GREENHOUSE GAS
EMISSIONS INVENTORY (2006)

Aspen Pitkin County Airport

The Barnard Dunkelberg & Company Team

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Pitkin County

Aspen-Pitkin County Airport

Greenhouse Gas Emissions Inventory - 2006

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EXECUTIVE SUMMARY

Pitkin County has voluntarily prepared a greenhouse gas emissions inventory associated with its Airport Section, which operates Aspen-Pitkin County Airport. To date, an industry accepted methodology to prepare airport-related greenhouse gas inventories has not been prepared. However, protocols for other industries were reviewed and following those approaches, this inventory identifies emissions by the party that has ownership and control over the various sources of emissions. In the Airport Section case, this is based on three categories:

1) Aspen Pitkin County Airport Section;
2) Airlines/tenants/aircraft operators; and
3) General public.

This analysis is purposefully structured to parallel approaches being prepared for other cities and counties in the State and country, as well as various climate registries. It is intended to guide emission reduction plans and future inventories associated with the County and Airport Section. It relies on methods published by the Intergovernmental Panel on Climate Change (IPCC), the US Environmental Protection Agency, the World Resource Institute (WRI), and the International Council for Local Environmental Initiatives (ICLEI). Where data is not available at this time to quantify emissions of various pollutants or sources, this report notes the status and how the availability (or lack thereof) could affect the results. For instance, because emissions for non-carbon dioxide greenhouse gases (such as methane and nitrous oxides) are not available for all sources, and because carbon dioxide (CO_2) is the dominant greenhouse gas, this report focused exclusively on CO_2 emissions.

In 2006, the City of Aspen produced its draft Canary Initiative that included an initial evaluation of aircraft emissions. The Canary Initiative evaluation considered CO_2 and other greenhouse gas emissions. As it used a different methodology and other greenhouse gases, its inventory can not be compared directly to this inventory.

This inventory was prepared reflecting two emerging themes for identifying the boundaries associated with greenhouse gas inventories: organization boundaries and operational boundaries. In the case of the Airport Section, the organization boundaries were limited for this review to the County's Airport Section activities and associated emissions. Operational boundaries reflect *direct, indirect, and optional emissions.* For Pitkin County, direct and indirect emissions are from sources that are owned and controlled by the Airport Section (terminal buildings, mobile sources, and the power required to operate these resources). Other indirect and optional emissions are a consequence of the activities of the County, but occur by sources owned and controlled by another party. At an airport, these indirect and optional emissions are associated with the airlines, tenants, and general public that use that airport.

Based on these boundaries, approximately 56,421 metric tons of CO_2 (direct, indirect, and optional emissions) were emitted in 2006 as a result of air travel associated with Aspen Pitkin County Airport. The distribution of emissions by ownership and control was:

Ownership/Control	Percent of Total	Key Sources
County Airport Section	0.6%	Airport support vehicles, on-airport roadway travel, and facility power
Airlines/Tenants	97.4%	Aircraft and GSE
Public	2.0%	Rental car travel, public vehicles

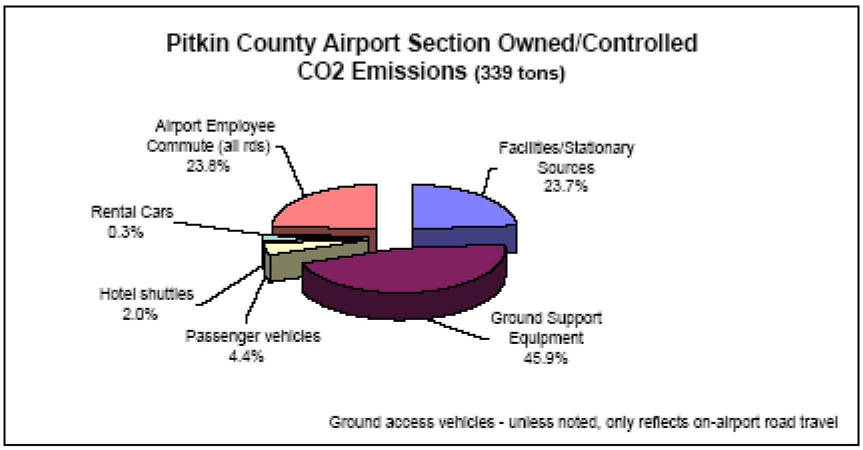
Pitkin County's Airport Section owned/controlled emissions represent about 339 metric tons of CO_2 in 2006. The largest portion of greenhouse gas emissions that the County owns and controls at the Airport is associated with powering airport support vehicles (snow removal, maintenance vehicles, etc.), vehicles traveling on-airport roadways, followed by power necessary for lighting and heating airport facilities.

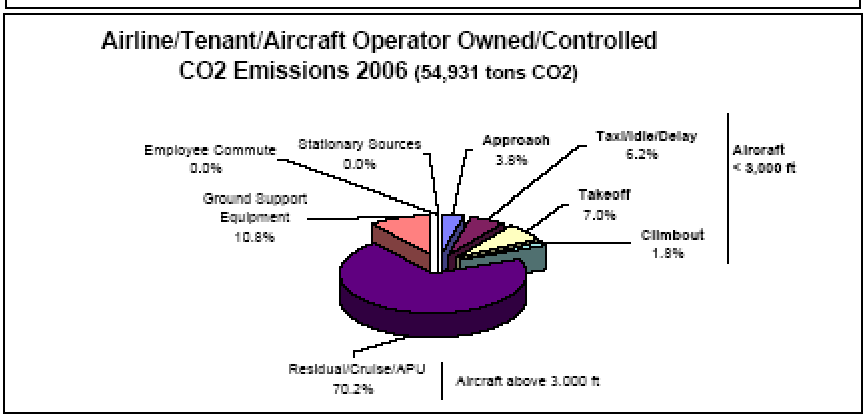
Airline/tenant/aircraft operator-owned and controlled emissions represent nearly 54,931 metric tons of CO_2 in 2006. Of this category of ownership and control, aircraft represent the single largest source of CO_2 emissions. Nearly 90% of the tenant/airline/aircraft operator emissions are from aircraft, and aircraft operating above 3,000 feet (cruise) represents the primary aircraft emissions mode.

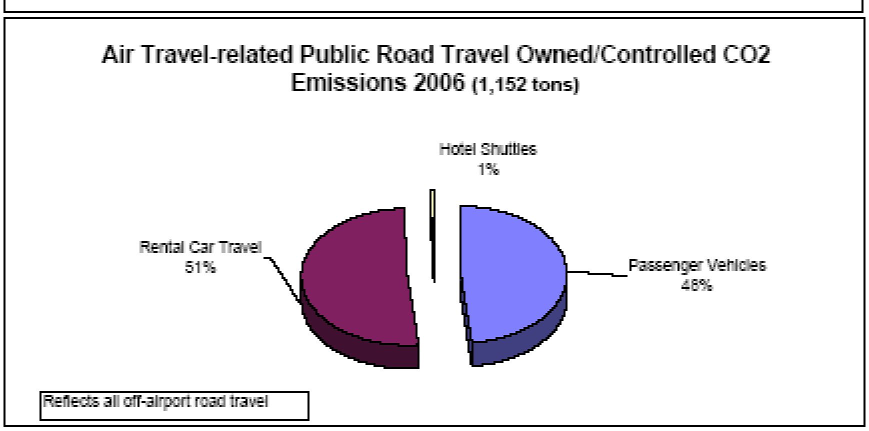
The final category of sources that were identified represents ground vehicle movements associated with air travel at Aspen-Pitkin County Airport. This category includes all ground travel on off-airport roadways and represents 1,152 tons of CO_2 in 2006. The largest sources of public owned emissions are associated with private vehicles accessing the terminal area and rental car travel.

Next Steps: This report identified a number of steps that the County can take to improve its future greenhouse gas emission inventory. These steps primarily focus on collecting data concerning airport activities in a way that enable the emissions to be identified by ownership and control. This inventory can also assist the County with identifying sources of emissions, which can then aid in focusing emission reduction actions.

FIGURE ES-1
SOURCES OF EMISSIONS







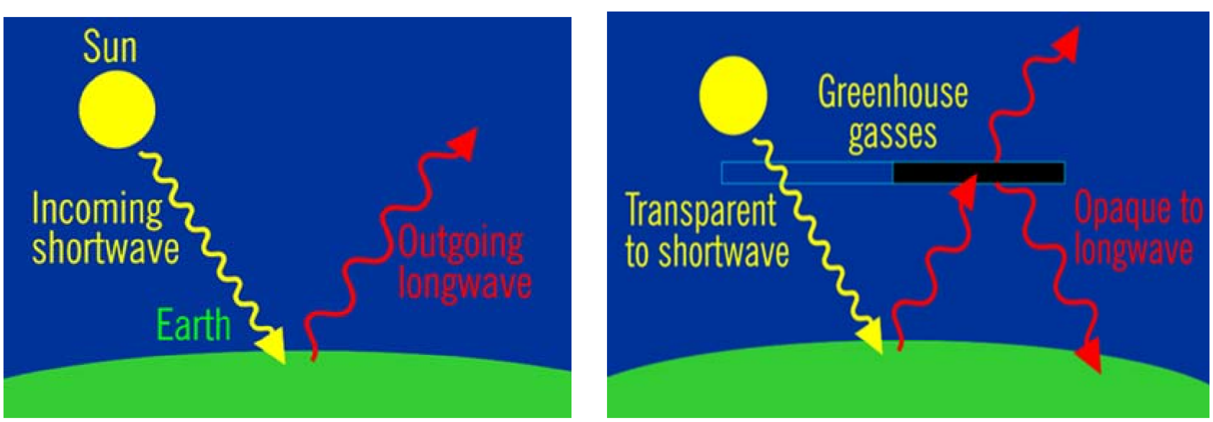
I. BACKGROUND

I.1 WHAT ARE GREENHOUSE GASES (GHG)?

Greenhouse gases are those that trap heat in the earth's atmosphere. Both naturally occurring and anthropogenic (man-made) greenhouse gases include water vapor (H_2O), carbon dioxide (CO_2),[1] methane (CH_4), nitrous oxide (N_2O), and ozone (O_3).[2] Because different greenhouse gases absorb and re-radiate different wavelengths of infrared light, and because they remain in the atmosphere at different lengths levels and lengths of time, each type of greenhouse gas traps a different amount of heat. Thus in an inventory, emissions of greenhouse gases often focus on CO_2, and if they include other greenhouse gases, are reported as "carbon dioxide equivalent" or $CO_{2\text{-eq}}$.

There are also gases that do not have a direct global warming effect but indirectly affect land and/or solar radiation absorption by influencing the formation or destruction of other greenhouse gases. These gases include carbon monoxide (CO), oxides of nitrogen (NOx), and non-methane volatile organic compounds (NMVOCs). Aerosols, which are extremely small particles or liquid droplets, such as those produced by sulfur dioxide (SO_2) or elemental carbon emissions, can also affect the ability of the atmosphere to absorb or shed heat.

FIGURE I-1
ATMOSPHERE WITHOUT GREENHOUSE GASES AND WITH GREENHOUSE GASES



Although the direct greenhouse gases CO_2, CH_4, and N_2O occur naturally in the atmosphere, human activities have changed their atmospheric concentrations. Since the pre-industrial era, concentrations of these greenhouse gases have increased substantially (according to IPCC (Intergovernmental Panel on Climate Change – see **Section I.2** of this report). CO_2 has

[1] All greenhouse gas inventories measure carbon dioxide emissions, but beyond carbon dioxide different inventories include different greenhouse gasses (GHGs).

[2] Several classes of halogenated substances that contain fluorine, chlorine, or bromine are also greenhouse gases, but they are, for the most part, solely a product of industrial activities. For example, chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are halocarbons that contain chlorine, while halocarbons that contain bromine are referred to as bromofluorocarbons (i.e., halons) or sulfur (sulfur hexafluoride: SF_6).

increased 31%, methane increased 150%, and nitrous oxides by 16%. Beginning in the 1950s, the use of CFCs and other stratospheric ozone depleting substances (ODSs) increased by nearly 10% per year until the mid-1980s, when international concern about ozone depletion led to phased reductions in ODSs.[3] In recent years, use of ODS substitutes such as hydrofluorocarbons (HFCs)[4] and perfluorocarbons (PFCs)[5] has grown as they begin to be phased-in as replacements for CFCs and hydrochlorofluorocarbons (HCFCs).

Gases in the atmosphere can contribute to the greenhouse effect both directly and indirectly. Direct effects occur when the gas itself absorbs radiation. Indirect radiative forcing occurs: 1) when chemical transformations produce other greenhouse gases; 2) when a gas influences the atmospheric lifetimes of other gases and/or; 3) when a gas affects atmospheric processes that alter the radiative balance of the earth (e.g., affect cloud formation, etc.). The IPCC developed the Global Warming Potential (GWP) concept to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas. As noted in later sections of this report, the greenhouse gas inventory for Pitkin County's Airport Section has focused on CO_2 as 1) it is the greatest greenhouse gas emitted by airport sources; and 2) emission rates of some sources are not available for many of the other greenhouse gases.

I.2 WHO ADDRESSES GREENHOUSE GASES

The following section discusses greenhouse gases from the perspective of an airport operator, such as the Pitkin County.

At this time in the US, there are no regulations specifically governing greenhouse gases. Concentrations of a few gasses that also represent greenhouse gases, such as nitrogen oxides, ozone, and carbon monoxide, are regulated by the Clean Air Act for visibility and human health implications rather than for climate change effects. The primary players currently addressing greenhouse gases and climate change are:

- **The Kyoto Protocol to the United Nations Framework Convention on Climate Change** (UNFCCC) is an amendment to the international treaty on climate change, assigning mandatory targets for the reduction of greenhouse gas emissions to signatory nations. Countries that ratify the Kyoto Protocol commit to reduce their emissions of carbon dioxide and five other greenhouse gases, or engage in emissions trading if they maintain or increase emissions of these gases.

  Governments are separated into two general categories: developed countries, referred to as Annex 1 countries who have accepted greenhouse gas emission reduction obligations; and developing countries, referred to as Non-Annex 1 countries who have no greenhouse gas emission reduction obligations. As of February 4, 2008, a total of 175 countries and the EEC have ratified the agreement (representing over 62% of emissions from Annex I countries) (UN 1998). Developing countries, such as India and China, which have

[3] Known as the Montreal Protocol.

[4] HFCs are used in many applications, such as solvents, domestic and commercial refrigerants, firefighting agents, propellants for pharmaceutical and industrial aerosols, foam-blowing agents, and in blends for air conditioning refrigerants

[5] PFCs are emitted as by-products of industrial processes and are also used in manufacturing.

ratified the protocol are not required to reduce carbon emissions under the present agreement despite their relatively large populations.

According to Article 25 of the protocol, it enters into force "on the ninetieth day after the date on which not less than 55 Parties to the Convention, incorporating Parties included in Annex I which accounted in total for at least 55% of the total CO_2 emissions for 1990 of the Parties included in Annex I, have deposited their instruments of ratification, acceptance, approval or accession." Of the two conditions, the "55 parties" clause was reached in 2002. The ratification by Russia in late 2004 satisfied the "55%" clause and brought the treaty into force, effective February 2005.

Emissions from international aviation were specifically excluded from the targets agreed under the Kyoto Protocol. Instead, countries were encouraged to control international aviation-related emissions through the activities of the International Civil Aviation Organization (ICAO). ICAO's Committee on Aviation Environmental Protection continues to consider the potential for using market-based mechanisms. ICAO is currently developing guidance for states who wish to include aviation in an emissions trading scheme (ETS) to meet their Kyoto commitments, and for airlines who wish to participate voluntarily in a trading scheme. Emissions from domestic aviation are included within the Kyoto targets agreed by countries.

Although a signatory to the protocol, the United States has neither ratified nor withdrawn from the protocol. In late 1998, then Vice President Al Gore signed the protocol; however, both Gore and Senator Joseph Lieberman indicated that the protocol would not be acted upon in the Senate until there was participation by the developing nations. The Clinton Administration never submitted the protocol to the Senate for ratification due to estimates of large declines in the Gross Domestic Product associated with compliance. To date, the Bush Administration has not supported the Kyoto principles because of the exemption granted to China which has surpassed the US as the greatest emitter of carbon.

- **Intergovernmental Panel on Climate Change (IPCC)**: While not a group that has established greenhouse gas reduction goals, the IPCC plays a major role in guiding international and national emission quantification and reduction work. Recognizing the problem of potential global climate change, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) in 1988. It is open to all members of the United Nations and WMO. The role of the IPCC is to understand the risk of human-induced climate change, its potential impacts, and options for adaptation and mitigation. The IPCC does not carry out research or establish regulation. It bases its assessments mainly on peer reviewed and published scientific/technical literature. The IPCC has completed four assessment reports, developed methodology guidelines for national greenhouse gas inventories, special reports, and technical papers. The IPCC has three working groups and an emissions inventory task force.

- **United States Greenhouse Gas Goals**: Although the US has not signed on to the Kyoto Protocol, a national greenhouse gas reduction goal has been established. In February 2002, the Bush administration affirmed his commitment to the UNFCCC and its central goal of stabilizing atmospheric greenhouse gas concentrations and committed the United States to a comprehensive strategy to reduce the greenhouse gas emission intensity by 18 percent by 2012. According to the EPA web site[6]

[6] http://epa.gov/climatechange/policy/intensitygoal.html

Greenhouse gas intensity is the ratio of greenhouse gas emissions to economic output. The U.S. goal is to lower emissions from an estimated 183 metric tons per million dollars of Gross Domestic Product (GDP) in 2002, to 151 metric tons per million dollars of GDP in 2012. The U.S. commitment will achieve 100 million metric tons of reduced emissions in 2012 alone, with more than 500 million metric tons in cumulative savings over the entire decade. The policy focuses on reducing emissions through technology improvements and dissemination, improving the efficiency of energy use, voluntary programs with industry and shifts to cleaner fuels.

- Even though the US has not ratified Kyoto, various regional, state, and local agencies have started to take action to quantify and/or reduce GHG emissions.

  - The **US Mayors Climate Protection Agreement** was launched on February 16, 2005 (the same day as the Kyoto Protocol came into effect) to advance the goals of the Kyoto Protocol through leadership and action. Two years later, when participation reached over 500 cities, the US Conference of Mayors launched its own Climate Protection Center to administer and track the Agreement. Under the Climate Protection Agreement, participants commit to:

    - Strive to meet or beat the Kyoto Protocol targets in their own communities;
    - Urge their state governments, and the federal government, to enact policies and programs to meet or beat the greenhouse gas emission reduction target suggested for the United States in the Kyoto Protocol -- 7% reduction from 1990 levels by 2012; and
    - Urge the U.S. Congress to pass the bipartisan greenhouse gas reduction legislation, which would establish a national emission trading system.

In addition, an extensive number of states, cities and counties have launched climate change initiatives. A few of these are noted below:

  - In July of 2000, the **Conference of New England Governors and Eastern Canadian Premiers** (NEG/ECP) adopted Resolution 25-9 on global warming and its impacts on the environment. As a result, the NEG/ECP Climate Change Action Plan was developed that includes regional emission reduction goals:

    - Short-term Goal: Reduce regional emissions to 1990 emissions by 2010.
    - Mid-term Goal: Reduce regional emissions by at least 10% below 1990 emissions by 2020, and establish an iterative five-year process, commencing in 2005, to adjust the goals if necessary and set future emissions reduction goals.
    - Long-term Goal: Reduce regional emissions sufficiently to eliminate any dangerous threat to the climate; current science suggests this will require reductions of 75–85% below current levels.

  - In June 2005, the Governor of California signed Executive Order S-3-05 which established statewide greenhouse gas emission targets and directed the Secretary of the California Environmental Protection Agency to lead the effort to achieve the targets. The targets developed are:

    - By 2010, reduce greenhouse gases to 2000 emission levels
    - By 2020, reduce to 1990 emission levels
    - By 2050, reduce to 80% below 1990 levels

The **Global Warming Solutions Act** (also known as Assembly Bill 32 or AB32) was signed on September 2006 codifying in state law the Executive Order. It sets up the first enforceable state-wide program in the US to cap all greenhouse gas emissions from major industries and includes penalties for non-compliance.

