8,750

The upper end of the mph range is based on the maximum speed of the Boeing 777-200 series (682), a high-speed cargo plane.[7] The low-end mph value is placed slightly above typical stall speeds for large jets (150).

The upper end of the hour per LTO range is based on the longest scheduled commercial cargo flight identified (UPS Louisville to Dubai, 12.5 hours).[8] The low-end hour per LTO value was assumed at one half hour for short haul cargo flights.

High and low miles per LTO values were calculated by multiplying the high/low miles per LTO values by the corresponding mph values.

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[7] See https://www.quora.com/What-is-the-fastest-cargo-plane-on-earth. Accessed 1-7-2024.

[8] Airways, UPS to Fly Ultra Long Haul: Non-stop between Louisville and Dubai. February 5, 2018. https://aircargonext.com/news/ups-launches-longest-ever-scheduled-flight-from-louisville-to-dubai-using-747-8f-video/ . Accessed 1-7-2024.

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Appendix A: Modeling Methodology for NO$_x$ and PM Emissions

CO_2 emissions are calculated from fuel burn in the SmartWay Air Tool, however NO$_x$ and PM$_{2.5}$ emissions are sensitive to engine operating mode, and so must be estimated by modeling aircraft operations. FAA's Aviation Environmental Design Tool (AEDT, version 2d) provides aircraft- and airport-specific fuel consumption and emissions estimates by operating mode. The operations of interest for this tool are LTO and cruise.

In order to represent the activity of typical freight aircraft, EPA modeled take-offs and landings for all aircraft listed in the tool at the ten busiest freight airports in the US. The airports are listed in Table A-1.[9]

Table A-1. Busiest Freight Airports - 2015

Rank	City, State	Airport Code	Annual Metric Tons of Cargo
1	Memphis TN	MEM	4,480,465
2	Anchorage AK	ANC	3,555,160
3	Louisville KY	SDF	3,052,269
4	Los Angeles CA	LAX	2,691,830
5	Chicago IL	ORD	2,536,576
6	Miami FL	MIA	2,520,859
7	Cincinnati OH	CVG	1,536,998
8	New York NY	JFK	1,461,020
9	Indianapolis IN	IND	1,331,313
10	Dallas/Ft. Worth TX	DFW	910,623

For each aircraft make/model/engine combination, emissions per LTO and time-in-mode for LTO vary from one airport to another and vary by runway at some airports. For each aircraft in the Air Tool, emissions and time-in-mode per LTO were calculated for each of the airports in Table A-1. These values were then averaged across the airports, with the average weighted by Annual Metric Tons of Cargo to obtain a single set of figures for each aircraft that are reasonably representative of the nationwide annual operations for each. The AEDT model and supporting documentation can be found at: https://aedt.faa.gov/2d_information.aspx.

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[9] Airports Council International, Airport Traffic Reports, https://airportscouncil.org/press_release/airports-council-releases-2021-north-america-airport-traffic-rankings/. Accessed 1-7-2024.

For more information:

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