Port of Seattle

Seattle-Tacoma International Airport

Greenhouse Gas Emissions Inventory - 2006

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Port of Seattle
Sea-Tac Airport

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Seattle-Tacoma International Airport

Greenhouse Gas Emissions Inventory - 2006

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EXECUTIVE SUMMARY

The Port of Seattle has voluntarily prepared a greenhouse gas emissions inventory associated with its Aviation Division. To date, an industry accepted methodology to prepare airport-related greenhouse gas inventories has not been prepared. Thus, the Port of Seattle is leading the airport community in the identification of the appropriate boundaries for quantifying Aviation Division emissions.

The protocol used in this analysis, while not complete, represents a substantial improvement in the data examined for Seattle-Tacoma International Airport (Sea-Tac) to date and is intended to guide emission reduction plans and future inventories. 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, 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, this report focused exclusively on carbon dioxide (CO_2) emissions.

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, the organization boundaries were limited for this review to the Port's Aviation Division activities and associated emissions. Operational boundaries reflect to *direct, indirect, and optional emissions.* For the Aviation Division, direct emissions are from sources that are owned and controlled by the Aviation Division (terminal buildings, mobile sources, and the power required to operate these resources). Indirect and Optional emissions are a consequence of the activities of the Port's Aviation Division, but occur at sources owned or 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 5.09 million metric tons of CO_2 in 2006 were identified as a result of direct and indirect airport activities.

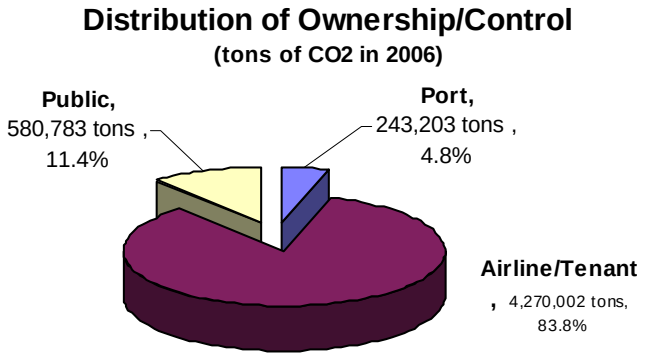
Ownership/Control	Percent of Total	Key Sources
Port of Seattle Aviation Division	4.8%	Hotel/parking lot shuttles, facility power
Airlines/Tenants	83.8%	Aircraft
Public	11.4%	Passenger vehicles, hotel/parking lot shuttles

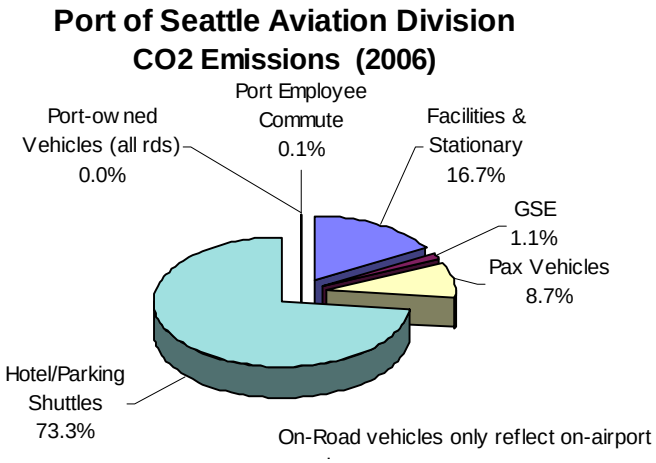
Port of Seattle Aviation Division owned/controlled emissions represent about 243,203 metric tons of CO_2 in 2006. The largest portion of greenhouse gas emissions that the Port either owns or has substantial control is that associated with hotel and parking lot shuttles accessing the Airport, followed by the emissions associated with lighting and heating airport facilities.