- In March 2006, the County Executive for King County Washington issued Executive Orders on Global Warming Preparedness which directed the County to reduce greenhouse gas emissions and to prepare for anticipated climate change impacts. These Executive Orders mandated that County departments take climate change actions with regard to land use, transportation, environmental management and clean energy use. In October 2006, the King County Council mandated that the County submit a Global Warming Mitigation and Preparedness Plan (the "Climate Plan"), as well as an annual report in each subsequent year. Consistent with the Executive Orders, the Council required specific actions to be taken relative to: emissions inventories, greenhouse gas reduction targets, land use, environmental management, emergency preparedness, energy use and transportation.

Table 1 identifies the eight (8) current regional greenhouse gas initiatives. The EPA further indicates[7] that as of end of 2007, only California has enacted a formal emission reduction cap, but that four other states (WA, OR, NM, and AZ) are in the process of enacting a cap, and two (WI and NJ) have proposed capping greenhouse gases. In addition, 14 states have adopted statewide greenhouse gas targets, with two additional states proposing targets.

As part of the regional, state, and local climate action initiatives, voluntary registries have evolved. Many cities, counties and corporate entities have already voluntarily joined the registries. Each registry has developed its protocol for generating emission inventories as well as the verification/certification process. According to The Climate Registry (TCR), the benefits of participation in a registry are:

- Demonstrate environmental leadership
- Document early actions to voluntarily emissions
- Identify and manage greenhouse gas risks and opportunities
- Gain access to user-friendly web-based software and technical assistance as you develop your inventory
- Participate in policy discussions relevant to your industry and evolving greenhouse gas policy
- Gain competitive advantage by increasing operational efficiency

TCR was formed in 2007 and reflects the combination of four main regional registries: California Climate Action Registry, Eastern Climate Registry, the Lake Michigan Air Directors Consortium, and the Western Regional Air Partnership. TCR represents 39 states (including Colorado), 4 Canadian provinces, and 2 two Mexican states.

[7] http://www.epa.gov/climatechange/wycd/stateandlocalgov/state_target_cap.html

TABLE 1. Summary of Regional Greenhouse Gas Initiatives

Effort	Description of Activities	Participating States
New England Governors: Climate Action Plan	A goal of achieving 1990 greenhouse gas emission levels by 2010 and 10% below 1990 levels by 2020.	CT, ME, MA, NH, RI, and VT
Regional Greenhouse Gas Initiative (RGGI)	RGGI is an effort by Northeastern and Mid-Atlantic states to reduce CO_2 emissions through a cap and trade program. Phase I (2009-2015) will stabilize emissions at 121.3 million short tons of CO_2 (this is a little above 2000-2004 levels). Phase II (2015-2020) will reduce emissions by 10% below Phase 1 levels (roughly equivalent to 1990 levels).	CT, DE, ME, MD (2007), NH, NJ, NY, and VT. (PA and RI are observers; MA participated in the design)
The Climate Registry (TCR)	TCR is an effort to develop a greenhouse gas Registry that will measure, track, verify and publicly report emissions accurately, transparently and consistently across borders and industry sectors. TCR supports voluntary, market-based and regulatory emissions reporting programs. They started accepting data in Jan. 2008.	AZ, CA, CO, CT, DE, FL, HI, IL, KS, ME, MD, MA, MI, MN, MS, MO, NH, NJ, NM, NY, NC, OH, OR, PA, RI, SC, UT, VT, WA, WI, and WY.
Southwest Climate Change Initiative (SCCI)	Launched in 2006, the SCCI creates ways for the two states to collaborate on climate change and emission reduction strategies.	AZ and NM
"Powering the Plains" Initiative	This initiative addresses climate issues surrounding energy and agriculture while adding value to the region's economy and mitigating the risk of climate change and other environmental concerns.	IA, MN, ND, SD, and WI
West Coast Governors' Global Warming Initiative	An effort between the Governors of Washington, Oregon, and California to reduce greenhouse gas emissions from their respective states.	CA, OR, and WA
Western Governor's Association Clean and Diversified Energy Initiative	Participating states agreed to examine the feasibility of: o Developing 30,000 Megawatts of clean and diverse energy by 2015. o Increasing energy efficiency 20 percent by 2020. o Providing adequate transmission to meet the region's needs through 2030.	AK, AZ, CA, CO, HI, ID, KS, MT, NE, NV, ND, OR, SD, TX, UT, WA, and WY
Western Regional Climate Action Initiative	The Governors of 5 western states established this initiative in 2007, committing to establish an overall regional goal to reduce greenhouse gas emissions within 6 months, develop a design for a regional market-based multi-sector mechanism within 18 months to achieve the regional goal, and participate in a multi-state greenhouse gas registry.	AZ, CA, NM, OR, and WA.

Source: EPA Web downloaded 1-1-08 http://www.epa.gov/climatechange/wycd/stateandlocalgov/state_actionslist.htm

I.3 SOURCES OF GREENHOUSE GASES AT AN AIRPORT

Research has shown that there is a direct link between fuel consumption and greenhouse gas emissions. Therefore, sources that require power/fuel at an airport typically are reflected in a pollutant emissions inventory and are the principal focus of a greenhouse gas inventory. Airport sources of greenhouse gas emissions would include:

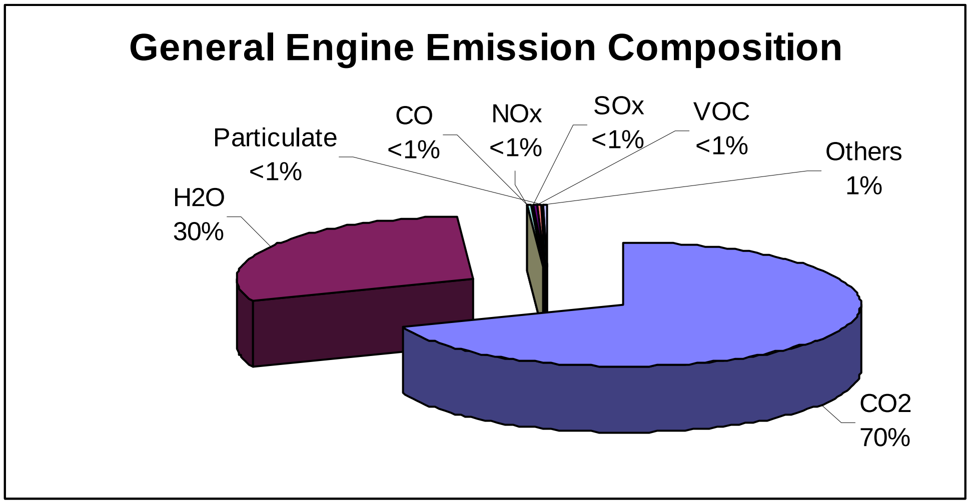
1. **Aircraft including auxiliary power units** (APU): The category of aircraft includes jet and propeller driven aircraft, as well as APUs. An APU generates electricity and compressed air to operate the aircraft's instruments, lights, ventilation, and other equipment and for starting the aircraft main engines. If ground-based power or air is not available, the APU may be operated for extended periods when the aircraft is on the ground with its engines shut down.
2. **Ground support equipment** (GSE): A variety of ground equipment service commercial aircraft while they unload and load passengers and freight at an airport. GSE primarily consist of vehicles that do not leave the airfield, such as aircraft tugs, air start units, loaders, tractors, ground power units, cargo-moving equipment, service vehicles, etc. In general GSE are off-road vehicles and include vehicles of the airport operator that maintain airport facilities (such as snow removal, fire fighting, etc).
3. **Ground access vehicles** (GAV): Ground access vehicles (GAV) encompass all on-road or highway vehicle trips generated by the users of the airport. GAV include all vehicles traveling to and from, as well as within the airport public roadway system (excluding GSE). On-road and highway vehicles include privately-owned vehicles, government-owned vehicles, rental cars, hotel shuttles, buses, taxicabs, private passenger vehicles, and trucks. For purposes of a greenhouse gas inventory, the on-airport roadway travel is itemized separately from the off-airport travel.
4. **Airport infrastructure and stationary sources** such as for lighting, cooling, etc. Included in airport infrastructure and stationary sources are fire-fighting training.
5. **Airport and airline maintenance industrial activities**.
6. **Airport construction activities.**

Depending on the airport, other sources of emissions may arise directly and/or indirectly. Some airports that have aggressive recycling programs may also attempt to capture their emissions savings from such programs.

As the inventory documented in this report is the first in-depth greenhouse gas inventory for Aspen-Pitkin County Airport related sources, it is scoped to only consider emissions from the first four sources (aircraft/APU, GSE, GAV, and airport infrastructure) as they are expected to be the dominant (key) sources of greenhouse gases. It is possible that in the future, construction and maintenance activities associated with Aspen Pitkin County Airport Section will be itemized, as well as the ongoing airport recycling.

Aircraft are probably the most often cited air pollutant source, but as is noted in FAA materials, they produce the same <u>types</u> of emissions as cars. Aircraft jet engines, like many other vehicle engines, produce carbon dioxide (CO_2), water vapor (H_2O), nitrogen oxides (NO_x), carbon monoxide (CO), oxides of sulfur (SO_x), unburned or partially combusted hydrocarbons [also known as volatile organic compounds (VOCs)], particulates, and other trace compounds. FAA data shows that aircraft engine emissions are roughly composed of emissions are reflected in **Figure I-2.**

FIGURE I-2



The *FAA's Emissions Primer* further notes that:

> About 10 percent of aircraft emissions of all types, except hydrocarbons (i.e., VOC) and CO, are produced during airport ground level operations and during landing and takeoff. The bulk of aircraft emissions (90 percent) occur at higher altitudes. For hydrocarbons and CO, the split is closer to 30 percent ground level emissions and 70 percent at higher altitudes.

According to most international reviews, aviation emissions comprise a potentially important and growing percentage of man-made greenhouse gases and other emissions that contribute to global warming. The IPCC estimated that global aircraft emissions accounted for about 3.5% of the total radiative forcing by all man-made activities. However, the scientific community has identified areas that need further study to enable them to more precisely estimate aviation's effects on the global atmosphere. As for the contributions of U.S. aviation relative to other U.S. industrial sources, data from the USEPA show that aircraft accounted for about 3% of U.S. greenhouse gas emissions (nearly 3.1% of CO_2 or 3.4% of CO_{2eq}).[8] As the US General Accounting Office (GAO) noted in 2000,[9] "global aviation emissions of carbon dioxide (measured in million metric tons of carbon) are a small percentage of carbon emissions worldwide; however, they are roughly equivalent to the carbon emissions of certain industrialized countries."

The GAO report noted the importance of aircraft emissions in greenhouse gases for the following reasons:

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8 USEPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2005*, USEPA #430-R-07-002, April 15, 2007 available at: http://www.epa.gov/climatechange/emissions/usinventoryreport.html

9 US General Accounting Office (GAO) *Environment: Aviation's Effects on the Global Atmosphere Are Potentially Significant and Expected to Grow*; GAO/RCED-00-57, February 2000.

- Jet aircraft are the primary source of human emissions deposited directly into the upper atmosphere. The IPCC noted that some of these emissions have a greater warming effect than they would have if they were released in equal amounts at the surface.
- CO_2 is relatively well understood and is the main focus of international concern, as it survives in the atmosphere for about 100 years and contributes to warming the earth.
- CO_2 emissions combined with other gases and particles emitted by jet aircraft - including water vapor, nitrogen oxide and nitrogen dioxide (collectively termed NOx), and soot and sulfate — could have two to four times as great an effect on the atmosphere as carbon dioxide alone.
- The IPCC concluded that the increase in aviation emissions attributable to a growing demand for air travel would not be fully offset by reductions in emissions achieved through technological improvements alone. Experts agree that the aviation industry will continue to grow globally and contribute increasingly to human-generated emissions. The experts differ, however, in the rates of growth they project and the effects they anticipate.

I.4 REVIEW OF EMISSIONS INVENTORIES

As of February 2008, few airports have initiated an inventory of greenhouse gas (GHG) emissions. Therefore, before initiating an inventory for Aspen-Pitkin County Airport, a review was conducted of the analyses conducted for non-airport sources, as well as those prepared for airport sources.

I.4.1 USEPA Greenhouse Gas Emissions Inventory

In 2005, total U.S. greenhouse gas emissions were 7,260.4 Tg $CO_{2\text{-eq}}$ (teragrams of CO_2 equivalent emissions – teragrams are 10^{12}).[10] Overall, total greenhouse gas emissions in the US have risen by 16.8% from 1990 to 2005, and at the same time the U.S. gross domestic product has increased by 55%. EPA noted that emissions between 2004 and 2005 increased 0.8%, a reduction over the 1.7% increase between 2003 and 2004, but higher than the increase between 2002-2003 of 0.6%.

To enable a comparison of national emissions with inventories prepared by states and other parties, the USEPA national inventory is prepared in two formats. One format that enables a clearer comparison with local emission inventories shows emissions by industry sector (residential, commercial, industry, transportation, electricity generation, and agriculture, and U.S. Territories.) Using these categories, 2005 emissions from electricity generation accounted for the largest portion (41%), with transportation activities accounting for the second largest portion (33%). Aviation is included in this transportation category. Aircraft emissions accounted for 3.05% of CO_2 emissions in 2005.[11]

The IPCC's 2000 *Good Practice Guidance* defines a key category as a "[source or sink category] that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both." By definition, a key category is one that has a notable contribution to the absolute overall level of national emissions. In the 2005 US emissions inventory, 16 key source categories were identified ranging from "CO2

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10 USEPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2005*, USEPA #430-R-07-002, April 15, 2007 available at: http://www.epa.gov/climatechange/emissions/usinventoryreport.html

11 Table 2-17 (186.1 Tg of CO2 out of a total of 6,089.5 Tg of CO2 per table ES-2)

emissions from stationary sources- coal" (the largest source), to "CO2 emissions from Steel and Iron Production" (the lowest source). The second largest emissions source was "Mobile emission sources – Roads and other" while "Mobile Combustion: Aviation" was the sixth largest source.

The methodology used by EPA in identifying aircraft emissions from the 2005 inventory was:

> For jet fuel used by aircraft, CO2 emissions were calculated directly based on reported consumption of fuel as reported by EIA, and allocated to commercial aircraft using flight-specific fuel consumption data from the Federal Aviation Administration's (FAA) System for assessing Aviation's Global Emission (SAGE) model.

It is important to note that the EIA (Energy Information Administration) data noted above is actually the quantity of fuel dispensed, as reported by fuel providers.

I.4.2 IPCC Methodologies

As noted above, the USEPA uses the IPCC methodologies for aviation GHG emission inventories. IPCC documentation notes that there are three tiers to their evaluation methodology: Tier 1, Tier 2, and Tier 3 go from the most simple to the most complicated/data intensive, respectively. Relative to aircraft activity, the methods differ by:

- Tier 1 – reflect total fuel consumed in the country;
- Tier 2 – requires a knowledge of aircraft Landing and Takeoff Cycles (LTOs)[12] and dispensed fuel to account for cruise level energy consumption;
- Tier 3 – uses method/model developed by the European Environment Agency (Denmark) which requires knowledge of origin/destination of flights. In the US, the FAA's SAGE model (System for Assessing Aviation's Global Emissions) is used, which is not available at the airport operator level at this time.

In general, the Tier 1 method and Tier 2 method, as applied to an airport setting would produce the same total fuel based emissions. However, Tier 2 allows the fuel use, and thus emissions, to be allocated to the local air area, as is associated with the landing and takeoff cycle (LTO). The LTO was developed to aid in the evaluation of local air quality, but identifying the emissions associated with an aircraft during four specific modes of operation: approach, taxi-in/delay/taxi-out, takeoff, and climbout. These emissions generally occur when aircraft are flying under 3,000 feet altitude. Thus, the Tier 2 method attempts to allocate emissions to the individual LTO cycles, as well as cruise-related emissions. **Figure I-3** shows the LTO cycle as well as cruise level.

The differences between Tier 2 and Tier 3 could relate to the quantity of fuel that is tankered or carried on a flight from one city so as to avoid the need for fueling in a city or to reduce the amount of refueling (as is identified in Tier 2) versus actual fuel required for the missions/flight (as is identified in Tier 3). At the time this analysis was prepared, the cost of fuel had risen substantially, and thus, it is anticipated that little fuel is tankered.

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[12] The LTO – landing and takeoff cycles – refers to the number of aircraft that land and then takeoff. LTOs are typically equal to the number of total aircraft operations (the sum of all arrivals and departures) divided by 2.

1.4.3 2006 Canary Initiative Inventory

In 2006, the City of Aspen released an emissions inventory for greenhouse gasses associated with various activities in Aspen. The objective of the Canary Initiative was

> In March of 2005, the City of Aspen adopted a plan to aggressively begin reducing global warming emissions (aka greenhouse gas emissions). These emissions are responsible for trapping additional heat in the atmosphere, causing global warming. And so, the Canary Initiative, so named because Aspen sees itself and other communities dependent on consistent water cycles as a canary in the coal mine, was born. This initiative serves as an action plan that identifies steps to reduce global warming pollution; inform the public about impacts from, and solutions for global warming; and to advocate for action on a regional, state, and national level. This *Greenhouse Gas Emissions Inventory* represents the completion of one of the initial steps in launching the Canary Initiative…..For Aspen to take any meaningful action to reduce its global warming emissions, it needed to identify the sources and the quantity of greenhouse gas emissions. This inventory of emissions serves as the tool to better understand the sources of emissions.

That inventory found the following distribution of emissions:

Summary of Aspen's greenhouse gas emissions in 2004 (Source: Canary Initative)

Source	Tons CO2-e	Percent
Electricity (buildings)	166,557	19.8
Natural Gas & Propane (buildings)	106,754	12.7
Ground Transportation	211,175	25.1
Air Travel: Commercial	**186,631**	**22.2**
Air Travel: Private	**157,856**	**18.8**
Landfill	11,577	1.4
Nitrous oxide:	325	0.04
Total	840,875	100.0

This inventory accounted for aircraft emissions at Aspen-Pitkin County Airport based on the average distance to the destination city for round trip travel. In general, the approach used consisted of the following:

- Identifying the number of domestic passenger and international passengers.
- Estimating the average domestic and average international travel distances to enable quantifying the overall passenger travel distance.
- Estimating the fuel consumed based on the average national aircraft fuel consumption per passenger mile traveled.
- Using known conversion factors to estimate the CO_2 equivalent based on the estimated fuel consumed for the previously identified travel.

The net effect of that approach was that the emissions associated with the large assumed travel distance produced emissions substantially greater than the emissions associated with the fuel dispensed from the Airport. This approach was used, as it represented the intention of the inventory -- to identify emissions as if Aspen were no longer developed. However, a consequence of the approach is that if added to (rolled-up) with the emissions from other cities and states, aircraft emissions would be double counted. The inventory documented in this report is intended to avoid double counting, and itemizes emissions by source and by ownership and control of the source.

I.4.4 Airport Inventories

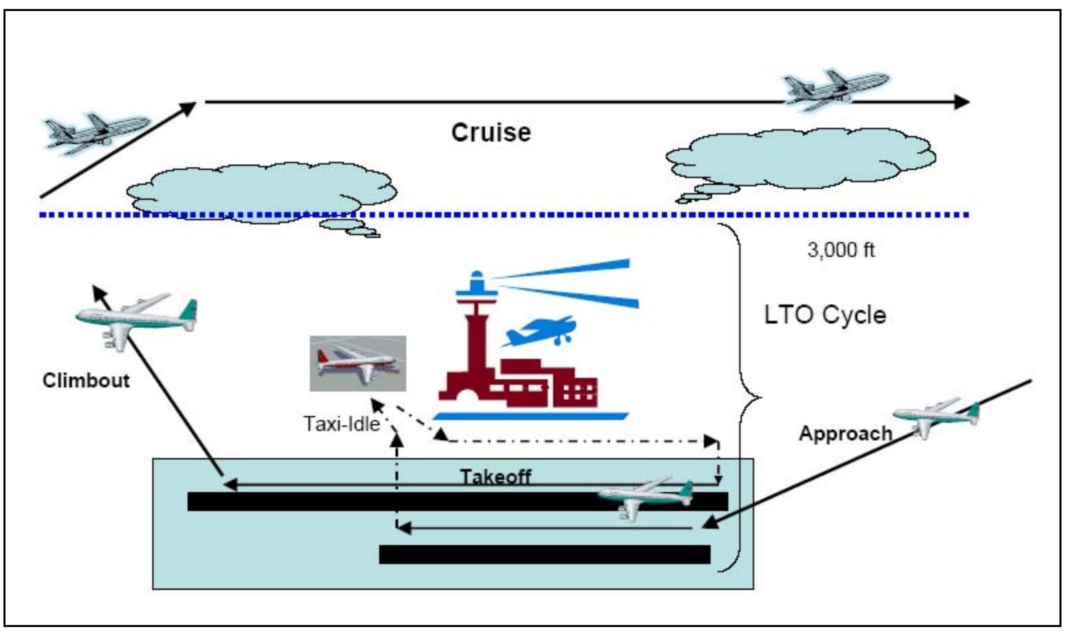
To date, neither the FAA nor the airport community have developed a greenhouse gas emissions inventory protocol that can be consistently applied at airports. Questions have arisen about:

1) Ownership and control: Clear lines exist concerning the ownership of mobile sources. Airlines or private parties either lease or own the aircraft; airlines (or their fixed based operators) own or contract for the GSE that service aircraft, while airport operators own/lease the vehicles that maintain and support airport operations and the airport buildings. Airport operators own the airport buildings (the terminal building and the airport operations building), the runway system, the parking lots, and the on-airport roadways. Hotels own the courtesy vehicles (shuttles) that transport passengers, and private parties own the vehicles that transport passengers to and from an airport. Rental car companies own the fleet of available rental cars, although the public that rents these vehicles controls where they travel and the amount of travel (distance).