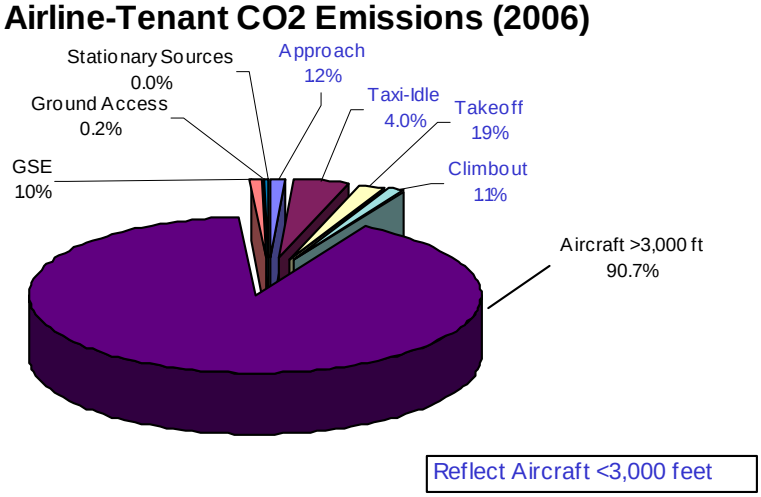
Airline/tenant-owned and controlled emissions represent nearly 4.3 million metric tons of CO_2 in 2006. As would be expected, aircraft represent the single largest source of CO_2 emissions. Over 90% of the airline emissions are from aircraft operating above 3,000 feet. All of the public-owned and controlled emissions reflect on-road travel associated with airport activity: either through vehicular access by passengers, hotel/parking lot shuttles off-airport, and airport employee work commute. Of airport-related emissions, public owned/controlled emissions represent 580,783 metric tons of CO_2 in 2006

Next Steps: This report identified a number of steps that the Port can take to improve its future Aviation Division 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 Port with identifying emission reduction actions.

FIGURE ES-1
SOURCES OF EMISSIONS







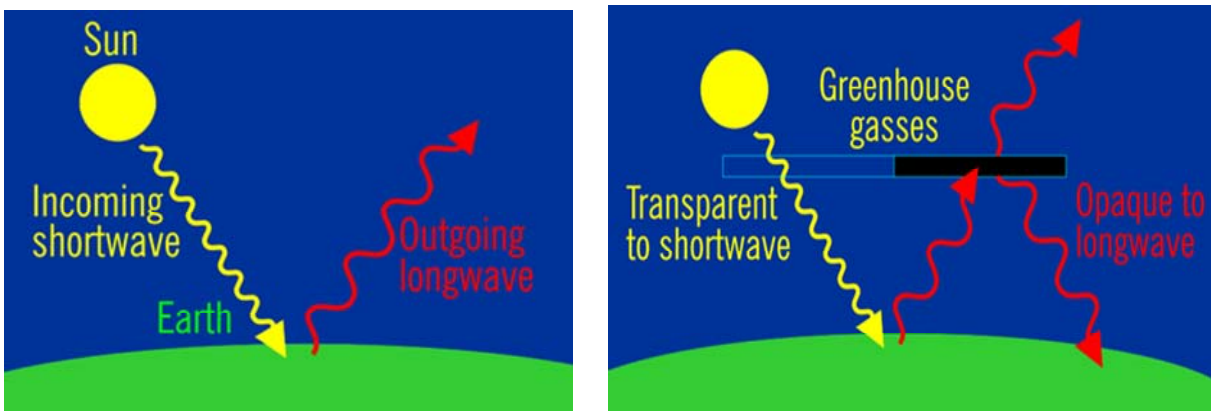
I. BACKGROUND

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 increased

[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).

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.

I.2 WHO ADDRESSES GREENHOUSE GASSES

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

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:

- **Kyoto Protocol**- 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 CO_2 and five other greenhouse gases, or engage in emissions trading if they maintain or increase emissions of these gases. The Kyoto Protocol now covers 171 countries globally and over 55% of global greenhouse gas emissions. 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 August 2007, a total of 171 countries[6] and other governmental entities have ratified the agreement (representing over 62% of emissions from Annex I countries). Notable exceptions include the United States and Australia. Other developing countries, such as India and China, which have ratified the protocol, are

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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.

6 http://maindb.unfccc.int/public/country.pl?group=kyoto

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 carbon dioxide 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.