   While airport operators, such as Pitkin County, may own the airfield infrastructure (runways and taxiways), the FAA controls how the airfield is used at an airport and the operational airspace. Airport operators, with federal approval, control the nature and extent of airport facilities. This availability (or lack thereof) can affect the operational efficiency of sources owned and controlled by others. Thus, there is some "gray" in the boundaries associated with an airport.

   In light of this "gray" are, if an airport operator generated an emissions inventory for voluntarily participating in a climate action registry (such as The Climate Registry - TCR), they would note emissions based on the boundaries, with a substantial portion of the source emissions falling into the category of optional as they are not owned and controlled by the airport operator.

FIGURE I-3
LANDING AND TAKEOFF CYCLE



Four LTO Modes: approach, taxi-in/taxi-out, takeoff, and climbout.

2) The boundaries of the aircraft emissions: Operators of public use airports, such as Pitkin County, have little control over the number and types of aircraft that operate at the airport. Thus, questions arise about including these emissions in an emissions inventory and to what extent. Some inventories have struggled with should aircraft emissions include the full flight of the aircraft, as well as questions about passenger's origin/destination to/from an airport; should only the LTO-based emissions be accounted as is done for criteria pollutants; should fuel dispensed be used as has been used to quantify emissions from other sources. See Chapter II for an additional discussion of boundaries.

3) The boundaries for other sources: while aircraft travel hundreds and, in some cases, thousands of miles to/from their origin and destination, surface vehicles also can travel great distances. The substantial portion of passenger travel is within the region served by an airport. However, some passengers and cargo can travel great distances. Traditionally most airport emissions inventories (for carbon monoxide, nitrogen oxides, etc) focus on surface travel in the area on-airport lands, but a few airports have inventoried emissions within a mile or two of the airport boundaries and some have accounted for the full length of the surface travel journey.

   As noted earlier, the FAA has developed the SAGE model that considers global emissions. However, at present, the SAGE model is not available to airport operators due to the extensive amount of information required for its operation. However, experienced users of the Emissions Dispersion Modeling System (EDMS) can use the model to quantify aircraft fuel burn in the LTO cycle. It is anticipated that in the future, models for air travel-related greenhouse gas inventories specific to the airport setting will become available.

4) Greenhouse gas emission factors are not available for airport ground support equipment;

5) Few airports collect or retain fuel/energy data concerning the airport and its users at a refined level to enable clear identification of the users of all sources, particularly those associated with ground access vehicles. As a result, the ability to clearly identify emissions by ownership and control may be limited.

6) As the quantification of airport emissions is at its infancy, limited emissions data is available from consistent sources. For instance, IPCC has identified emission factors for CO_2, methane, and NOx for aircraft in the LTO (below 3,000 feet operation). However, no emission factors exist for cruise operations (above 3,000 feet) for aircraft. While data is available in the UK from CORINAIR for cruise, such data is not available for all aircraft; rather general categories of aircraft are identified, and it is expected that such data may be dated, not representing current aircraft fuel consumption. As noted earlier, the FAA's EDMS can be used to quantify fuel burn for aircraft in the LTO cycle, which can be translated into CO_2, as well as NOx emissions, but doe not evaluate methane (CH_4). Because CO_2 is the largest total quantity directly emitted, and because consistent factors are not available for all pollutants, a CO_2equivalent ($CO_{2\text{-eq}}$) is not evaluated in this report at this time.

Recognizing these deficiencies, the Transportation Research Board's Airport Cooperative Research Program (ACRP) embarked on the preparation of a guidebook in late 2007 concerning the preparation of airport greenhouse gas emission inventories. Thus, the inventories that have been prepared to date, many of which deploy methodologies unique to the local needs and circumstances, represent an initial start at identifying emissions at airports. Further, this inventory was prepared prior to the release of the ACRP guidebook, which is expected to occur in 2008.

An internet search identified four publicly available greenhouse gas emission inventories that have identified airport-related sources: the previously noted Aspen Canary Initiative, City of Seattle, City and County of Denver, the Sacramento Airport Master Plan, and the San Diego Airport Master Plan. **Table I-2** summarizes these inventories in a comparative format. This comparison is illustrative of the evolution in the preparation of greenhouse gas inventories, and clearly shows that a standard approach has not been identified.

The City of Seattle 2000 emissions inventory identifies airport emissions associated with Seattle-Tacoma International Airport and Boeing Field. The city inventory includes one lump-sum number of emissions associated with both airports. That inventory indicates that about 15% of city-wide emissions are associated with the airports. While Sea-Tac Airport is not within the city boundaries, it was the one exception made in the city boundary definition. The documentation associated with the 2002 effort indicates the following:

> **Transportation – SeaTac and King County Airport:** The airline industry has, over the past 30 years, improved fuel economy per passenger mile by 61 percent. Growth in air travel, however, has resulted in energy use by commercial aircraft nearly doubling in the same period[13] - which accounts for this category being the third largest source of GHG emissions. Emissions in this category were based on fuel sales data from the two airports (reported to the Clean Air Agency annually) and assigning a percentage of those sales to Seattle business and residents (King County data indicate that 29% of passengers are from Seattle.) Emissions of CO2 from jet fuel and aviation gasoline were computed using IPCC methods. (source: page 14 - note 3b)

Because of California's Global Solutions Act, a greenhouse gas emissions inventory is being prepared for public actions. California projects are subject to the California Environmental Quality Act (CEQA), which is a state-based act similar to the National Environmental Policy Act (NEPA). The Sacramento County owns and operates Sacramento International Airport, and has proposed improvements to the airport that have been the subject of a recent Environmental Impact Report (EIR) that included a greenhouse gas emissions inventory. A similar evaluation was conducted for the EIR at San Diego International Airport. The emissions inventories were prepared for purpose of meeting CEQA and would not necessarily represent the same format that a city would prepare for purposes of quantifying city/community emissions or for a climate action plan. While IPCC methods were used in that analysis to quantify aircraft emissions, they only represented LTO based emissions and did not reflect cruise (flight operations beyond the LTO modes).

The City and County of Denver has prepared a city-wide and community based greenhouse gas inventory that includes a section on emissions associated with Denver International Airport - DIA. Aircraft-related greenhouse gas emissions were identified based on the IPCC Tier 1 method (fuel dispensed at DIA). Similar to the City of Seattle inventory, Denver apportioned the aircraft emissions to DIA based on the passengers living in the city, and based that proportion on citywide vehicle trips. The "fleet vehicle fuel use" was based on the City and County vehicle fuel use and does not appear to include airline ground support equipment. Because of the amount of waste incinerated at DIA, a separate line item (other - 6 tons) for this emission was identified. Airport facility based emissions were determined as a combination of expended electricity and natural gas, but also based on water consumption, land filled solid waste, and recycling. Ground access vehicle emissions were computed based on data from the Denver Region Council of Governments estimates of vehicular travel in the region and fuel consumption.

[13] Rocky Mountain Institute, Colorado.

TABLE I-2
Comparison of Airport Greenhouse Gas Inventories

Source	City of Seattle (2000)	Aspen Canary Initiative (2004)	Sacramento Airport (2004)	Vancouver BC Airport (2004)	San Diego Airport (2005)	Denver (2005)	Port of Seattle Aviation Division (2006)
Aircraft	NA				Reported as direct and indirect		
LTO		na	177,307	170,916		na	348,195
Cruise		na	na	Na		na	3,816,707
Total		344,487	177,307	170,916		4,569,696	4,164,902
Ground Support Equipment		NA	10	26,669		14,051	9,926
Ground Access Vehicles		NA	39,723	35,304		21,968	403,354
Facilities		1,103	0	Na		211,000	40,636
Other		NA	0	Na		6	Na
Total (tons)	1,040,000 $CO_{2\text{-eq}}$	345,590 $CO_{2\text{-eq}}$	217,040 $CO_{2\text{-eq}}$	232,889 CO_2	1,595,759 CO_2	4,816,721 $CO_{2\text{-eq}}$	4,654,330 CO_2
Annual Operations	444,630 (SEA)/ 359,626 (BFI)	43,256	164,805	270,000	209,512	566,036	340,058
Annual Enplaned Passengers	13,853,299 (SEA)/ 11,526 (BFI)	180,519	4,671,560	7,850,000	8,686,261	20,675,380	14,989,549
Notes	Includes Sea-Tac and King County Airport. 1996 IPCC methods and WRI used. For SEA, includes only passengers originating from Seattle locations.	Method designed to address local conditions	Emissions are noted for CH4 and N20, but not included in the above. Used 2006 LTO (EDMS) emissions only.	Aircraft LTO/EDMS, Mobile6 for GAV	Emissions are noted for CH4 and N20, but not included in the above. Examined direct and indirect, defined were direct = occur on airport site/LTO (EDMS), indirect: off site, and outside LTO	2006 IPCC Tier 1 for aircraft, airport ground fleet, facilities and GAV. Does not appear to include airline GSE	IPCC Tier 2 (EDMS/dispensed), EPA NonRoad2005 for GSE rates. Emissions for airport owned/controlled, tenants, and public

Sources: ***Aspen Greenhouse Gas Emissions 2004, For the City of Aspen's Canary Initiative***, Climate Mitigation Services, January 2006. ***Inventory and Report: Seattle's Greenhouse Gas Emissions***, City of Seattle, Sept 2002. ***Final Environmental Impact Report, Sacramento International Airport Master***; County of Sacramento Department of Environmental Review and Assessment, July 2007; ***Greenhouse Gas Inventory for the City and County of Denver***, University of Colorado Denver, City and County of Denver, Department of Environmental Health, May 2007. ***Draft EIR Airport Master Plan San Diego International Airport***, October 2007. Port of Seattle, ***Seattle-Tacoma International Airport Greenhouse Gas Inventory - 2006***, Synergy Consultants, updated March 2008.

Finally, the most recent airport-specific greenhouse gas inventory that was identified was that prepared by Synergy Consultants for the Port of Seattle's Aviation Division. The approach to that inventory was similar to that documented in this report for Pitkin County's Airport Section, as it identified direct and indirect emissions associated with sources owned and controlled by the Port of Seattle's Aviation Division, and then separately itemizes emissions associated with tenants and public on-road travel.

I.4.5 Other Inventories

Based on the internet search, state emission inventories have been prepared by numerous states. Cities have prepared inventories for city-owned resources as well as overall emission sources. This section briefly provides examples of a few of these inventories.

State emissions inventories. In 1999, The USEPA issued guidance documents concerning the preparation of emission inventories for purposes of developing a consistent framework for the state inventories. The EPA methodology is based on the IPCC method discussed previously and is the same methodology that USEPA used in preparing the national inventory.

The State of Colorado prepared a greenhouse gas emissions inventory[14] representing source emissions within the state. **Table I-3** shows that inventory in comparison to the county and city inventories. Each inventory was prepared using differing methods and are formatted to facilitate the consideration of emissions.

TABLE I-3
UNITED STATES AND COLORADO GREENHOUSE GAS EMISSIONS (CO2eq)

Source	United States (2005)	State of Colorado (2005)
Total Tons $CO_{2\text{-eq}}$	7,206 million	116.1 million (gross)
Source Distribution		
Electrical Consumption	33.5%	36.95%
Residential/Commercial/Industrial Fuel Use	11.2%	18.3%
Transport	27.7%	24.1%
Industrial (fossil fuel & processes)	18.6%	11.2%
Other (waste management & agriculture, US Territories)	9.0%	9.5%
Aviation (if identified)	3.45%	2.76% est.

Source: *Final Colorado Greenhouse Gas Inventory and Reference Case Projections 1990-2020*

The State of Colorado's greenhouse gas inventory indicates that in 2005, gross state-wide emissions were approximately 116.1 million metric tons of $CO_{2\text{-eq}}$ before subtracting out forestry-land use and agriculture soil sequestration, resulting in net emissions of 89.4 million metric tons of $CO_{2\text{-eq}}$. Of the gross emissions, electric consumption is the largest

[14] Center for Climate Strategies, *Final Colorado Greenhouse Gas Inventory and Reference Case Projections 1990-2020*, October 2007. Available at http://www.coloradoclimate.org/ewebeditpro/items/O14F13894.pdf

source (36.95%), followed by all modes of transportation (24.12%) and residential/commercial/industrial fuel use (18.26%). Aviation fuel use is within the transportation category. As a percent of total, aviation fuel based emissions in Colorado represents nearly 2.8% of $CO_{2\text{-}eq}$ or 11.4% of transportation related emissions; these proportions are similar to the national levels.

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II. INVENTORY PROTOCOL

This chapter documents the methodologies used to prepare the 2006 greenhouse gas emissions inventory for Aspen-Pitkin County Airport. This chapter discusses:

- Pitkin County Airport organization and operational boundaries
- Methods to quantify airport-related sources
- Uncertainties and Data Cautions

The principles by which this inventory was prepared reflect general factors considered in most greenhouse gas inventories:

- *Relevance* means that the inventory includes the appropriate facilities and types of emissions sources to meet the entity's goals.
- *Completeness* means that an adequate percentage of the entity's (ie, Pitkin County Airport Section) total facilities and emissions sources have been included in the inventory.
- *Accuracy* means using accepted quantification methods and emissions factors as well as managing data quality.
- *Transparency* means that the important boundary decisions, data sources, and quantification methods are well documented.
- *Consistency* means that the same facilities, emissions sources, and emissions quantification methods are used from year to year. As noted earlier, it is anticipated that the approach to considering airport-related emissions will evolve with time. This inventory then is prepared in a transparent way to enable the emissions presented herein to be re-tabulated if needed.

II.1 PITKIN COUNTY AIRPORT ORGANIZATION AND OPERATIONAL BOUNDARIES

While a standard greenhouse gas inventory protocol has not been developed for the airport setting, protocols have evolved from a number of sources that can be used in whole or part including:

- **Intergovernmental Panel on Climate Change** (IPCC) - focused on inventories for nations, but provide guidance for other parties on various sources, including aviation;
- **US EPA** - has prepared guidance for states to prepare inventories, but has also prepared a protocol through the Climate Leaders effort to assist other entities, particular corporations with consistent greenhouse gas inventories;
- **World Resource Institute (WRI)** an environmental think tank, in collaboration with the World Business Council for Sustainable Development, has developed comprehensive guidance to assist corporations prepare emission inventories, both representing the corporate entity as well as corporate projects.

- **International Council for Local Environmental Initiatives (ICLEI)** - is an international association of local governments and national and regional local government organizations that have made a commitment to sustainable development. ICLEI has implemented a program titled, the Cities for Climate Protection (CCP) to assists cities with adopting policies and programs to reduce local greenhouse gas emissions, improve air quality, and enhance urban livability and sustainability. According to their web site, more than 800 local governments participate in the CCP.

The inventories discussed in the preceding section all rely on one or more of the above protocols or methodologies for quantifying greenhouse gases. As noted by these protocols, for a greenhouse gas to be of use, it must contain information in a way that allows the data to be useful. In most cases, the preparation of an inventory enables the identification of notable or key sources of greenhouse gases and the identification of measures to reduce those emissions. To be useful requires the use an appropriate inventory boundary that reflects "the substance and economic reality of the entities activities" and responsibilities and presents emissions at a source level that enables the capture of changes in emissions over time and with mitigation/offset. For corporate entities, this often relates to the legal form of the business. For governmental parties, this can become less clear, but typically focuses on emissions directly from the governmental activities (sources owned by the entity), as well as those within its control. Thus, the choice of the inventory boundary is typically dependent on the characteristics of the entity, the intended purpose of the information, and the needs of the information users.

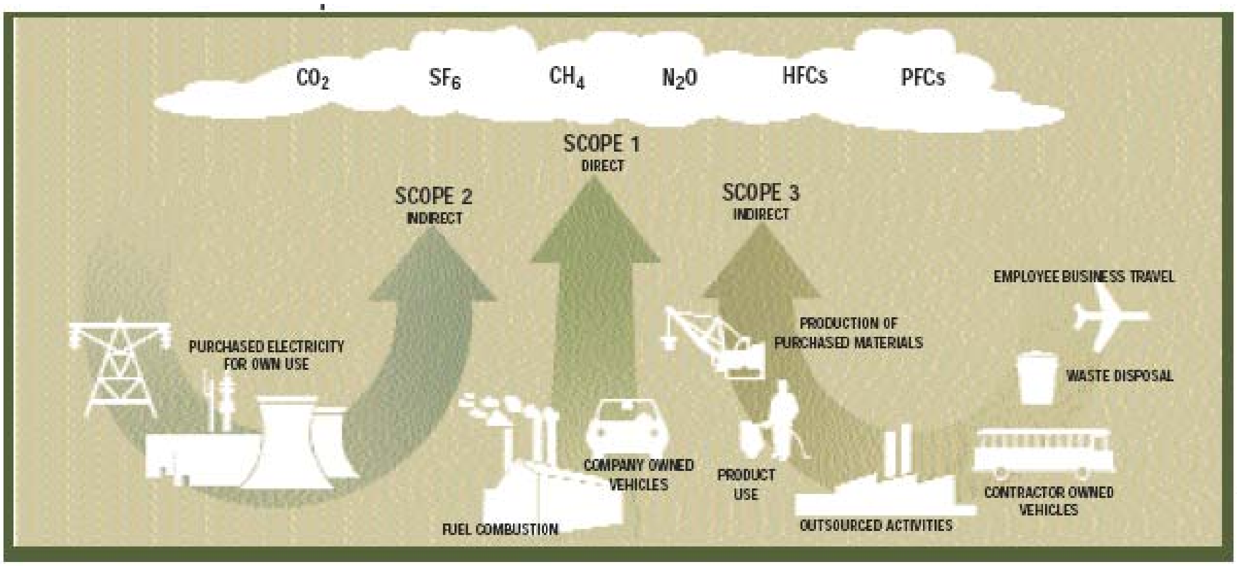
EPA and WRI guidance suggest that the following be considered when establishing the boundaries:

- **Organizational structure**: as reflected by control through ownership, legal agreements, joint ventures, etc. In the case of the Airport, the organization boundaries were limited for this review to the County's Airports Department activities and associated emissions. This approach will enable the County to combine, if it desires, the emissions associated with the airport organizational structure, with those of other elements or departments of the County.
- **Operational boundaries**: Once an entity has determined its organizational boundaries in terms of the operations that it owns or controls, it then sets its operational boundaries. This involves identifying the emissions associated with its operations and categorizing them as *direct, indirect, and optional emissions.*
    - **Direct** emissions are from sources that are owned or controlled by the party. For example, emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc. The WRI methods refer to direct emissions as Scope 1 emissions. In the case of Aspen-Pitkin County Airport Section, direct emissions reflect energy consumed by County facilities, and fuel powering County owned vehicles.
    - **Indirect and Optional** emissions are a consequence of the activities of the entity, but occur at sources owned or controlled by another party. An example of indirect emissions is the emissions from the generation of purchased electricity consumed by a company. The WRI method identified two forms of indirect emissions: Scope 2 and Scope 3. Scope 2 emissions are those from the generation of purchased electricity consumed by the entity. Scope 3 is an optional reporting category that allows for the identification of all other emissions that are a consequence of the activities of the entity, but occur from sources not owned or controlled by the entity. Indirect emissions associated with Aspen-Pitkin County

Airport Section purchased electricity, whereas optional emissions are all emissions associated with the tenants and ground travel by the public to and from the Airport.