Although a signatory to the protocol, the United States has neither ratified nor withdrawn from the protocol. In late 1998, 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. The current Bush Administration does not support the Kyoto principles because of the exemption granted to China (which recently surpassed the U.S. as the greatest emitter of carbon).

- **Intergovernmental Panel on Climate Change (IPCC)** - 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 nor does it monitor climate-related data or other relevant parameters. It bases its assessment 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.
- **State and Local Actions**: In February, 2005 the Kyoto Protocol became law for 171 countries. Even though the US has failed to ratify Kyoto, local action is taking place. Seattle Mayor Greg Nickels launched the US Mayors Climate Protection Agreement 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, the following specific actions have occurred at the State and local level:

    - The **City of Seattle** has prepared the *Seattle Climate Action Plan.* The Action Plan addressed the recommendations of Mayor Nickels' *Green Ribbon Commission on Climate Protection.* Mayor Nickels has proposed $37 million over two years for climate protection actions such as expanded transit service and improved and new bicycling and pedestrian facilities. It includes money to

convert to more fuel efficient vehicles and equipment throughout the City, to start a new business partnership devoted to climate protection, and to launch a broad campaign to educate residents and businesses greenhouse gases and climate change. The Port of Seattle is a charter member and participant of the Green Ribbon Commission.

- **King County Climate Plan** - In March 2006, King County Executive Ron Sims 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. Effective September 1, 2007, all County environmental reviews conducted under the State Environmental Policy Act (SEPA) must include a greenhouse gas inventory. The County has indicated plans to develop significance thresholds for greenhouse gases and a requirement for mitigation.
- 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.
- In August 2006, the State of California, which is ranked as one of the largest greenhouse gas emitter in the world, agreed to reduce the state's greenhouse-gas emissions by 25% by the year 2020. This resulted in the ***California Global Warming Solutions Act*** which effectively puts California in line with the Kyoto initiative.
- The **governors of Washington**, Oregon, Arizona, New Mexico, and California have joined together in a regional strategy addressing global warming. Several parties, including Utah, the Providence of British Columbia, and portions of Mexico have joined as observers. *The west coast governors' regional strategy* includes the following actions:
  - Purchase of state vehicles that are fuel-efficient vehicles for motor pool fleets.
  - Reduce diesel emissions by:
    - reducing diesel generators used by ships in west coast ports; and
    - creating an emission-free truck stop system along the I-5 corridor from Mexico to Canada.
  - Remove barriers to and encourage the development of renewable electricity generation resources and technologies.
  - Develop uniform efficiency standards for items such as appliances that can potentially reduce greenhouse gas emissions.
  - Develop better ways to collect data on greenhouse gas emissions and their sources.
  - Updating state energy codes for new construction and promoting state-funded weatherization assistance for energy-efficient homes.

- Providing tax incentives to companies for developing renewable and alternative energy projects.
- Creating a biodiesel use pilot program to substitute biodiesel for fossil fuels in school buses.
- Develop and implement a CO_2 market-based cap and trade mechanism.

I.3 SOURCES OF GREENHOUSE GASES AT AN AIRPORT

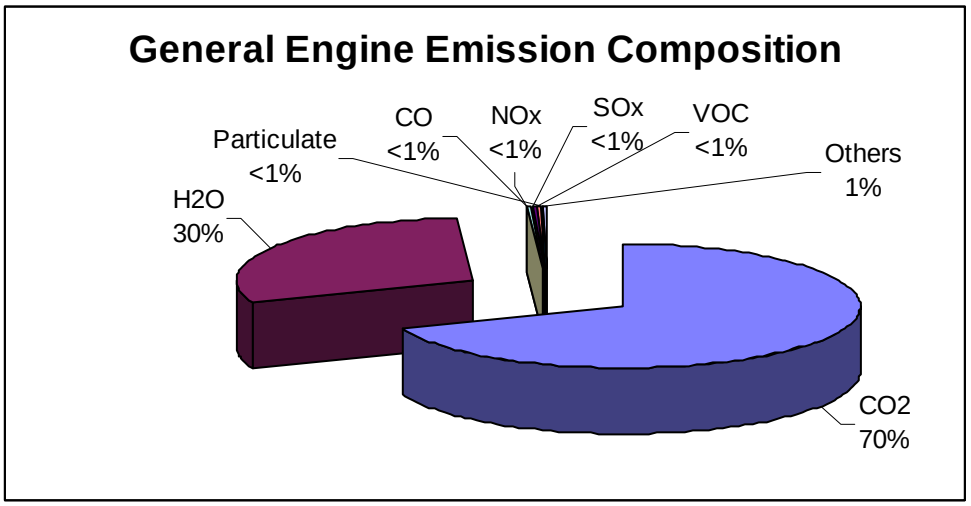
Research has shown that there is a direct link between fuel consumption and greenhouse gas emissions. Therefore, sources that require power/fuel at an airport typically are reflected in a pollutant emissions inventory. Given the experience with emission inventories prepared for criteria pollutants, it is expected that the same sources would generate greenhouse gases. Airport sources of greenhouse gas emissions would include:

1. **Aircraft including auxiliary power units** (APU): APU refers to the on-board engine that is used to support the aircraft while parked on the ground;
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, air-conditioning units, 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, shuttles, buses, taxicabs, private passenger vehicles, and trucks.
4. **Airport infrastructure and stationary sources** such as for lighting, cooling, etc.
5. **Airport and airline maintenance industrial activities**.
6. **Airport construction activities.**

As the inventory documented in this report is the first in depth greenhouse gas inventory for Seattle-Tacoma International Airport, 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.

Aircraft are probably the most often cited air pollutant source, but as is noted in FAA materials, they produce the same types 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 anthropogenic 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 quantity of greenhouse gas from human 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 aviation accounted for about 3% of U.S. greenhouse gas emissions. As the US General Accounting Office (GAO) in 2000[7] noted, "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:

- 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. Moreover, as noted, global aviation's carbon dioxide emissions (measured in million metric tons of carbon) are roughly equivalent to the carbon emissions of certain industrialized countries.

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7 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.

- 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

To date, few airports have initiated an inventory of greenhouse gas (GHG) emissions. Therefore, before initiating an inventory for Sea-Tac 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 2004, total U.S. greenhouse gas emissions were 7,074.5 Tg $CO_{2\text{-eq}}$ (teragrams of CO_2 equivalent emissions – teragrams are 10^{12}). Overall, total U.S. emissions have risen by 15.8% from 1990 to 2004, while the U.S. gross domestic product has increased by 51% over the same period.

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, emissions from electricity generation accounted for the largest portion (33%), with transportation activities accounting for the second largest portion (28%). Aviation is included in the transportation category.

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 2004 emissions inventory, 21 source categories were identified ranging from "CO2 emissions from stationary sources- coal" (the largest source), to "HFC-23 Emissions from HCFC-22 Manufacture" (the lowest source). The second largest emissions source was "Mobile emission sources – Roads and other" while "Mobile Combustion: Aviation" was the fourth largest source.

The methodology used by EPA in defining transportation activity, and specifically the "mobile emissions sources – aviation" employed the following steps:

- Determine total fuel consumption. The source of this data was FAA's *Fuel Cost and Consumption*. While the report notes "fuel consumed", few mobile sources actually identify fuel consumed, but rather rely on fuel dispensed, assuming that all fuel dispensed is consumed in travel.
- Emissions factors for fuel consumption were derived from the IPCC *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories.*