Indirect and direct emissions as advocated by USEPA are similar to the Scope 1 and 2 emissions noted by WRI, whereas WRI Scope 3 emissions are the emissions that EPA considers optional.

FIGURE II-1
WRI BOUNDARIES - SCOPE 1, 2, AND 3



Given the organization boundaries, the operational boundary for the Airport Section was defined as the County's airport-owned land at Aspen-Pitkin County Airport. Because of the visibility of aircraft and their emissions within the physical boundaries of the Airport, as well as other activities by tenants, attempts were made to capture the emissions with those activities and note that they are owned and controlled by airlines/tenants and private parties using the Airport. In addition, because of the high amount of on-road vehicular travel associated with passengers using the Airport, emissions from these sources were also quantified based on the information available, but noted as associated with public (private) activities. The inclusion of these emissions provides further information about Airport-related activities and their emissions.

An important element of the inventory protocol is the use of proper boundaries that avoid the double counting of emissions. As noted in the IPCC 2006 guidance[15] "National inventories include greenhouse gas emissions and removals taking place within national territory and offshore areas over which the country has jurisdiction. … For example, emissions from fuel used in road transport are included in the emissions of the country where the fuel is sold and not where the vehicle is driven, as fuel sale statistics are widely available and usually much more accurate."

15 *2006 IPCC Guidelines for Preparing National Greenhouse Gas Inventories , Volume I - General Guidance and Reporting*, IPCC, 2006, Page 1.4

In an airport setting, the issue of ownership is clear, as ownership is related to the party that has title to the asset (i.e., the aircraft is owned or leased by an airline or private entity, most buildings and facilities are owned by the County, but may be the subject of a long-term lease by a tenant). However, control can be more difficult to identify, as many parties contribute to the control of various sources. Therefore, the Pitkin County Airport Section inventory identifies sources of emissions and attempts to focus first on ownership and then control.

II.2 METHODS USED TO QUANITY GREENHOUSE GASES AT ASPEN-PITKIN COUNTY AIRPORT

Based on the types of sources at Aspen-Pitkin County Airport, emissions from the following were quantified:

II.2.1. Aircraft Emissions (Tenant or Public Owned Sources)

Aircraft greenhouse gas emissions would be expected to be the largest sources of greenhouse gases at most commercial service airports due to the fuel requirements of air travel. To quantify aircraft-related greenhouse gases, the following steps were used:

- Information concerning the quantity of fuel dispensed at Aspen-Pitkin Airport to aircraft (jet fuel and aviation gas) was obtained by Pitkin County. In 2006, a total of 5,084,919 gallons of Jet-A and 39,229 gallon of AvGas were dispensed (sometimes referred to as fuel sales). Fuel dispensed represents the amount of fuel that airlines acquired at Aspen-Pitkin County Airport in order for departures to reach their desired destination. It does not reflect the fuel acquired in origin cities that is necessary to enable travel to Aspen (arrival-based fuel). While the arrival-based fuel consumption is not reflected in fuel dispensed, as it would be attributed to that flight origination city, a subsequent step accounts for arrival fuel consumption in the local setting and considers fuel consumed in the LTO approach mode.

  As noted earlier, fuel sales or fuel dispensed data does not reflect account for fuel obtained in other locations that enables the aircraft to fly to Aspen and, in some cases, achieve the desired destination (travel from Aspen to a destination). This is often called tankering. With the methodology used herein, fuel dispensed at another airport would result in the emissions then being associated with that other airport. In light of the cost of fuel in the 1st quarter 2008, it is anticipated that the "tankering" of fuel is minimized, as the added fuel increases the weight of the aircraft, requiring the aircraft to burn more fuel just to carry the added weight.

  Fuel dispensed can be translated into CO_2 emissions based on a the US Energy Information Administrations estimate that about 21.095 pounds of CO_2 is generated by burning one gallon of Jet A fuel or 18.355 pounds of CO_2 per gallon of AvGas**.** Thus, aircraft fuel dispensed at Aspen-Pitkin County Airport generated about 48,981 metric tons of CO_2.

- In accord with the 2006 IPCC protocol, the Tier 2 method was used to quantify aircraft greenhouse gas. In Tier 2, the second step of the evaluation process requires the calculation of fuel burn in the LTO cycle (approach, taxi-in, taxi-out, takeoff, and climbout). To quantify emissions in the LTO cycle, the FAA's Emissions Dispersion Modeling System (EDMS) Version 5.0.2 was used. While this model does not currently generate CO_2 emissions, it does provide the ability to identify fuel consumption in each of the LTO cycle modes. **Appendix A** provides a listing of the numbers of LTOs by aircraft type at Aspen-Pitkin County Airport which consumed about 1,090,159 gallons of fuel (1,082,370 gallons of Jet-A and 7,789 gallons AvGas), and thus produced about 10,422 metric tons of CO_2 in the LTO cycle.

- Using the IPCC Tier 2 method, LTO based CO_2 emissions (10,422 metric tons) was subtracted from fuel dispensed CO_2 (48,981 metric tons) to identify cruise/residual CO_2 emissions. As APU use is also reflected in this emission, it is titled “residual/cruise/APU use”.

  Data necessary to run the EDMS includes:

  - Types and numbers of aircraft operating: FAA ASDi data was obtained for 2006 to identify all flights at Aspen-Pitkin County Airport and the types of aircraft being operated. Based on knowledge of the airline operating each flight, the specific aircraft type and engine combinations could be identified, using industry publications, such as *Jane's Information Group* - Airline Fleet and *JP Airline Fleets International*. Information about private aircraft operating at the Airport was used to further identify the types of general aviation aircraft. The aircraft fleet used in this analysis was closely coordinated with the noise analysis prepared for Aspen-Pitkin County Airport.
  - Time-in-mode: FAA's T1 data was also accessed to identify the specific time that aircraft operating at Aspen-Pitkin County Airport actually operate to taxi-in and taxi-out. By using actual airport data, the analysis is able to incorporate any delay and inefficiencies that aircraft actually experience at a location. Default time-in-mode data was then used for approach, takeoff, and climbout, as these times are not known to vary substantially from airport to airport.

  Fuel burn was then converted to emissions for each mode using the same factor as noted above. Emissions from the EDMS were then reported according to: 1) approach, 2) taxi-in/taxi-out, 3) takeoff, and 4) climbout.

  As the Pitkin County Airport Section does not own, control, or operate aircraft, the emissions associated with these sources are identified as Airline/Tenant/Aircraft Operator-owned/controlled emissions.

As the quantification of airport emissions is at its infancy, limited emissions data is available from consistent sources. For instance, IPCC has identified emission factors for CO_2, methane (CH_4), and NOx for aircraft in the LTO (below 3,000 feet operation). However, no IPCC emission factors exist for cruise operations (above 3,000 feet) for aircraft. As noted above, the FAA's EDMS can be used to quantify fuel burn for aircraft, which can be translated into CO_2, as well as NOx emissions, but does not evaluate methane. **Because CO_2 is the largest total quantity directly emitted, and because consistent factors are not available for all pollutants, a CO_2 equivalent (CO_{2-eq}) is not evaluated in this report at this time**.

II.2.2 Ground Support Equipment (GSE)

This category refers to all Airport-owned and airline/tenant-owned vehicles that support aircraft and airport activity. In general, these vehicles are considered off-road as they do not typically travel off of the Airport. The method used to quantify GSE emissions was:

Pitkin County GSE

Separate from airline/tenant GSE, the Pitkin County operates GSE that include: fire fighting equipment, snow removal, airport administrative ground travel, and airport maintenance vehicles. In 2006, the County purchased nearly 3,317 gallons of gasoline and 12,401 gallons of diesel that serviced GSE, police, fire, and stationary sources. CO_2

emissions associated with the consumption of these fuels were computed based on standard CO_2 factors (i.e., 19.564 lbs of CO_2 per gallon of gasoline, 22.384 lbs of CO_2 per gallon of diesel).

Airline/Tenant GSE

- At this time, a publicly available source of GSE greenhouse gas emission factors could not be identified. EPA's NONROAD2005 model was run for the national fleet of non-road vehicles to identify the range of emission factors associated with various horse-power ranges (i.e., 175<hp<=300) non-road equipment in 2006. An average emission factor for each range of horse-power was calculated from the NONROAD2005 data and used as a surrogate for GSE. Given the relative consistent emission factors across various engine sizes, this approach appears reasonable. The NONROAD2005 emission factor represents the emissions in grams per break-horse-power hour of CO_2.
- For criteria pollutant emissions, the FAA EDMS is used by the airport community to prepare an emissions inventory. Unfortunately, at this time, the FAA's EDMS does not generate greenhouse gas emissions or fuel burn associated with GSE. However, the EDMS has the ability to estimate a default mix of GSE and their use if local data is not available. A site specific GSE vehicle and vehicle use survey is not available for Aspen-Pitkin Airport. Such surveys are not typically undertaken for airports of this size. Therefore, the EDMS default data was obtained to identify the types of GSE that would be expected, and their use. Use of the default EDMS GSE times indicates about 5,924 tons of CO_2 were emitted in 2006. It is unclear as to how accurate this data may be relative to the operations at ASE.
- Emissions associated with each vehicle type were computed as the product of the total hours of use, the horsepower, the load factor, and the emission rate.

II.2.3 Ground Access Vehicles (GAV)

Ground access vehicles (GAV) generally are all of the street-licensed vehicles that operate to and from the Airport. GAV vehicles at Aspen-Pitkin County Airport are primarily associated with passengers, employees, and cargo travel. Limited data exists for ground access vehicle use associated with Aspen Pitkin County Airport. Therefore, substantial estimates were made to identify GAV travel and thus emissions.

In 2006, Aspen-Pitkin County Airport accommodated 399,938 passengers. A total of 22,232 annual aircraft operations occurred. Based on this level of enplaned passenger travel, as well as the general aviation activity-related travel, estimates of the mode that passengers travel to and from the Airport were necessary. The following assumptions were made to arrive at an estimate of GAV travel and the emissions from GAV sources.

- It was assumed that each travel party consists of 3 passengers. Each travel party was assumed to generate a GAV movement.
- Information was collected from a key rental car company that showed the average rental car travels 265 miles and, based on airport revenue data, that about 17,410 vehicle rentals occurred in 2006.
- Pitkin County data for use of the parking lots indicate that 54,711 vehicles entered the parking lot. These vehicles were assumed to be associated with air traveler drop-off and/or pickup.
- Of the vehicles not using the parking lot, half were assumed to be associated with hotel shuttles, 40% by local taxi's, and 10% were associated with a second party dropping off/picking up a passenger on the curbfront, but not using the parking lot.

- In surveying rental car companies, only one company responded. Information was provided concerning the number of leased vehicles and distance traveled. Using that information, and airport revenue data, estimates of other rental car company vehicle rentals were prepared. The distance traveled, which has a large effect on the results reported herein, were assumed to be the same among all rental car companies.
- An average travel of non-rental car GAV was assumed to be 15 miles (the average of vehicles traveling into the City of Aspen or to Snowmass).
- An average fuel economy was obtained from the Energy Information Administration (22.9 MPG) and assumed for non-taxi related travel. Taxi travel was assumed to have a 16 MPG per vehicle, attempting to reflect a higher level of idle waiting for the air traveler. One rental car company national press release[16] indicates that on a national basis, their rental cars have an average fuel economy is 28 MPG, and thus, the fuel economy used for Aspen-Pitkin County Airport Section may be overstated.

County employees reporting to duty at Aspen Pitkin County Airport were also separately itemized. The County supplied information on the number of employees, their weekly commute mode, and distance travelled. It is important to note that this analysis does not reflect the recently instituted employee commute van that the County has implemented which is designed to reduce congestion and emissions associated with employee commute.

Tenant employee commute information was difficult to obtain. Only two tenants provided information on their employees (one rental car and one airline). No attempt was make to supplement this data, and thus, tenant employee travel and associated emissions are under-reported.

Hotel shuttle information was not available. Therefore, estimates of the number of trips and distance travel were made. As noted early, due to the recreational/resort nature of the area, it was estimated that a substantial portion of the passengers use hotel shuttles. Based on visual notes, most of the hotel shuttles use gas powered vans, and thus an average fuel economy of 22.9 MPG was used, which is likely to be a conservative estimate.

II.2.4. Facility/Stationary Source Emissions

Stationary fossil fuel burning equipment primarily include heating and cooling, power supplies for building (i.e., electrical consumption), and cooking activities. The following data was collected in order to quantify emissions from these sources:

- A substantial quantity of electricity is consumed at an airport to power lighting in the terminal, parking garage, support facilities and airfield. Pitkin County records indicate that about 94,899 kilowatt hours (kWh) of electricity was purchased from Holy Cross Energy by the County in 2006. Using the Canary Initiative's CO_2 generation for electrical power 1.77 pounds of CO_2 per kWh, County controlled airport facilities generate about 76 metric tons of electricity-based CO_2.
- In addition to electricity, the County purchases natural gas for purposes of heating various airport-related facilities. In 2006, nearly 726 therms of natural gas were purchased, which generated about 4 metric tons of CO_2.

It is important to note that the Airport Section has made a commitment to purchase greenpower (ie, renewable energy) for airport uses. At this time, the inventory does not

16 Press release by Enterprise Rent-A-Car, National Car Rental and Alamo Rent A Car on January 21, 2008.

capture the "credit" associated with greenpower, which in the context of emissions reporting would ultimately be subtracted from the total emissions associated with the Airport Section.

At this time, data was not collected from airport tenants to identify tenant-related facility and stationary source emissions. Thus, all facility and stationary source-related emissions are based on data associated with Pitkin County activities.

II.3 UNCERTAINTIES AND DATA CAUTIONS

As noted earlier in this report, a consistent protocol for preparing airport greenhouse gas inventories has not been prepared and/or accepted by the aviation and airport community. However, in the interim, inventories are being prepared and to date, not one consistent methodology has been deployed. While the approach taken in preparing this inventory is relying on industry accepted approaches for non-aviation sources, so have most of the cited inventories prepared for other airports and situations. Such uncertainties are demonstrated by the review of tenant GSE emissions or the need to estimate GAV travel associated with passengers and other uses of an airport.

The previous section, coupled with the discussion in **Chapter IV, *Future Considerations*** shows that improvements in the data underlying the greenhouse gas inventory can be undertaken, and that airport operators will require emission factor information to be generated for various sources to further improve the integrity of the emissions inventory. Further, airport operators will be required to collect data in a format to assist with greenhouse gas inventories, and for some airports to begin collecting data on activity that has not been collected in the past.

This inventory, however, represents the next step to improve the inventory prepared by the Canary Initiative and should assist Pitkin County and airport tenants/users with examining and possibly reducing their contribution to greenhouse gases and the effects of these gases on climate change. The data that is the least reliable in the inventory is that which is associated with the ground access vehicle travel. As noted earlier, substantial estimates were required. Surveys could be conducted and vehicles counts undertaken to better quantify emissions from these sources. Most airport operators have not had access to rental car travel information, which was available for one rental car operator at Aspen Pitkin County Airport. While estimates were made for the other operators, the inclusion of all rental car travel in the inventory likely over-estimates airport-related emissions. Of the 264 miles identified, such travel within the region is associated with entertainment and area visitor attractions. Thus, while emissions may be underestimated for some ground travel, the inclusion of the full travel distance from rental cars more than compensates for the data gaps.

Given the infancy of the methods available to quantify airport-related emissions, it is not possible to quantify the degree of uncertainty associated with this inventory. Rather, the quality of the investigation is greater than that for other local inventories, but additional data collection could be undertaken in the future to improve on the identification of source emissions.

III. EMISSIONS INVENTORY

Table III-1 provides a summary of the 2006 greenhouse gas inventory. Three colors are used to differentiate and separate the emissions by the previously discussed ownership and control, with a forth color (yellow) identifying the percent of totaling emissions by all three categories. As the table notes, 56,421 metric tons of CO_2 were emitted in 2006, not including the non-CO_2 greenhouse gases. Relative to this total, 0.6% are associated with Pitkin County Airport Section activities, 97.4% of the emissions are associated with tenant/aircraft operator activities, and 2.0% by public access to/from the Airport and related travel.

TABLE III-1
SUMMARY OF GREENHOUSE GAS EMISSIONS ASSOCIATED WITH ASPEN-PITKIN COUNTY AIRPORT ACTIVITY (2006)

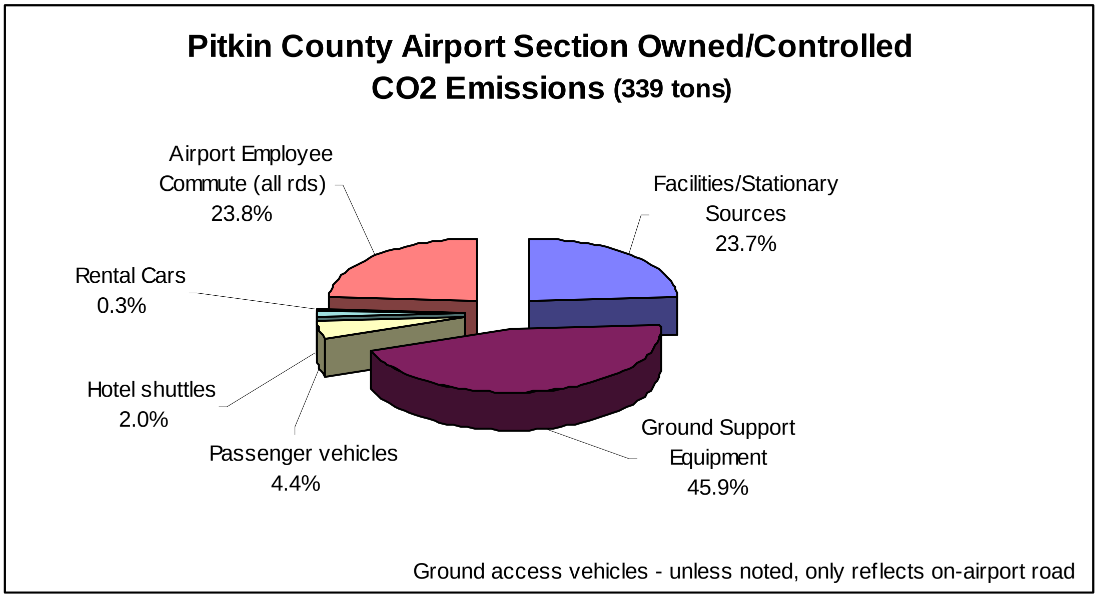
User/Source Category	CO2 (tons/year)	Percent of User	Percent of Total
Airport-owned/controlled			
Facilities/Stationary Sources	80	23.7%	0.1%
Ground Support Equipment	155	45.9%	0.3%
Ground Access Vehicles			
Passenger vehicles (on-airport roads)	15	4.4%	0.0%
Hotel shuttles (on-airport roads)	7	2.0%	0.0%
Rental Cars (on-airport roads)	1	0.3%	0.0%
Airport Employee Commute (all roads)	81	23.8%	0.1%
Subtotal	**339**	**100.0%**	**0.6%**
Airlines/Tenants/Aircraft Operator-owned/controlled			
Aircraft			
Approach	2,110	3.8%	3.7%
Taxi/Idle/Delay	3,433	6.2%	6.1%
Takeoff	3,869	7.0%	6.9%
Climbout	1,009	1.8%	1.8%
Residual/Cruise/APU	38,560	70.2%	68.3%
Sub-total	48,982	89.2%	86.8%
Ground Support Equipment	5,924	10.8%	10.5%
Ground Access Vehicles			
Tenant GAV	0	0.0%	0.0%
Tenant Employee Commute (all roads)	25	0.0%	0.0%
Stationary Sources	0	0.0%	0.0%
Subtotal	**54,931**	**100.0%**	**97.4%**
Public-owned/controlled			
Passenger Vehicles (off-airport roads)	557	48.4%	1.0%
Rental Car Travel (all roads)	589	51.1%	1.0%
Hotel Shuttles (off airport roads)	6	0.5%	0.0%
Subtotal	**1,152**	**100.0%**	**2.0%**
Total	**56,421**		**100%**

*** Note that County-owned vehicles traveling on public roads are noted in the GSE, due to fuel format.
Note: At this time, only CO_2 emissions are reflected, as factors for other GHG are not available for all sources. Note that the greenpower purchased by the County has not been subtracted from the facility emissions.

III.1 PITKIN COUNTY OWNED/CONTROLLED EMISSIONS

As noted in **Table III-1**, Pitkin County Airport Section-related emissions represent 339 metric tons of CO_2 in 2006. **Figure III-1** shows the proportion of emissions associated with the Pitkin County Airport Section.

FIGURE III-1

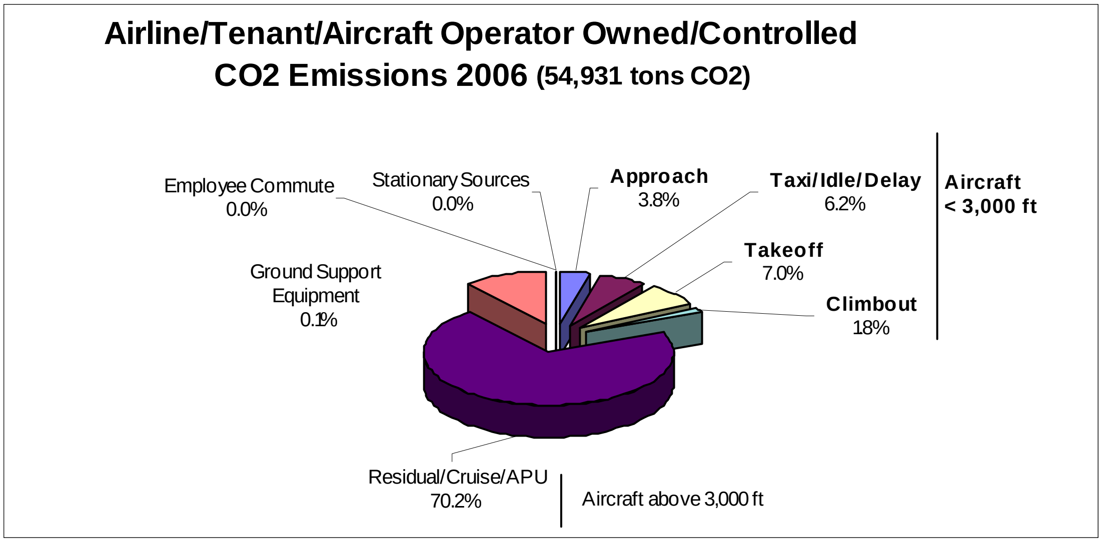


As this chart notes, the largest portion of greenhouse gas emissions that the County owns and controls is associated with energy necessary to power airport support vehicles (ground support vehicles), ground access vehicles traveling on airport roads, and power associated with airport facilities.

III.2 AIRLINE/TENANT/AIRCRAFT OPERATOR OWNED/CONTROLLED EMISSIONS

Airline/tenant/aircraft operator-owned and controlled emissions represent 97.4% of total airport-related emissions or 54,931 metric tons of CO_2 in 2006. As would be expected, aircraft represent the single largest source of CO_2 emissions for this category of source ownership at 89% (48,982 metric tons of CO_2) as shown in **Figure III-2**. GSE represent the second largest source of airline/tenant emissions at 10.8% of the airline/tenant/aircraft operator emissions. No tenant information was pursued concerning facility of stationary source emissions and no data was available concerning tenant ground access travel with the exception of a limited response for tenant employee data. It is likely that some facility-based power is expended by tenants, and tenant maintenance and industrial activities are conducted with some leaseholds which are not reflected in this inventory. Thus, emissions for the airline/tenant/aircraft operator owned and controlled sources are likely to be slightly underestimated.

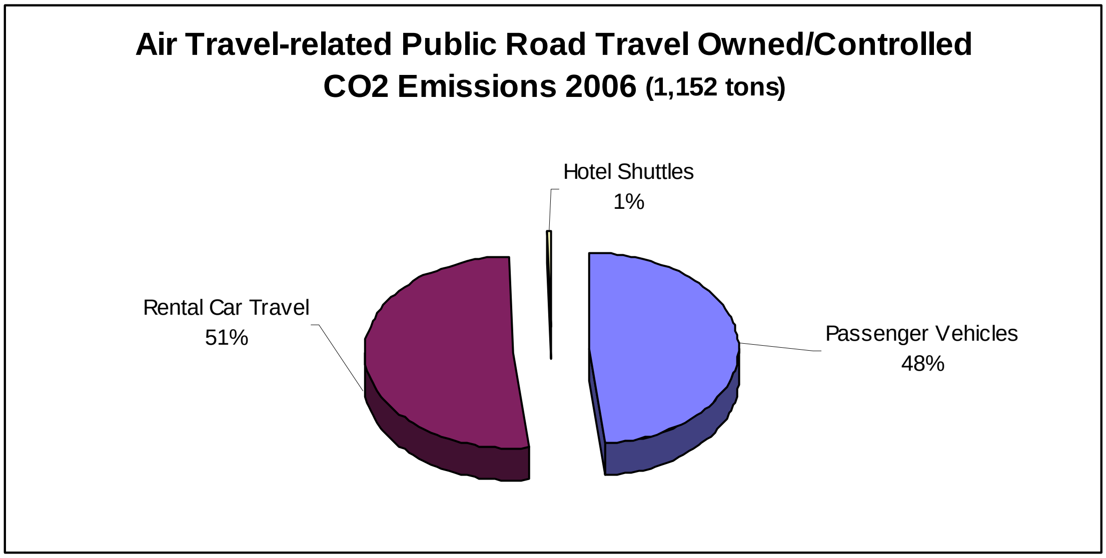
FIGURE III-2



III.3 PUBLIC-OWNED/CONTROLLED EMISSIONS

Within this inventory, all of the public-owned and controlled emissions reflect on-road travel associated with airport activity: either through employee work-commute travel or vehicular access by passengers. Of airport-related emissions this user group represents 2% of all emissions or 1,152 metric tons of CO_2 in 2006. **Figure III-3** shows the proportion of emissions associated with each category of public owned and controlled ground access vehicle use of the Airport.

FIGURE III-3



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IV. FUTURE CONSIDERATIONS

The inventory presented in the prior chapter represents a more in depth presentation of airport-related greenhouse gas emissions over that prepared by the Canary Initiative. However, as noted through the documentation of the methodologies deployed on other airport-related inventories, as well this version, improvements could be made in the data collection and emission estimation methodologies. This chapter of the report discusses the data limitations and their potential consequences on the emissions inventories, and identifies steps that could be taken to improve future inventories.

IV.1. DATA LIMITATIONS/IMPACT ON THE EMISSIONS INVENTORY

As a consistent methodology is not available for quantifying airport-related greenhouse gas emissions, the inventory prepared for this evaluation relies on known data, where data is available. The following bullets note limits associated with the various source inventories:

- Aircraft: the aircraft emissions inventory is of high quality. At this time, the fuel dispensed approach is the optimal method available to quantify aircraft-related emissions. In the future, it is likely that alternative methods may become available. Limitations with this data are the uncertainty associated to the quantity of fuel that may be uplifted in other cities, not dispensed at the airport, and thus underreporting the emissions associated with the airport under review. At this time it is not possible to identify the specific uncertainty that is introduced by this data. In addition, given the current format of fuel data, it is not possible to separate out the emissions associated with Auxiliary Power Unit (APU). However, it is anticipated that in the future either fuel consumption data or emissions data may become available for APU use.
- Ground Support Equipment (GSE): As noted, no greenhouse gas emission factor data is currently available for GSE, and thus this evaluation relied on average emission factors associated with other non-road vehicles. Further, a GSE vehicle and vehicle use inventory was not available for Aspen Pitkin County Airport. Consideration should be given to completing an inventory of such vehicles for future inventories.
- Ground Access Vehicles (GAV): Virtually no Aspen Pitkin County Airport specific surface transportation data was available. This affects the ability to identify emissions associated with the on-airport or off-airport surface travel. Therefore, as noted in Section II.2.3, estimates of surface travel were prepared for this analysis. With improved surface travel data, consideration could be made to use the EPA's MOBILE model, with either Colorado or Pitkin County specific vehicle mix data.
- Facilities/Stationary Sources: The County retains data concerning fuel use by airport facilities. This enables a clear identification of CO_2 emissions. Data concerning tenant utility use was not available.

IV.2 FUTURE DATA COLLECTION

To date, the County has collected data for Aspen-Pitkin County Airport commensurate with its size and needs for various planning efforts. That information collection and interpretation process has been designed to assist the County with understanding its customer service and operational conditions. Consideration should be given to modifying these data collection efforts to allow clearer identification of characteristics associated with various airport user groups, and thus their greenhouse gas emissions. Such examples could include:

- Passenger survey: The County could conduct an in-flight/General Aviation User flight survey to identify passenger and ground movements associated with air travel. However, such surveys can be costly. They are often undertaken during the peak travel months and require the cooperation of the airlines and fixed based operators. If such a survey were conducted, the following information could be collected:
  - Size of the travel party;
  - Type of vehicle(s) transporting the party to/from the Airport (auto, SUV, pickup truck, van, bus)
  - Location and distance that each passenger traveled on area roadways
- Surface Vehicle Travel: Given the limited data available concerning airport-related roadway travel, the following data could be undertaken in the future:
  - Periodic survey of the vehicles using the airport roadway system. Data should be categorized by the general type of vehicles (i.e., auto, SUV, pickup truck, delivery truck, heavy truck, etc.), fuel type (diesel or gas), and the facility (terminal, parking lot, etc) that each vehicle visited. Should the County conduct an airport-wide roadway traffic analysis that simulates the roadway system, travel could be segregated by user type and vehicle type, and then the miles traveled by each category could be reported.
  - The County could consider conducting a survey to follow-up on the release of this greenhouse gas inventory of the on-airport rental car operators to identify the size of the rental car fleet, the miles driven, and the total dispensed/acquired by the rental car firms. As the analysis in this report assumes that all rental car operators are the same as the one respondent to this study's survey, substantial changes could arise in this category of emissions.
  - While one rental car operator reported average miles traveled, little other Aspen-Pitkin County Airport specific data was available. Data concerning rental car use that could be collected could include: 1) fuel dispensed by fueling operators to rental cars at the Airport as part of their quick-turn-around service; 2) average miles travelled per vehicle, 3) total vehicles rented by class of vehicle, etc.

  Confirmation concerning these uses would improve the accuracy of the analysis in the future.
- Facilities/Stationary Sources: information available to this evaluation focused on the total power required to power County-owned facilities. Consideration should be given to stratifying this power demand by resource (terminal, support facilities, airfield, etc). In addition, tenant based energy use should be collected.
- Ground Support Equipment (GSE):
  - The County could conduct a survey of off-road vehicle use at the Airport. Such a survey should note: vehicle type, fuel type (diesel, gas, CNG, electric), number of vehicles present on the airport, hours used per year or minutes used per LTO.

Appendices

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Appendix A - Abbreviations, Glossary, and References

Abbreviations

ACRP - Airport Cooperative Research Program of the Transportation Research Board
APU - Auxiliary Power Unit
ASE - Aspen-Pitkin County Airport

BTU - British Thermal Units

CCP - Climate Protection Program of ICLEI
CEQA - California Environmental Quality Act
CNG - Compressed Natural Gas
CO_2 - Carbon Dioxide
$CO_{2\text{-eq}}$ -Carbon Dioxide equivalent (sometimes CO_{2e})

EDMS - Emissions Dispersion Modeling System
EIA - Energy Information Administration of the Department of Energy
EPA - US Environmental Protection Agency

FAA - Federal Aviation Administration

GAV - Ground Access Vehicle
GHG - Greenhouse Gases
GSE - Ground Support Equipment
g-bhp-hr: Grams per brake horsepower hour

ICLEI - International Council for Local Environmental Initiatives
IPCC - Intergovernmental Panel on Climate Change

kWh - Kilowatt hour

LTO - Landing and Takeoff Cycle

NEPA - National Environmental Policy Act

WRI - World Resource Institute

USEPA - US Environmental Protection Agency

Glossary

ABSORPTION OF RADIATION: The uptake of radiation by a solid body, liquid or gas. The absorbed energy may be transferred or re-emitted.

AEROSOL: Particulate matter, solid or liquid, larger than a molecule but small enough to remain suspended in the atmosphere. Natural sources include salt particles from sea spray, dust and clay particles as a result of weathering of rocks, both of which are carried upward by the wind. Aerosols can also originate as a result of human activities and are often considered pollutants. Aerosols are important in the atmosphere as nuclei for the condensation of water droplets and ice crystals, as participants in various chemical cycles, and as absorbers and scatters of solar radiation, thereby influencing the radiation budget of the Earth's climate system.

AFFORESTATION: Planting of new forests on lands that have not been recently forested.

AIR CARRIER: An operator (e.g., airline) in the commercial system of air transportation consisting of aircraft that hold certificates of Public Convenience and Necessity issued by the Department of Transportation to conduct scheduled or non-scheduled flights within the country or abroad.

AIR POLLUTION: One or more chemicals or substances in high enough concentrations in the air to harm humans, other animals, vegetation, or materials. Such chemicals or physical conditions (such as excess heat or noise) are called air pollutants.

ALTERNATIVE ENERGY: Energy derived from nontraditional sources (e.g., compressed natural gas, solar, hydroelectric, wind).

ANTHROPOGENIC: Human made. In the context of greenhouse gases, anthropogenic emissions are produced as the result of human activities.

ATMOSPHERE: The mixture of gases surrounding the Earth. The Earth's atmosphere consists of about 79.1 percent nitrogen (by volume), 20.9 percent oxygen, 0.036 percent carbon dioxide and trace amounts of other gases. The atmosphere can be divided into a number of layers according to its mixing or chemical characteristics, generally determined by its thermal properties (temperature). The layer nearest the Earth is the troposphere, which reaches up to an altitude of about 8 kilometers (about 5 miles) in the polar regions and up to 17 kilometers (nearly 11 miles) above the equator. The stratosphere, which reaches to an altitude of about 50 kilometers (31miles) lies atop the troposphere. The mesosphere, which extends from 80 to 90 kilometers atop the stratosphere, and finally, the thermosphere, or ionosphere, gradually diminishes and forms a fuzzy border with outer space. There is relatively little mixing of gases between layers.

AVIATION GASOLINE: All special grades of gasoline for use in aviation reciprocating engines, as cited in the American Society for Testing and Materials (ASTM) specification D 910. Includes all refinery products within the gasoline range that are to be marketed straight or in blends as aviation gasoline without further processing (any refinery operation except mechanical blending). Also included are finished components in the gasoline range, which will be used for blending or compounding into aviation gasoline.

BIODEGRADABLE: Material that can be broken down into simpler substances (elements and compounds) by bacteria or other decomposers. Paper and most organic wastes such as animal manure are biodegradable.

BIOFUEL: Gas or liquid fuel made from plant material (biomass). Includes wood, wood waste, wood liquors, peat, railroad ties, wood sludge, spent sulfite liquors, agricultural waste, straw, tires, fish oils, tall oil, sludge waste, waste alcohol, municipal solid waste, landfill gases, other waste, and ethanol blended into motor gasoline.

BIOMASS: Total dry weight of all living organisms that can be supported at each tropic level in a food chain. Also, materials that are biological in origin, including organic material (both living and dead) from above and below ground, for example, trees, crops, grasses, tree litter, roots, and animals and animal waste.

BIOMASS ENERGY: Energy produced by combusting biomass materials such as wood. The carbon dioxide emitted from burning biomass will not increase total atmospheric carbon dioxide if this consumption is done on a sustainable basis (i.e., if in a given period of time, re-growth of biomass takes up as much carbon dioxide as is released from biomass combustion). Biomass energy is often suggested as a replacement for fossil fuel combustion.

BRITISH THERMAL UNIT (Btu): The quantity of heat required to raise the temperature of one pound of water one degree of Fahrenheit at or near 39.2 degrees Fahrenheit.

BUNKER FUEL: Fuel supplied to ships and aircraft for international transportation, irrespective of the flag of the carrier, consisting primarily of residual and distillate fuel oil for ships and jet fuel for aircraft.

CARBON BLACK: An amorphous form of carbon, produced commercially by thermal or oxidative decomposition of hydrocarbons and used principally in rubber goods, pigments, and printer's ink.

CARBON CYCLE: All carbon reservoirs and exchanges of carbon from reservoir to reservoir by various chemical, physical, geological, and biological processes. Usually thought of as a series of the four main reservoirs of carbon interconnected by pathways of exchange. The four reservoirs, regions of the Earth in which carbon behaves in a systematic manner, are the atmosphere, terrestrial biosphere (usually includes freshwater systems), oceans, and sediments (includes fossil fuels). Each of these global reservoirs may be subdivided into smaller pools, ranging in size from individual communities or ecosystems to the total of all living organisms (biota).

CARBON DIOXIDE: A colorless, odorless, non-poisonous gas that is a normal part of the ambient air. Carbon dioxide is a product of fossil fuel combustion. Although carbon dioxide does not directly impair human health, it is a greenhouse gas that traps terrestrial (i.e., infrared) radiation and contributes to the potential for global warming.

CARBON EQUIVALENT (CE) or Carbon Dioxide Equivalent: A metric measure used to compare the emissions of the different greenhouse gases based upon their global warming potential (GWP). Greenhouse gas emissions in the United States are most commonly expressed as "million metric tons of carbon equivalents" (MMTCE). Global warming potentials are used to convert greenhouse gases to carbon dioxide equivalents ($CO_{2\text{-eq}}$).

CARBON SEQUESTRATION: The uptake and storage of carbon. Trees and plants, for example, absorb carbon dioxide, release the oxygen and store the carbon. Fossil fuels were at one time biomass and continue to store the carbon until burned.

CARBON SINKS: Carbon reservoirs and conditions that take-in and store more carbon (i.e., carbon sequestration) than they release. Carbon sinks can serve to partially offset greenhouse gas emissions. Forests and oceans are large carbon sinks.

CARBON TETRACHLORIDE (CCl_4): A compound consisting of one carbon atom and four chlorine atoms. It is an ozone depleting substance. Carbon tetrachloride was widely used as a raw material in many industrial applications, including the production of chlorofluorocarbons, and as a solvent. Solvent use was ended in the United States when it was discovered to be carcinogenic.

CHLOROFLUOROCARBONS (CFCs): Organic compounds made up of atoms of carbon, chlorine, and fluorine. An example is CFC-12 ($CC_{l2}F_2$), used as a refrigerant in refrigerators and air conditioners and as a foam blowing agent. Gaseous CFCs can deplete the ozone layer when they slowly rise into the stratosphere, are broken down by strong ultraviolet radiation, release chlorine atoms, and then react with ozone molecules.

CLIMATE: The average weather, usually taken over a 30 year time period, for a particular region and time period. Climate is not the same as weather, but rather, it is the average pattern of weather for a particular region. Weather describes the short-term state of the atmosphere. Climatic elements include precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, and hailstorms, and other measures of the weather.

CLIMATE CHANGE: The term “climate change” is sometimes used to refer to all forms of climatic inconsistency, but because the Earth’s climate is never static, the term is more properly used to imply a significant change from one climatic condition to another. In some cases, “climate change” has been used synonymously with the term, “global warming”; scientists however, tend to use the term in the wider sense to also include natural changes in climate.

CLIMATE FEEDBACK: An atmospheric, oceanic, terrestrial, or other process that is activated by direct climate change induced by changes in radiative forcing. Climate feedbacks may increase (positive feedback) or diminish (negative feedback) the magnitude of the direct climate change.

CLIMATE SYSTEM (OR EARTH SYSTEM): The atmosphere, the oceans, the biosphere, the cryosphere, and the geosphere, together make up the climate system.

COMBUSTION: Chemical oxidation accompanied by the generation of light and heat.

CONCENTRATION: Amount of a chemical in a particular volume or weight of air, water, soil, or other medium.

CONIFEROUS TREES: Cone-bearing trees, mostly evergreens that have needle-shaped or scale-like leaves. They produce wood known commercially as softwood.

CONTRAIL: Contrails are line-shaped clouds or “condensation trails,” composed of ice particles that are visible behind jet aircraft engines, typically at cruise altitudes in the upper atmosphere. Aircraft engines emit water vapor, carbon dioxide (CO_2), small amounts of nitrogen oxides (NOx), hydrocarbons, carbon monoxide, sulfur gases, and soot and metal particles formed by the high-temperature combustion of jet fuel during flight.

CRITERIA POLLUTANT: A pollutant determined to be hazardous to human health and regulated under EPA’s National Ambient Air Quality Standards. The 1970 amendments to the Clean Air Act require EPA to describe the health and welfare impacts of a pollutant as the “criteria” for inclusion in the regulatory regime. In this report, emissions of the criteria pollutants are carbon monoxide (CO), nitrogen oxides (NOx), volatile organic compounds (VOCs), and sulfur oxides (SOx).

DECIDUOUS TREES: Trees such as oaks and maples that lose their leaves during part of the year.

DEFORESTATION: Those practices or processes that result in the conversion of forested lands for non-forest uses. This is often cited as one of the major causes of the enhanced greenhouse effect for two reasons: 1) the burning or decomposition of the wood releases carbon dioxide; and 2) trees that once removed carbon dioxide from the atmosphere in the process of photosynthesis are no longer present.

DISTILLATE FUEL OIL: A general classification for the petroleum fractions produced in conventional distillation operations. Included are products known as No. 1, No. 2, and No. 4 fuel oils and No. 1, No. 2, and No. 4 diesel fuels. Used primarily for space heating, on and off-highway diesel engine fuel (including railroad engine fuel and fuel for agricultural machinery), and electric power generation.

EMISSION FACTOR: The rate at which pollutants are emitted into the atmosphere by one source or a combination of sources.

EMISSION INVENTORY: A list of air pollutants emitted into a community's, state's, nation's, or the Earth's atmosphere in amounts per some unit time (e.g. day or year) by type of source. An emission inventory has both political and scientific applications.

EMISSIONS COEFFICIENT/FACTOR: A unique value for scaling emissions to activity data in terms of a standard rate of emissions per unit of activity (e.g., grams of carbon dioxide emitted per barrel of fossil fuel consumed).

EMISSIONS: Releases of gases to the atmosphere (e.g., the release of carbon dioxide during fuel combustion). Emissions can be either intended or unintended releases.

ENERGY CONSERVATION: Reduction or elimination of unnecessary energy use and waste.

ENERGY INTENSITY: Ratio between the consumption of energy to a given quantity of output; usually refers to the amount of primary or final energy consumed per unit of gross domestic product.

ENERGY QUALITY: Ability of a form of energy to do useful work. High-temperature heat and the chemical energy in fossil fuels and nuclear fuels are concentrated high quality energy. Low quality energy such as low-temperature heat is dispersed or diluted and cannot do much useful work.\

ENERGY: The capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Most of the world's convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means in order to accomplish tasks. In the United States, electrical energy is often measured in kilowatt-hours (kWh),while heat energy is often measured in British thermal units (Btu).

ENERGY-EFFICIENCY: The ratio of the useful output of services from an article of industrial equipment to the energy use by such an article; for example, vehicle miles traveled per gallon of fuel (mpg).

ENHANCED GREENHOUSE EFFECT: The concept that the natural greenhouse effect has been enhanced by anthropogenic emissions of greenhouse gases. Increased concentrations of carbon dioxide, methane, and nitrous oxide, CFCs, HFCs, PFCs, SF6, NF3, and other photochemically important gases caused by human activities such as fossil fuel consumption, trap more infra-red radiation, thereby exerting a warming influence on the climate.

ENPLANEMENTS: The number of passengers on departing aircraft.

ETHANOL (C_2H_5OH): Otherwise known as ethyl alcohol, alcohol, or grain spirit. A clear, colorless, flammable oxygenated hydrocarbon with a boiling point of 78.5 degrees Celsius in the anhydrous state. In transportation, ethanol is used as a vehicle fuel by itself (E100), blended with gasoline (E85), or as a gasoline octane enhancer and oxygenate (10 percent concentration).

FAA ASDi (Aircraft Situation Display to Industry): This represents data collected by the FAA that tracks the minute-by-minute progress of their aircraft in real-time. The ASDI information includes the location, altitude, airspeed, destination, estimated time of arrival and tail number or designated identifier of air carrier and general aviation aircraft operating on IFR flight plans within U.S. airspace.

FAA T-1 DATA: This data base refers to information collected by the FAA and reported by the Bureau of Transportation Statistics concerning on-time arrival data for non-stop domestic flights by major air carriers, and provides such additional items as departure and arrival delays, origin and destination airports, flight numbers, scheduled and actual departure and arrival times, cancelled or diverted flights, taxi-out and taxi-in times, air time, and non-stop distance.

FIXED BASED OPERATOR (FBO): A private operator that may conduct refueling, aircraft or ground support equipment services for others at the airport.

FLUOROCARBONS: Carbon-fluorine compounds that often contain other elements such as hydrogen, chlorine, or bromine. Common fluorocarbons include chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs).

FORCING MECHANISM: A process that alters the energy balance of the climate system (i.e., changes the relative balance between incoming solar radiation and outgoing infrared radiation from Earth). Such mechanisms include changes in solar irradiance, volcanic eruptions, and enhancement of the natural greenhouse effect by emission of carbon dioxide.

FOREST: Terrestrial ecosystem (biome) with enough average annual precipitation (at least 76 centimeters or 30 inches) to support growth of various species of trees and smaller forms of vegetation.

FOSSIL FUEL: A general term for buried combustible geologic deposits of organic materials, formed from decayed plants and animals that have been converted to crude oil, coal, natural gas, or heavy oils by exposure to heat and pressure in the Earth's crust over hundreds of millions of years.

FOSSIL FUEL COMBUSTION: Burning of coal, oil (including gasoline), or natural gas. The burning needed to generate energy release carbon dioxide by-products that can include unburned hydrocarbons, methane, and carbon monoxide. Carbon monoxide, methane, and many of the unburned hydrocarbons slowly oxidize into carbon dioxide in the atmosphere. Common sources of fossil fuel combustion include cars and electric utilities.

FUGITIVE EMISSIONS: Unintended gas leaks from the processing, transmission, and/or transportation of fossil fuels, CFCs from refrigeration leaks, SF6 from electrical power distributor, etc.

GENERAL AVIATION: That portion of civil aviation, which encompasses all facets of aviation except air carriers. It includes any air taxis, commuter air carriers, and air travel clubs, which do not hold Certificates of Public Convenience and Necessity.

GEOTHERMAL ENERGY: Heat transferred from the Earth's molten core to underground deposits of dry steam (steam with no water droplets), wet steam (a mixture of steam and water droplets), hot water, or rocks lying fairly close to the Earth's surface.

GLOBAL WARMING POTENTIAL (GWP): The index used to translate the level of emissions of various gases into a common measure in order to compare the relative radiative forcing of different gases without directly calculating the changes in atmospheric concentrations. GWPs are calculated as the ratio of the radiative forcing that would result from the emissions of one kilogram of a greenhouse gas to that from the emission of one kilogram of carbon dioxide over a period of time (usually 100 years). Gases involved in complex atmospheric chemical processes have not been assigned GWPs.

GLOBAL WARMING: The progressive gradual rise of the Earth's surface temperature thought to be caused by the greenhouse effect and responsible for changes in global climate patterns.

GREENHOUSE EFFECT: Trapping and build-up of heat in the atmosphere (troposphere) near the Earth's surface. Some of the heat flowing back toward space from the Earth's surface is absorbed by water vapor, carbon dioxide, ozone, and several other gases in the atmosphere and then reradiated back toward the Earth's surface. If the atmospheric concentrations of these greenhouse gases rise, the average temperature of the lower atmosphere will gradually increase.

GREENHOUSE GAS (GHG): Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include, but are not limited to, water vapor, carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrochlorofluorocarbons (HCFCs), ozone (O3), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6).

HEAT CONTENT: The amount of heat per unit mass released upon complete combustion.

HEAT: Form of kinetic energy that flows from one body to another when there is a temperature difference between the two bodies. Heat always flows spontaneously from a hot sample of matter to a colder sample of matter. This is one way to state the second law of thermodynamics.

HYDROCARBONS: Substances containing only hydrogen and carbon. Fossil fuels are made up of hydrocarbons.

HYDROCHLOROFLUOROCARBONS (HCFCS): Compounds containing hydrogen, fluorine, chlorine, and carbon atoms. Although ozone depleting substances, they are less potent at destroying stratospheric ozone than chlorofluorocarbons (CFCs). They have been introduced as temporary replacements for CFCs and are also greenhouse gases.

HYDROELECTRIC POWER PLANT: Structure in which the energy of fading or flowing water spins a turbine generator to produce electricity.

HYDROFLUOROCARBONS (HFCS): Compounds containing only hydrogen, fluorine, and carbon atoms. They were introduced as alternatives to ozone depleting substances in serving many industrial, commercial, and personal needs. HFCs are emitted as by-products of industrial processes and are also used in manufacturing. They do not significantly deplete the stratospheric ozone layer, but they are powerful greenhouse gases with global warming potentials ranging from 140 (HFC-152a) to 11,700 (HFC-23).

HYDROPOWER: Electrical energy produced by falling or flowing water.

HYDROSPHERE: All the Earth's liquid water (oceans, smaller bodies of fresh water, and underground aquifers), frozen water (polar ice caps, floating ice, and frozen upper layer of soil known as permafrost), and small amounts of water vapor in the atmosphere.

INDUSTRIAL SECTOR: Construction, manufacturing, agricultural and mining establishments.

INFRARED RADIATION: The heat energy that is emitted from all solids, liquids, and gases. In the context of the greenhouse issue, the term refers to the heat energy emitted by the Earth's surface and its atmosphere. Greenhouse gases strongly absorb this radiation in the Earth's atmosphere, and re-radiate some of it back towards the surface, creating the greenhouse effect.

INORGANIC COMPOUND: Combination of two or more elements other than those used to form organic compounds.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC): The IPCC was established jointly by the United Nations Environment Programme and the World Meteorological Organization in 1988. The purpose of the IPCC is to assess information in the scientific and technical literature related to all significant components of the issue of climate change. The IPCC draws upon hundreds of the world's expert scientists as authors and thousands as expert reviewers. Leading experts on climate change and environmental, social, and economic sciences from some 60 nations have helped the IPCC to prepare periodic assessments of the scientific underpinnings for understanding global climate change and its consequences. With its capacity for reporting on climate change, its consequences, and the viability of adaptation and mitigation measures, the IPCC is also looked to as the official advisory body to the world's governments on the state of the science of the climate change issue. For example, the IPCC organized the development of internationally accepted methods for conducting national greenhouse gas emission inventories.

INTERNATIONAL COUNCIL FOR LOCAL ENVIRONMENTAL INITIATIVES (ICLEI): is an international association of local governments and national and regional local government organizations that have made a commitment to sustainable development. More than 630 cities, towns, counties, and their associations worldwide comprise ICLEI's growing membership. ICLEI works with these and hundreds of other local governments through international performance-based, results-oriented campaigns and programs. The ICLEI Cities for Climate Protection (CCP) Campaign assists cities to adopt policies and implement quantifiable measures to reduce local greenhouse gas emissions, improve air quality, and enhance urban livability and sustainability. More than 800 local governments participate in the CCP, integrating climate change mitigation into their decision-making processes. http://www.iclei.org/index.php?id=800

JET FUEL: Includes both naphtha-type and kerosene-type fuels meeting standards for use in aircraft turbine engines. Although most jet fuel is used in aircraft, some is used for other purposes such as generating electricity.

JOULE: The energy required to push with a force of one Newton for one meter.

KEROSENE: A petroleum distillate that has a maximum distillation temperature of 401 degrees Fahrenheit at the 10 percent recovery point, a final boiling point of 572 degrees Fahrenheit, and a minimum flash point of 100 degrees Fahrenheit. Used in space heaters, cookstoves, and water heaters, and suitable for use as an illuminant when burned in wick lamps.

KYOTO PROTOCOL: An international agreement struck by nations attending the Third Conference of Parties (COP) to the United Nations Framework Convention on Climate Change (held in December of 1997 in Kyoto, Japan) to reduce worldwide emissions of greenhouse gases. If ratified and put into force, individual countries have committed to reduce their greenhouse gas emissions by a specified amount.

LANDING AND TAKEOFF CYCLE (LTO): LTO refers to an aircraft's landing and takeoff (LTO) cycle. One aircraft LTO is equivalent to two aircraft operations (one landing and one takeoff). The standard LTO cycle begins when the aircraft crosses into the mixing zone as it approaches the airport on its descent from cruising altitude, lands and taxis to the gate. The cycle continues as the aircraft taxis back out to the runway for takeoff and climbout as its heads out of the mixing zone and back up to cruising altitude. The five specific operating modes in a standard LTO are: approach, taxi/idle-in, taxi/idle-out, takeoff, and climbout. Most aircraft go through this sequence during a complete standard operating cycle.

LIFETIME (ATMOSPHERIC): The lifetime of a greenhouse gas refers to the approximate amount of time it would take for the anthropogenic increment to an atmospheric pollutant concentration to return to its natural level (assuming emissions cease) as a result of either being converted to another chemical compound or being taken out of the atmosphere via a sink. This time depends on the pollutant's sources and sinks as well as its reactivity. The lifetime of a pollutant is often considered in conjunction with the mixing of pollutants in the atmosphere; a long lifetime will allow the pollutant to mix throughout the atmosphere. Average lifetimes can vary from about a week (e.g., sulfate aerosols) to more than a century (e.g., CFCs, carbon dioxide).

LIGHT-DUTY VEHICLES: Automobiles and light trucks combined.

LIQUEFIED NATURAL GAS (LNG): Natural gas converted to liquid form by cooling to a very low temperature.

LIQUEFIED PETROLEUM GAS (LPG): Ethane, ethylene, propane, propylene, normal butane, butylene, and isobutane produced at refineries or natural gas processing plants, including plants that fractionate new natural gas plant liquids.

LONGWAVE RADIATION: The radiation emitted in the spectral wavelength greater than 4 micrometers corresponding to the radiation emitted from the Earth and atmosphere. It is sometimes referred to as terrestrial radiation or infrared radiation, although somewhat imprecisely.

LOW EMISSION VEHICLE (LEV): A vehicle meeting the low-emission vehicle standards.

METHANE (CH_4): A hydrocarbon that is a greenhouse gas with a global warming potential most recently estimated at 21. Methane is produced through anaerobic (without oxygen) decomposition of waste in landfills, animal digestion, decomposition of animal wastes, production and distribution of natural gas and petroleum, coal production, and incomplete fossil fuel combustion. The atmospheric concentration of methane has been shown to be increasing at a rate of about 0.6 percent per year and the concentration of about 1.7 per million by volume (ppmv) is more than twice its pre-industrial value. However, the rate of increase of methane in the atmosphere may be stabilizing.

METHANOL (CH_3OH): A colorless, poisonous liquid with essentially no odor and little taste. It is the simplest alcohol with a boiling point of 64.7 degrees Celsius. In transportation, methanol is used as a vehicle fuel by itself (M100), or blended with gasoline (M85).

METRIC TON: Common international measurement for the quantity of greenhouse gas emissions. A metric ton is equal to 1,000 kilograms, 2,204.6 pounds, or 1.1023 short tons.

MIXING HEIGHT: The height of the completely mixed portion of atmosphere that begins at the earth's surface and extends to a few thousand feet overhead where the atmosphere becomes fairly stable. See also "inversion".

MOBILE SOURCE: A moving vehicle that emits pollutants. Such sources include airplanes, cars, trucks and ground support equipment.

MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER: The Montreal Protocol and its amendments control the phase-out of ozone depleting substances production and use. Under the Protocol, several international organizations report on the science of ozone depletion, implement projects to help move away from ozone depleting substances, and provide a forum for policy discussions. In the United States, the Protocol is implemented under the rubric of the Clean Air Act Amendments of 1990.

MOTOR GASOLINE: A complex mixture of relatively volatile hydrocarbons, with or without small quantities of additives, obtained by blending appropriate refinery streams to form a fuel suitable for use in spark-ignition engines. Motor gasoline includes both leaded and unleaded grades of finished gasoline, blending components, and gasohol.

NATURAL GAS: Underground deposits of gases consisting of 50 to 90 percent methane (CH_4) and small amounts of heavier gaseous hydrocarbon compounds such as propane (C_3H_4) and butane (C_4H_{10}).

NITROGEN CYCLE: Cyclic movement of nitrogen in different chemical forms from the environment, to organisms, and then back to the environment.

NITROGEN OXIDES (NO_X): Gases consisting of one molecule of nitrogen and varying numbers of oxygen molecules. Nitrogen oxides are produced, for example, by the combustion of fossil fuels in vehicles and electric power plants. In the atmosphere, nitrogen oxides can contribute to formation of photochemical ozone (smog), impair visibility, and have health consequences; they are considered pollutants.

NITROUS OXIDE (N_2O): A powerful greenhouse gas with a global warming potential most recently evaluated at 310. Major sources of nitrous oxide include soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production, and biomass burning.

NONBIODEGRADABLE: Substance that cannot be broken down in the environment by natural processes.

NON-METHANE VOLATILE ORGANIC COMPOUNDS (NMVOCS): Organic compounds, other than methane, that participate in atmospheric photochemical reactions.

NON-POINT SOURCE: Large land area such as crop fields and urban areas that discharge pollutant into surface and underground water over a large area.

NUCLEAR ELECTRIC POWER: Electricity generated by an electric power plant whose turbines are driven by steam generated in a reactor by heat from the fissioning of nuclear fuel.

NUCLEAR ENERGY: Energy released when atomic nuclei undergo a nuclear reaction such as the spontaneous emission of radioactivity, nuclear fission, or nuclear fusion.

ORGANIC COMPOUND: Molecule that contains atoms of the element carbon, usually combined with itself and with atoms of one or more other element such as hydrogen, oxygen, nitrogen, sulfur, phosphorus, chlorine, or fluorine.

OXIDIZE: To chemically transform a substance by combining it with oxygen.

OZONE: A colorless gas with a pungent odor, having the molecular form of O3, found in two layers of the atmosphere, the stratosphere and the troposphere. Ozone is a form of oxygen found naturally in the stratosphere that provides a protective layer shielding the Earth from ultraviolet radiation's harmful health effects on humans and the environment. In the troposphere, ozone is a chemical oxidant and major component of photochemical smog. Ozone can seriously affect the human respiratory system.

OZONE DEPLETING SUBSTANCE (ODS): A family of man-made compounds that includes, but is not limited to, chlorofluorocarbons (CFCs), bromofluorocarbons (halons), methyl chloroform, carbon tetrachloride, methyl bromide, and hydrochlorofluorocarbons (HCFCs). These compounds have been shown to deplete stratospheric ozone, and therefore are typically referred to as ODSs.

OZONE LAYER: Layer of gaseous ozone (O_3) in the stratosphere that protects life on Earth by filtering out harmful ultraviolet radiation from the sun.

OZONE PRECURSORS: Chemical compounds, such as carbon monoxide, methane, non-methane hydrocarbons, and nitrogen oxides, which in the presence of solar radiation react with other chemical compounds to form ozone, mainly in the troposphere.

PARTICULATE MATTER (PM): Solid particles or liquid droplets suspended or carried in the air.

PARTS PER BILLION (ppb): Number of parts of a chemical found in one billion parts of a particular gas, liquid, or solid mixture.

PARTS PER MILLION (ppm): Number of parts of a chemical found in one million parts of a particular gas, liquid, or solid.

PERFLUOROCARBONS (PFCs): A group of human-made chemicals composed of carbon and fluorine only. These chemicals (predominantly CF_4 and C_2F_6) were introduced as alternatives, along with hydrofluorocarbons, to the ozone-depleting substances. In addition, PFCs are emitted as by-products of industrial processes and are also used in manufacturing. PFCs do not harm the stratospheric ozone layer, but they are powerful greenhouse gases: CF_4 has a global warming potential (GWP) of 6,500 and C_2F_6 has a GWP of 9,200.

POINT SOURCE: A single identifiable source that discharges pollutants into the environment. Examples are smokestack, sewer, ditch, or pipe.

POLLUTION: A change in the physical, chemical, or biological characteristics of the air, water, or soil that can affect the health, survival, or activities of humans in an unwanted way. Some expand the term to include harmful effects on all forms of life.

POLYVINYL CHLORIDE (PVC): A polymer of vinyl chloride. It is tasteless, odorless and insoluble in most organic solvents. A member of the family vinyl resin, used in soft flexible films for food packaging and in molded rigid products, such as pipes, fibers, upholstery, and bristles.

RADIATION: Energy emitted in the form of electromagnetic waves. Radiation has differing characteristics depending upon the wavelength. Because the radiation from the Sun is relatively energetic, it has a short wavelength (e.g., ultraviolet, visible, and near infrared) while energy re-radiated from the Earth's surface and the atmosphere has a longer wavelength (e.g., infrared radiation) because the Earth is cooler than the Sun.

RADIATIVE FORCING: A change in the balance between incoming solar radiation and outgoing infrared (i.e., thermal) radiation. Without any radiative forcing, solar radiation coming to the Earth would continue to be approximately equal to the infrared radiation emitted from the Earth. The addition of greenhouse gases to the atmosphere traps an increased fraction of the infrared radiation, reradiating it back toward the surface of the Earth and thereby creates a warming influence.

RECYCLING: Collecting and reprocessing a resource so it can be used again. An example is collecting aluminum cans, melting them down, and using the aluminum to make new cans or other aluminum products.

REFORESTATION: Replanting of forests on lands that have recently been harvested.

RENEWABLE ENERGY: Energy obtained from sources that are essentially inexhaustible, unlike, for example, fossil fuels, of which there is a finite supply. Renewable sources of energy include wood, waste, geothermal, wind, photovoltaic, and solar thermal energy.

RESIDENCE TIME: Average time spent in a reservoir by an individual atom or molecule. Also, this term is used to define the age of a molecule when it leaves the reservoir. With respect to greenhouse gases, residence time usually refers to how long a particular molecule remains in the atmosphere.

RESIDUAL FUEL OIL: The heavier oils that remain after the distillate fuel oils and lighter hydrocarbons are distilled away in refinery operations and that conform to ASTM Specifications D396 and D975. Included are No. 5, a residual fuel oil of medium viscosity; Navy Special, for use in steam-powered vessels in government service and in shore power plants; and No. 6, which includes Bunker C fuel oil and is used for commercial and industrial heating, electricity generation, and to power ships. Imports of residual fuel oil include imported crude oil burned as fuel.

SECTOR: Division, most commonly used to denote type of energy consumer (e.g., residential) or according to the Intergovernmental Panel on Climate Change, the type of greenhouse gas emitter (e.g., industrial process).

SHORT TON: Common measurement for a ton in the United States. A short ton is equal to 2,000 lbs. or 0.907 metric tons.

SINK: A reservoir that uptakes a pollutant from another part of its cycle. Soil and trees tend to act as natural sinks for carbon.

SOLAR ENERGY: Direct radiant energy from the sun. It also includes indirect forms of energy such as wind, falling or flowing water (hydropower), ocean thermal gradients, and biomass, which are produced when direct solar energy interact with the Earth.

SOLAR RADIATION: Energy from the Sun. Also referred to as short-wave radiation. Of importance to the climate system, solar radiation includes ultra-violet radiation, visible radiation, and infrared radiation.

SOURCE: Any process or activity that releases a greenhouse gas, an aerosol, or a precursor of a greenhouse gas into the atmosphere.

STRATOSPHERE: Second layer of the atmosphere, extending from about 19 to 48 kilometers (12 to 30 miles) above the Earth's surface. It contains small amounts of gaseous ozone (O3), which filters out about 99 percent of the incoming harmful ultraviolet (UV) radiation. Most commercial airline flights operate at a cruising altitude in the lower stratosphere.

STRATOSPHERIC OZONE: See ozone layer.

SULFUR CYCLE: Cyclic movement of sulfur in different chemical forms from the environment, to organisms, and then back to the environment.

SULFUR DIOXIDE (SO_2): A compound composed of one sulfur and two oxygen molecules. Sulfur dioxide emitted into the atmosphere through natural and anthropogenic processes is changed in a complex series of chemical reactions in the atmosphere to sulfate aerosols. These aerosols are believed to result in negative radiative forcing (i.e., tending to cool the Earth's surface) and do result in acid deposition (e.g., acid rain).

SULFUR HEXAFLUORIDE (SF_6): A colorless gas soluble in alcohol and ether, slightly soluble in water. A very powerful greenhouse gas used primarily in electrical transmission and distribution systems and as a dielectric in electronics. The global warming potential of SF_6 is 23,900.

TEMPERATURE: Measure of the average speed of motion of the atoms or molecules in a substance or combination of substances at a given moment.

TERRESTRIAL: Pertaining to land.

TERRESTRIAL RADIATION: The total infrared radiation emitted by the Earth and its atmosphere in the temperature range of approximately 200 to 300 Kelvin. Terrestrial radiation provides a major part of the potential energy changes necessary to drive the atmospheric wind system and is responsible for maintaining the surface air temperature within limits of livability.

TRANSPORTATION SECTOR: Consists of private and public passenger and freight transportation, as well as government transportation, including military operations.

TROPOSPHERE: The lowest layer of the atmosphere and contains about 95 percent of the mass of air in the Earth's atmosphere. The troposphere extends from the Earth's surface up to about 10 to 15 kilometers. All weather processes take place in the troposphere. Ozone that is formed in the troposphere plays a significant role in both the greenhouse gas effect and urban smog.

ULTRAVIOLET RADIATION (UV): A portion of the electromagnetic spectrum with wavelengths shorter than visible light. The sun produces UV, which is commonly split into three bands of decreasing wavelength. Shorter wavelength radiation has a greater potential to cause biological damage on living organisms. The longer wavelength ultraviolet band, UVA, is not absorbed by ozone in the atmosphere. UVB is mostly absorbed by ozone, although some reaches the Earth. The shortest wavelength band, UVC, is completely absorbed by ozone and normal oxygen in the atmosphere.

UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC): The international treaty unveiled at the United Nations Conference on Environment and Development (UNCED) in June, 1992. The UNFCCC commits signatory countries to stabilize anthropogenic (i.e., human-induced) greenhouse gas emissions to "levels that would prevent dangerous anthropogenic interference with the climate system". The UNFCCC also requires that all signatory parties develop and update national inventories of anthropogenic emissions of all greenhouse gases not otherwise controlled by the Montreal Protocol. http://www.ipcc.ch/

VEHICLE MILES TRAVELED (VMT): One vehicle traveling the distance of one mile. Thus, total vehicle miles is the total mileage traveled by all vehicles.

VOLATILE ORGANIC COMPOUNDS (VOCs): Organic compounds that evaporate readily into the atmosphere at normal temperatures. VOCs contribute significantly to photochemical smog production and certain health problems.

WATER VAPOR: The most abundant greenhouse gas; it is the water present in the atmosphere in gaseous form. Water vapor is an important part of the natural greenhouse effect. While humans are not significantly increasing its concentration, it contributes to the enhanced greenhouse effect because the warming influence of greenhouse gases leads to a positive water vapor feedback. In addition to its role as a natural greenhouse gas, water vapor plays an important role in regulating the temperature of the planet because clouds form when excess water vapor in the atmosphere condenses to form ice and water droplets and precipitation.

WEATHER: Weather is the specific condition of the atmosphere at a particular place and time. It is measured in terms of such things as wind, temperature, humidity, atmospheric pressure, cloudiness, and precipitation. In most places, weather can change from hour-to-hour, day-to-day, and season-to-season. Climate is the average of weather over time and space. A simple way of remembering the difference is that climate is what you expect (e.g. cold winters) and 'weather' is what you get (e.g. a blizzard).

WORLD RESOURCE INSTITUTE (WRI): The World Resources Institute (WRI) is an environmental think tank. WRI, in combination with the World Business Council for Sustainable Development published guidance in 2005 concerning the development of greenhouse gas inventories. www.wri.org

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APPENDIX B

Aspen-Pitkin County Airport Greenhouse Gas Calculations

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Aspen Pitkin County Airport CO2 Emissions 2006

User/Source Category	Fuel Data	Fuel Units	CO2 (tons/year)	Percent of User	Percent of Total
Airport-owned/controlled					
Facilities/Stationary Sources	396	Million BTU	80	23.7%	0.1%
Ground Support Equipment	2,135	Million BTU	155	45.9%	0.3%
Ground Access Vehicles					
Passenger vehicles (on-airport roads)	0	Million BTU	15	4.4%	0.0%
Hotel shuttles (on-airport roads)	96	Million BTU	7	2.0%	0.0%
Rental Cars (on-airport roads)	36	Million BTU	1	0.3%	0.0%
Airport Employee Commute (all roads)	1,135	Million BTU	81	23.8%	0.1%
Subtotal			**339**	**100.0%**	**0.6%**
Airlines/Tenants/Aircraft Operator-owned/controlled					
Aircraft					
Approach	29,828	Million BTU	2,110	3.8%	3.7%
Taxi/Idle/Delay	48,463	Million BTU	3,433	6.2%	6.1%
Takeoff	54,607	Million BTU	3,869	7.0%	6.9%
Climbout	14,273	Million BTU	1,009	1.8%	1.8%
Residual/Cruise/APU	544,589	Million BTU	38,560	70.2%	68.3%
Sub-total	691,760	Million BTU	48,982	89.2%	86.8%
Ground Support Equipment	79,155	Million BTU	5,924	10.8%	10.5%
Ground Access Vehicles					
Tenant GAV	0	Million BTU	0	0.0%	0.0%
Tenant Employee Commute (all roads)	2,258	Million BTU	25	0.0%	0.0%
Stationary Sources	0	Million BTU	0	0.0%	0.0%
Subtotal			**54,931**	**100.0%**	**97.4%**
Public-owned/controlled					
Passenger Vehicles (off-airport roads)	0	Million BTU	557	48.4%	1.0%
Rental Car Travel (all roads)	25,089	Million BTU	589	51.1%	1.0%
Hotel Shuttles (off airport roads)	82	Million BTU	6	0.5%	0.0%
Subtotal			**1,152**	**100.0%**	**2.0%**
Total			**56,421**		**100%**

ASPEN PITKIN COUNTY AIRPORT

Greenhouse Gas Inventory

Aspen Pitkin County Airport

Power Type	Use	Units	Use	Source	CO2 Emission Rate (lb/unit)	Conver	Unit Conv	CO2 (tons)	M BTU
Electrical	94,899	Kwh	Total airport	City Electric	1.26	0.000453592	lbs to ton	0	0
				Holy Cross Energy	1.77	0.000453592	lbs to ton	76	323.80
				GreenPwr	0.00	0.000453592	lbs to ton	0	0
Natural Gas	0	Therms	Heating	NG (kg/therm)	5.33	0.001	kg to ton	0	-
	364.0	ccf	Terminal	NG (lb/1000 ft3)	5.33	0.001	kg to ton	2.0	36.40
	361.7	ccf	Airport Ops Center	NG (lb/1000 ft3)	5.33	0.001	kg to ton	1.9	36.17
Fuel Oil/Diesel	-	Ga	Generators	Diesel (lb/gal)	22.384	0.000453592	lbs to ton	0	-
Data from Airport: Electrical - Aug 05-July 06									
AOC estimated/annualized from June-Dec use. Airport data for terminal					Total			80.1	396.37

Tenant Facilities

Power Type	Use	Units	Use	Source	CO2 Emission Rate (lb/unit)	Conver	Unit Conv	CO2 (tons)	M BTU
Electrical	0	Kwh	Total airport	City Electric	1.26	0.000453592	lbs to ton	0	0
				Holy Cross Energy	1.77	0.000453592	lbs to ton	0	0.0
				GreenPwr	0.00	0.000453592	lbs to ton	0	0.0
Natural Gas	0	Therms	Heating	NG (kg/therm)	5.33	0.001	kg to ton	0	0.0
	0	ft3		NG (lb/1000 ft3)	120.593	0.000453592	lbs to ton	0	0.0
Fuel Oil/Diesel	-	Ga	Generators	Diesel (lb/gal)	22.384	0.000453592	lbs to ton	0	-
No data available for tenants					Total			0	0.0

Reported in Metric Ton — See worksheet "Energydata" for sources — 1 ccf = 1.024 therm

BTU Conversion - electric: 3412 BTU per Kwh — ccf = 100 cubic feet

Natural Gas: 100,000 BTU per Therm

Diesel - 138,700 BTU per gallon (Data Energy Book B.4)

Gas - 125,000 BTU per gallon (Data Energy Book B.4)

CNG CO2 rate	120.593	lb/ft3 per 1000ft
	0.4536	convert lb/kg 1 lb=0.4536 kg
	54.70098	kg/ft3
	97.37	1 therm = (100,000/1027)=97.37ft3
	5.326235	kg/therm

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Ground Support Equipment - GSE

Aspen Off-Road GSE

Power Type	Use	Units	Use	Conversion Factors	Converted	CO2 factor	Units CO2	CO2 (tons)	BTUs
Gasoline	3,316.70	gal	ASE Pitkin Co	none	None	19.564	Lbs/gal	29.4	414,587,500
			On-airfield equip						
CNG	-	gal equiv	and limited		-	120.593	lb/ft3	-	-
CNG	-	ft3	off airport		None	120.593	lb/ft3	-	-
			uses						
Diesel	12,401.47	Gal		none	None	22.384	lbs/gal	125.9	1,720,083,889
						Total		155.3	2,134,671,389

Source: Airport fuel records

Airline/Tenant GSE -- See GSE_2006

CO2 Factor Source: See worksheet EnergyData

to calculate the energy eqivalent of CNG to gallons

Diesel	138,700	BTU/gal	Transportation Data Energy Book
CNG	960	BTU/ft3	Transportation Data Energy Book
Motor Gas	125,000	BTU/gal	Transportation Data Energy Book
CNG gal equiv	130.2083	ft3/gal	@sum(125,000/960)

CNG	120.593	lb CO2/1000 ft3

0.00045359237 Lbs/ton

ASPEN PITKIN COUNTY AIRPORT

Greenhouse Gas Inventory

Aspen Pitkin County Airport Passenger Travel

Passenger On Road Travel	%	Vehicles	MPG	Dist (mi)	Fuel (Gallons)	CO2 lbs/gal	CO2 (lbs)	BTU
Annual Passengers								
Total Passengers		399,938						
Passenger parties (3.0 pax per party)		133,313						
Rental Cars	13.1%	17,410						
Parking Lot	41.0%	54,711						
Residual		61,192						
Pickup/Dropoff Percents are of residual	10.0%	6,119						
Taxi	40.0%	24,477						
Hotel Shuttles	50.0%	30,596						
On-Airport Roads (2,400 ft)								
Parking Lot Use		54,711	22.9	0.4	956	19.5640	18,696.3	119,456,332
Pickup Dropoff		6,119	22.9	0.4	107	19.5640	2,091.1	13,360,626
Taxi		24,477	16.0	0.4	612	19.5640	11,971.5	76,489,583
				Total Gallons	1,063	Total Lbs	32,759.0	209,306,541
						Tons	14.9	-
Off-Airport (avg distance to Snowmasas and Aspen rdtrp)								-
Parking Lot Use		54,711	22.9	15	35,837	19.5640	701,113.1	4,479,612,445
Pickup		6,119	22.9	15	4,008	19.5640	78,416.2	501,023,472
Taxi		24,477	16.0	15	22,947	19.5640	448,932.7	2,868,359,375
				Total Gallons	62,792	Total Lbs	1,228,462.0	7,848,995,292
Average Distance to Snowmass and Aspen - roundtrip						Tons	557.2	
MPG - Transp Data Energy Book #26 Table				Total	63,854	Total Tons	572.1	8,058,301,833

Data from Airport or calculated from aerials/mapquest

Data Estimated   EIA data

Airport Owned On-Road Vehicles (all travel)

Fuel type	Amount	Units	Conversion	Use	Conversion	CO2 Factor	units	CO2 (lbs)	BTUs Fuel
Fuel and Use Gas	-	Gal	NA	OnRoad travel	NA	19.564	lb/gal	0	-
Fuel and Use CNG	-	ft3				120.593	lb/ft3	0	0
Fuel and Use CNG	-	gal equiv	gal eq to ft3	130.2083	ft3/gal	120.593	lb/ft3	0	0
Fuel and Use Diesel	-	gal	NA	OnRoad travel	NA	22.384	lb/gal	0	0
Source: Airport fuel records - Note that fueling record can not separate GSE from GAV for County Vehicles (for County see GSE)							Tons CO2	0.0	0

ASE Airport Employees Commute Travel

Employee On Road Travel		Employees	MPG	Rnd trip Dist (mi)	Fuel (Gallons)	CO2 lbs/gal	CO2 (lbs)	BTUs Fuel
ASE Employee 1 - 2.5 day week drives		1	22.9	150	819	19.5640	16,019	102,347,162
ASE Employee 2 - 4 day week		1	22.9	90	786	19.5640	15,378	98,253,275
ASE Employee 3		2	22.9	90	1,965	19.5640	38,445	245,633,188
ASE Employee 4		1	22.9	120	1,310	19.5640	25,630	163,755,459
ASE Employee 5		2	22.9	40	873	19.5640	17,086	109,170,306
ASE Employee 6		4	22.9	10	437	19.5640	8,543	54,585,153
ASE Employee 7		1	22.9	32	349	19.5640	6,835	43,668,122
ASE Employee 8		1	22.9	5	55	19.5640	1,068	6,823,144
ASE Employee 9		2	22.9	12	262	19.5640	5,126	32,751,092
ASE Employee 10		1	22.9	31.5	344	19.5640	6,728	42,985,808
ASE Employee 11		1	22.9	60	655	19.5640	12,815	81,877,729
ASE Employee 12		1	22.9	42	459	19.5640	8,970	57,314,410
ASE Employee 13 - 1 day week		1	22.9	12	26	19.5640	513	3,275,109
ASE Employee 14		1	22.9	68	742	19.5640	14,523	92,794,760
ASE Employee Bus		5	0	0	0	19.5640	0	-
Source - Airport records		25			Total Pounds		177,678	
Miles = employees*miles*50 weeks*5 days unless noted				Total	9,082	Tons	80.6	1,135,234,716

Tenant Employees Commute Travel

Employee On Road Travel		Employees	MPG	Rnd trip Dist (mi)	Fuel (Gallons)	CO2 lbs/gal	CO2 (lbs)	BTUs Fuel
GAV Tenant 1		8	22.9	32.0	2,795	19.5640	54,677	349,344,978
Air Tenant 1		70	22.9	20.0	15,273	19.5640	298,800	1,909,115,721
		-				19.5640	0	-
ASE Diesel		-				22.3840	0	-
					Total Pounds		54,677	
Miles = employees*miles*50 weeks*5 days				Total	18,068	Tons	24.80	2,258,460,699

Source: BDC Survey

Greenhouse Gas Inventory

Airport Rental Car Travel

Rental car Off-Airport Travel		Rented Vehicles	MPG	Rnd trip Dist (mi)	Fuel (Gallons)	CO2 lbs/gal	CO2 (lbs)	BTUs Fuel
Tenant 1		5,758	22.9	264.0	66,380	19.5640	1,298,667	8,297,554,585
Other On-Airport Rental Cars (estimated)		10,508	22.9	264.0	121,140	19.5640	2,369,988	15,142,532,751
Other Off-Airport Rental Cars (estimated)		1,144	22.9	264.0	13,188	19.5640	258,019	1,648,558,952
		-	22.9	22.0	0	22.3840	0	-
Estimated based on reported revenue					Total Pounds		1,298,667	
Source: BDC Survey				Total	200,709	Tons	589.07	25,088,646,288

Rental car On-Airport Travel		Rented Vehicles	MPG	Rnd trip Dist (mi)	Fuel (Gallons)	CO2 lbs/gal	CO2 (lbs)	BTUs Fuel
Tenant 1		5,758	22.9	0.4	101	19.5640	1,968	12,572,052
Other On-Airport Rental Cars (estimated)		10,508	22.9	0.4	184	19.5640	3,591	22,943,231
Other Off-Airport Rental Cars (estimated)		1,144	22.9	-	0	19.5640	0	-
		-	22.9	0.4	0	22.3840	0	-
Assume that all rental cars travel same distance as Tenant 1					Total Pounds		1,968	
Source: BDC Survey				Total	284	Tons	0.89	35,515,284

ASPEN PITKIN COUNTY AIRPORT

Greenhouse Gas Inventory

Hotel Shuttles

30,596

Hotel			Annual trips	MPG	Off Airport Dist (mi)	Fuel (Gallons)	CO2 lbs/gal	CO2 (lbs)
Hotel 1 - Aspen			7,000	16	3.9	79	19.5640	1,544
Hotel 2 - Snowmass			7,000	16	10.9	221	19.5640	4,314
Hotel 3 - Aspen			5,000	16	3.9	56	19.5640	1,103
Hotel 4- Aspen			5,000	16	10.9	158	19.5640	3,082
Hotel 5 - Snowmass			2,000	16	10.9	63	19.5640	1,233
Hotel 6 - Others			2,000	16	3.9	23	19.5640	441
Hotel 7- Aspen			450	16	3.9	5	19.5640	99
Hotel 8 - Aspen			450	16	10.9	14	19.5640	277
Hotel 9 - Aspen			398	16	3.9	4	19.5640	88
Hotel 10 - Snowmass			398	16	10.9	13	19.5640	245
Hotel 11 - Snowmass			300	16	10.9	9	19.5640	185
Hotel 12			300	16	3.9	3	19.5640	66
Hotel 13			200	16	3.9	2	19.5640	44
Hotel 14			100	16	7.8	2	19.5640	44
total trips			30,596					
Off-Airport Roads			30,596		Gal -->	652	Tons	6
					M BTU	82		
On-Airport Roads	Miles -->	0.4	30,596	16		765	19.5640	7
					M BTU	96		

Miles doubled in gallon calculation to account for roundtrip except on curb
Assume vehicles to be Shuttle vehicles to be gas

CO2 Factor Source: See worksheet EnergyData
to calculate the energy eqivalent of CNG to gallons

Diesel	138,700	BTU/gal	Transportation Data Energy Book
CNG	960	BTU/ft3	Transportation Data Energy Book
Motor Gas	125,000	BTU/gal	Transportation Data Energy Book
CNG gal equiv	130.2083	ft3/gal	
CNG	120.593	lb CO2/1000 ft3	
0.00045359237	Lbs/ton		

Airline GSE

EDMS default

						CO2 Emissions Rate					Calculation	
GSE Type	Fuel	Hp	Load Factor	Annual Minutes	Min/LTO	Diesel g/hp-hr	Gas g/hp-hr	Prop g/hp-hr	Elect g/hp-hr	CO2 g/hp-hr	Fuel Gal	CO2 lbs
Air Conditioner	E	0	0.75	34,740	1.563	547.1	803.7	636.5	0	0.0	-	-
Air Start	D	425	0.9	7	0.000	537.4	0.0	0.0	0	537.4	2	53
Aircraft Tractor	D	88	0.8	7,368	0.331	607.5	797.4	627	0	607.5	517	11,580
Aircraft Tractor	D	86	0.8	70,400	3.167	607.5	797.4	627	0	607.5	4,831	108,135
Baggage Tractor	G	107	0.55	308,281	13.867	547.1	803.7	636.5	0	803.7	27,390	535,852
Belt Loader	D	71	0.5	4,770	0.215	626.7	803.1	632.8	0	626.7	174	3,900
Belt Loader	G	107	0.5	218,919	9.847	547.1	803.7	636.5	0	803.7	17,682	345,930
Cabin Service Truck	D	71	0.53	20,810	0.936	626.7	803.1	632.8	0	626.7	806	18,035
Cabin Service Truck	D	210	0.53	23,160	1.042	540.0	781.6	0.0	0	540.0	2,285	51,155
Catering Truck	D	71	0.53	56,035	2.520	626.7	803.1	632.8	0	626.7	2,170	48,564
Catering Truck	D	210	0.53	17,370	0.781	540.0	781.6	0.0	0	540.0	1,714	38,366
Fuel Truck	D	175	0.25	366,550	16.487	547.1	803.7	636.5	0	547.1	14,404	322,430
Ground Power Unit	G	107	0.75	343,360	15.444	547.1	803.7	636.5	0	803.7	36,359	813,853
Ground Power Unit	D	71	0.75	164,280	7.389	626.7	803.1	632.8	0	626.7	9,001	201,475
Ground Power Unit	D	194	0.75	35,000	1.574	540.0	781.6	0	0	540.0	4,515	101,061
Hydrant Truck	D	235	0.7	14,172	0.637	540.0	781.6	0.0	0	540.0	2,067	46,265
Lavatory Truck	D	56	0.25	40,020	1.800	626.7	803.1	632.8	0	626.7	576	12,904
Lavatory Truck	G	97	0.25	45,090	2.028	607.5	797.4	627	0	797.4	1,638	32,042
Service Truck	D	235	0.2	102,026	4.589	540.0	781.6	0.0	0	540.0	4,251	95,161
Water Service	E	0	0.2	13,896	0.625	547.1	803.7	636.5	0	0.0	-	-
Ground Power Unit	G	107	0.75	59,240	2.665	547.1	803.7	636.5	0	803.7	7,177	140,414
Ground Power Unit	D	71	0.75	2,054,800	92.425	626.7	803.1	632.8	0	626.7	112,582	2,520,033
Hydrant Truck	D	235	0.7	1,360,140	61.179	540.0	781.6	0	0	540.0	198,364	4,440,180
Lavatory Truck	D	56	0.25	2,259,315	101.624	626.7	803.1	632.8	0	626.7	32,545	728,487
Lavatory Truck	G	97	0.25	55,440	2.494	607.5	797.4	627	0	797.4	2,014	39,397
Lavatory Truck	D	235	0.25	134,925	6.069	540.0	781.6	0	0	540.0	7,028	157,308
Lift	D	115	0.5	540	0.024	547.1	803.7	636.5	0	547.1	28	624
Service Truck	D	235	0.2	2,408,406	108.331	540.0	781.6	0	0	540.0	100,355	2,246,356
Water Service	E	0	0.2	13,896	0.625	547.1	803.7	636.5	0	0.0	-	-

Time per LTO from EDMS

Gas

Diesel

Electric

0.002205 conversion of grams to lbs

Emission factors from NONROAD2005 (averages for hp-ranges by fuel)

0.0004536200 Conversion of lbs to metric tons

Gas gal	55,900	Total Lbs CO2	13,059,561
Diesel gal	534,575	Tons CO2	5,924
tot Gal	590,475		
MBTU	79,155		

	Units CO2	CO2 factor
LPG	Lbs/gal	12.669
Gas	Lbs/gal	19.564
Diesel	lbs/gal	22.384
		Total

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ASPEN PITKIN COUNTY AIRPORT

Greenhouse Gas Inventory

Aircraft CO2 Emissions

Aircraft	KG Fuel Burn	Convert Factor kg to Lbs Fuel	Lbs Fuel	Convert Factor Lbs to Gal	Gallons	Convert gal to CO2 (lbs/gal)	CO2 (lbs)	CO2 Tons
JET A								
Approach	673,649.5	2.2046	1,485,128	6.8200	217,761	21.095	4,593,661	2,083.6
Taxi-Idle-Delay	1,105,010.7	2.2046	2,436,107	6.8200	357,200	21.095	7,535,142	3,417.9
Takeoff	1,248,228.8	2.2046	2,751,845	6.8200	403,496	21.095	8,511,756	3,860.9
Climbout	321,456.6	2.2046	708,683	6.8200	103,912	21.095	2,192,034	994.3
Subtot	3,348,345.5		7,381,763		1,082,370		22,832,592	10,356.7
AvGas								
Approach	8,665.6	2.2046	19,104	6.0000	3,184	18.355	58,443	26.5
Taxi-Idle-Delay	4,862.6	2.2046	10,720	6.0000	1,787	18.355	32,794	14.9
Takeoff	2,725.4	2.2046	6,008	6.0000	1,001	18.355	18,381	8.3
Climbout	4,944.8	2.2046	10,901	6.0000	1,817	18.355	33,349	15.1
Subtot	21,198.4		46,734		7,789.0		142,967	64.8
Total LTO	3,369,543.9		7,428,496		1,090,159			10,421.5

Fuel Dispensed				**Jet A**	5,084,919	21.095	107,266,366	48,655.2
				Av Gas	39,229	18.355	720,048	326.6
				Total	5,124,148		107,986,415	48,981.8
Cruise (Fuel dispensed - LTO)				**Jet A**	4,002,549	21.095	84,433,774	38,298.5
				Av Gas	31,440	18.355	577,081	261.8
				Total	4,033,989		85,010,855	38,560.3

EDMS output

0.00045359237 Lbs/ton

1 gallon =	6.84	lbs Jet A	lbs Jet A
	6.0	lbs Av-Gas (100LL)	lbs Av-Gas (100LL)

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Aspen 2006 LTOs and Emissions		EDMS Output					Jet A Fuel				
Aircraft Name	Engine	Annual LTO	Annual NOx (kg)	Annual Fuel (kg)	FUEL KG/LTO	Fuel Type	Approach (kg)	Taxi-In (kg)	Taxi-Out (kg)	Takeoff (kg)	Climbout (kg)
Bombardier Challenger 300	AE3007A1 Type 2	211	466	39,078	185	Jet A	8,398	3,922	9,984	15,139	1,636
Embraer ERJ135	AE3007A1/3 Type 3 (reduc	80	399	30,990	387	Jet A	10,020	1,795	3,687	7,542	7,947
Cessna 750 Citation X	AE3007C Type 2	790	3,725	244,386	309	Jet A	83,572	12,189	30,570	118,057	
Bombardier Challenger 600	ALF 502L-2	481	714	90,138	187	Jet A	19,144	9,205	23,550	34,511	3,730
BAE 146-200	ALF 502R-5	897	5,924	575,263	641	Jet A	114,750	32,771	75,130	292,869	59,745
Gulfstream G550	BR700-710A1-10	158	483	49,790	315	Jet A	8,557	5,391	14,434	12,054	9,356
Bombardier Global Express	BR700-710A2-20	484	2,520	210,696	435	Jet A	48,861	18,709	44,215	73,101	25,812
Bombardier Challenger 604	CF34-3B	8	11	1,645	206	Jet A	312	163	402	670	99
Bombardier CRJ-700	CF34-8C1	1,506	2,185	300,883	200	Jet A	44,955	39,437	106,661	94,212	15,620
Rockwell Sabreliner 80	CF700-2D	45	23	9,052	201	Jet A	1,851	983	2,679	3,541	
Boeing 737-700 Series	CFM56-7B22	1	8	598	598	Jet A	109	49	108	204	130
Bombardier Learjet 24	CJ610-6	18	0	2,461	137	Jet A	273	405	1,182	603	
Bombardier Learjet 25	CJ610-6	82	8	10,165	124	Jet A	943	1,823	5,387	2,015	
Cessna 182	IO-360-B	4,241	81	13,959	3	AvGas	-	-	-	-	-
Cessna 500 Citation I	JT15D-1 series	34	7	2,422	71	Jet A	376	284	803	861	99
Cessna 501 Citation ISP	JT15D-1 series	33	7	2,351	71	Jet A	365	276	779	836	96
Cessna 525 CitationJet	JT15D-1 series	336	80	23,943	71	Jet A	3,713	2,805	7,932	8,513	981
Cessna 550 Citation II	JT15D-4 series	575	215	49,068	85	Jet A	8,972	5,453	15,404	10,304	8,936
Mitsubishi MU-300 Diamond	JT15D-4 series	45	13	3,230	72	Jet A	471	421	1,206	999	134
Cessna 560 Citation Excel	JT15D-5, -5A, -5B	751	302	74,433	99	Jet A	14,644	8,292	22,817	17,238	11,442
Cessna 560 Citation XLS	JT15D-5, -5A, -5B	691	278	68,486	99	Jet A	13,474	7,630	20,994	15,861	10,528
Raytheon Beechjet 400	JT15D-5, -5A, -5B	791	291	70,993	90	Jet A	11,977	8,483	24,032	26,503	
BAE 146-RJ85	LF507-1F, -1H	260	1,962	178,577	687	Jet A	35,345	10,441	24,179	90,221	18,391
Piper PA46-TP Meridian	PT6A-42	58	9	2,062	36	Jet A	713	121	351	356	523
Raytheon Super King Air 200	PT6A-42	458	26	11,461	25	Jet A	1,838	1,857	5,538	909	1,320
Raytheon Super King Air 300	PT6A-60A	145	7	4,019	28	Jet A	582	686	2,046	288	418
Piaggio P.180 Avanti	PT6A-66	204	6	4,283	21	Jet A	52	1,052	3,153	18	9
Pilatus PC-12	PT6A-67B	151	23	5,845	39	Jet A	1,856	434	1,269	927	1,361
Raytheon Beech 1900-D	PT6A-67D	200	25	9,758	49	Jet A	1,464	1,187	3,494	3,616	
Bombardier Dash 8 Q200	PW123D	2,081	1,827	203,547	98	Jet A	29,210	24,305	69,783	44,252	35,998
BAE Jetstream 61 ATP	PW126A	114	62	8,837	78	Jet A	989	1,328	3,899	1,355	1,267
Gulfstream G200	PW306A Annular	2	8	564	282	Jet A	114	37	87	154	174
Cessna 680 Citation Sovereign	PW308C Annular	133	61	13,351	100	Jet A	1,568	2,101	6,116	2,801	767
Dassault Falcon 2000	PW308C Annular	358	1,352	106,317	297	Jet A	34,343	6,283	16,462	49,230	
Raytheon Premier I	PW308C Annular	71	34	7,875	111	Jet A	1,108	1,128	3,265	1,272	1,103
Gulfstream II	SPEY Mk511 Transply IIH	168	487	66,927	398	Jet A	9,573	7,956	21,900	12,922	14,577
Gulfstream II-B	SPEY Mk511 Transply IIH	318	906	126,117	397	Jet A	15,749	15,044	41,454	27,337	26,535
Gulfstream IV-SP	TAY 611-8C Transply IIJ	598	1,731	201,349	337	Jet A	32,974	24,322	64,450	40,149	39,455
Bombardier Learjet 60	TFE731-2/2A	333	245	30,633	92	Jet A	5,455	3,312	8,887	11,921	1,059
Raytheon Hawker 1000	TFE731-2/2A	47	117	8,563	182	Jet A	2,106	506	1,254	4,699	
Bombardier Learjet 31	TFE731-2-2B	116	39	8,076	70	Jet A	1,225	1,013	2,858	2,686	296
Bombardier Learjet 35	TFE731-2-2B	708	245	49,299	70	Jet A	7,476	6,182	17,441	16,392	1,809
Bombardier Learjet 40	TFE731-2-2B	94	58	8,389	89	Jet A	1,540	871	2,316	3,365	299
Bombardier Learjet 45	TFE731-2-2B	311	194	27,758	89	Jet A	5,095	2,880	7,661	11,134	989
Dassault Falcon 10	TFE731-2-2B	42	18	3,446	82	Jet A	636	370	1,035	1,407	

ASPEN PITKIN COUNTY AIRPORT

Greenhouse Gas Inventory

Aspen 2006 LTOs and Emissions

Aircraft Name	Engine	EDMS Output: Annual LTO	EDMS Output: Annual NOx (kg)	EDMS Output: Annual Fuel (kg)	EDMS Output: FUEL KG/LTO	Fuel Type	Jet A Fuel: Approach (kg)	Jet A Fuel: Taxi-In (kg)	Jet A Fuel: Taxi-Out (kg)	Jet A Fuel: Takeoff (kg)	Jet A Fuel: Climbout (kg)
Bombardier Learjet 55	TFE731-3	180	75	13,026	72	Jet A	1,901	1,695	4,804	4,167	460
Cessna 650 Citation III	TFE731-3	184	86	13,736	75	Jet A	2,169	1,723	4,910	3,875	1,061
Dassault Falcon 20-F	TFE731-3	74	262	17,813	241	Jet A	3,672	809	1,975	8,292	3,065
Dassault Falcon 50-EX	TFE731-3	428	766	70,418	165	Jet A	14,785	6,479	17,133	26,829	5,194
Dassault Falcon 900-EX	TFE731-3	405	352	48,614	120	Jet A	8,377	5,792	16,213	14,926	3,307
Hawker HS-125 Series 400	TFE731-3	31	77	5,648	182	Jet A	1,389	334	827	3,099	
Hawker HS-125 Series 700	TFE731-3	902	2,287	164,380	182	Jet A	40,422	9,714	24,072	90,174	
Israel IAI-1124-A Westwind II	TFE731-3	113	386	26,136	231	Jet A	5,689	1,477	3,016	13,726	2,230
Israel IAI-1125 Astra	TFE731-3	109	372	25,211	231	Jet A	5,487	1,424	2,909	13,240	2,151
Lockheed L-1329 Jetstar II	TFE731-3	23	184	10,663	464	Jet A	2,379	360	614	6,038	1,274
Cirrus SR22	TIO-540-J2B2	8		101	13	Av Gas	-	-	-	-	
Raytheon Beech Baron 58	TIO-540-J2B2	370	3	7,136	19	AvGas	-	-	-	-	
Cessna 441 Conquest II	TPE331-10	167	23	5,053	30	Jet A	533	943	2,811	767	
Mitsubishi MU-2	TPE331-10	10	2	454	45	Jet A	103	57	168	51	76
		22,232	**32,060**	**3,369,473**			**673,649**	**304,707**	**800,304**	**1,248,229**	**321,457**

User Input from EDMS

Taxi in Time	Taxi out Time
3	9

Total Taxi time 11 minutes (assume 2 minu

Aspen 2006 LTOs and	AvGas Fuel				
Aircraft Name	Approach (kg)	Taxi-In (kg)	Taxi-Out (kg)	Takeoff (kg)	Climbout (kg)
Bombardier Challenger 300	-	-	-	-	-
Embraer ERJ135	-	-	-	-	-
Cessna 750 Citation X	-	-	-	-	-
Bombardier Challenger 600	-	-	-	-	-
BAE 146-200	-	-	-	-	-
Gulfstream G550	-	-	-	-	-
Bombardier Global Express	-	-	-	-	-
Bombardier Challenger 604	-	-	-	-	-
Bombardier CRJ-700	-	-	-	-	-
Rockwell Sabreliner 80	-	-	-	-	-
Boeing 737-700 Series	-	-	-	-	-
Bombardier Learjet 24	-	-	-	-	-
Bombardier Learjet 25	-	-	-	-	-
Cessna 182	5,516	857	2,220	1,885	3,482
Cessna 500 Citation I	-	-	-	-	-
Cessna 501 Citation ISP	-	-	-	-	-
Cessna 525 CitationJet	-	-	-	-	-
Cessna 550 Citation II	-	-	-	-	-
Mitsubishi MU-300 Diamond	-	-	-	-	-
Cessna 560 Citation Excel	-	-	-	-	-
Cessna 560 Citation XLS	-	-	-	-	-
Raytheon Beechjet 400	-	-	-	-	-
BAE 146-RJ85	-	-	-	-	-
Piper PA46-TP Meridian	-	-	-	-	-
Raytheon Super King Air 200	-	-	-	-	-
Raytheon Super King Air 300	-	-	-	-	-
Piaggio P.180 Avanti	-	-	-	-	-
Pilatus PC-12	-	-	-	-	-
Raytheon Beech 1900-D	-	-	-	-	-
Bombardier Dash 8 Q200	-	-	-	-	-
BAE Jetstream 61 ATP	-	-	-	-	-
Gulfstream G200	-	-	-	-	-
Cessna 680 Citation Sovereign	-	-	-	-	-
Dassault Falcon 2000	-	-	-	-	-
Raytheon Premier I	-	-	-	-	-
Gulfstream II	-	-	-	-	-
Gulfstream II-B	-	-	-	-	-
Gulfstream IV-SP	-	-	-	-	-
Bombardier Learjet 60	-	-	-	-	-
Raytheon Hawker 1000	-	-	-	-	-
Bombardier Learjet 31	-	-	-	-	-
Bombardier Learjet 35	-	-	-	-	-
Bombardier Learjet 40	-	-	-	-	-
Bombardier Learjet 45	-	-	-	-	-
Dassault Falcon 10	-	-	-	-	-

Aspen 2006 LTOs and	AvGas Fuel				
Aircraft Name	Approach (kg)	Taxi-In (kg)	Taxi-Out (kg)	Takeoff (kg)	Climbout (kg)
Bombardier Learjet 55	-	-	-	-	-
Cessna 650 Citation III	-	-	-	-	-
Dassault Falcon 20-F	-	-	-	-	-
Dassault Falcon 50-EX	-	-	-	-	-
Dassault Falcon 900-EX	-	-	-	-	-
Hawker HS-125 Series 400	-	-	-	-	-
Hawker HS-125 Series 700	-	-	-	-	-
Israel IAI-1124-A Westwind II	-	-	-	-	-
Israel IAI-1125 Astra	-	-	-	-	-
Lockheed L-1329 Jetstar II	-	-	-	-	-
Cirrus SR22	47	5	13	12	25
Raytheon Beech Baron 58	3,103	572	1,196	828	1,438
Cessna 441 Conquest II	-	-	-	-	-
Mitsubishi MU-2	-	-	-	-	-
	8,666	**1,433**	**3,429**	**2,725**	**4,945**

User Input from EDMS

utes for engine start)

The Barnard Dunkelberg & Company Team