I.4.2 IPCC Methodologies

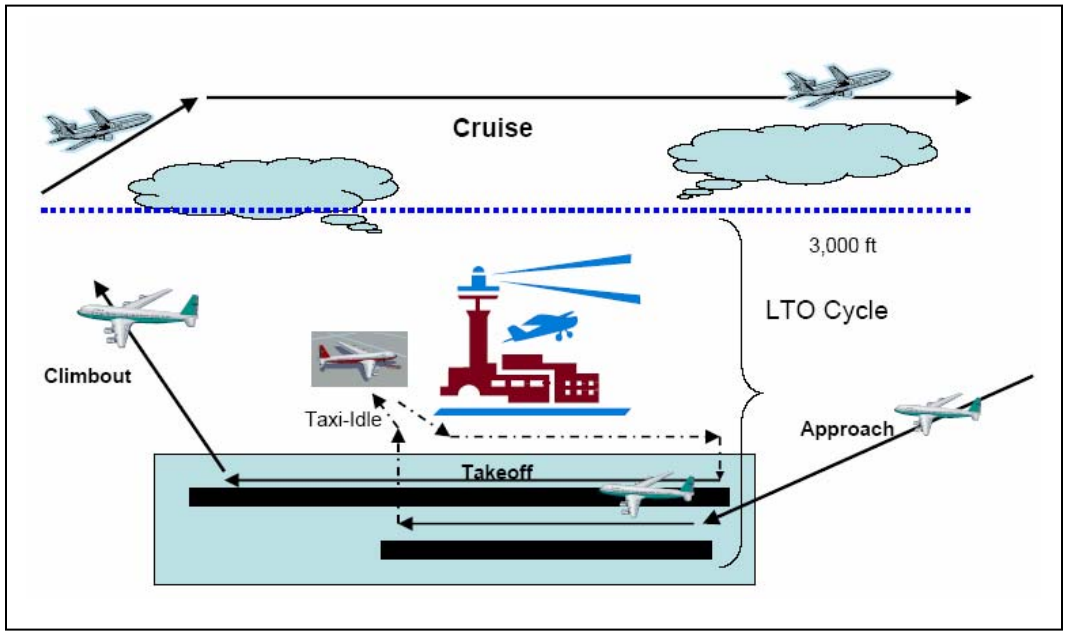
As noted above, the USEPA uses the IPCC methodologies for aviation GHG emission inventories. However, IPCC documentation notes that there are three tiers to their evaluation methodology: Tier 1, Tier 2, and Tier 3 go from the most simple to the most complicated/data intensive, respectively.

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)[8] 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.

There may be significant discrepancies between the results of a bottom-up approach and a top-down fuel-based approach for aircraft and the choice of methodology usually depends on the type of fuel, the data available, and the relative importance of aircraft emissions. **Figure I-3** shows the LTO cycle as well as cruise level.

FIGURE I-3
LANDING AND TAKEOFF CYCLE



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

[8] 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.

I.4.3 Airport Inventories

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

1) Ownership and control: Rather clear lines exist concerning the ownership of mobile sources. Airlines either lease or own the aircraft; airlines 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. Hotels and parking operators own the courtesy vehicle that transport passenger, and private parties own the vehicles that transport passengers to and from the airport. However, 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 that can affect the operational efficiency of airport facilities. Thus, there is some "gray" in the boundaries associated with an airport.

2) The boundaries of the aircraft emissions: Operators of public use airports, such as Sea-Tac Airport, have no control over the number and types of aircraft that operate at the airport. Thus, questions arise about including these emissions 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 the area within the airport boundaries, 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 journey.

4) In the US, no models available to the airport operator exist to facilitate the quantification of aircraft-related greenhouse gases. Experienced users of the Emissions Dispersion Modeling System (EDMS) can use the model to quantify aircraft fuel burn in the LTO cycle.

5) Emission factors are not available for airport ground support equipment;

6) 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.

7) 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. 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 doe 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_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) has issued a request for proposals to prepare a guidebook 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.

A recent search has found four publicly available greenhouse gas emission inventories that have identified airport-related sources: Aspen Canary Initiative, City of Seattle, City and County of Denver, and the Sacramento Airport Master Plan. **Table I-1** summarizes these inventories.

TABLE I-1
Comparison of Airport Greenhouse Gas Inventories

Source	Aspen (2004)	City of Seattle (2000)	Sacramento (2004)	Denver (2005)
Aircraft	344,487	NA	177,307	4,569,696
Ground Support Equipment	NA		10	14,051
Ground Access Vehicles	NA		39,723	21,968
Facilities	1,103		0	211,000
Other	NA		0	6
Total (tons)	345,590 $CO_{2\text{-eq}}$	1,040,000 $CO_{2\text{-eq}}$	217,040 $CO_{2\text{-eq}}$	4,816,721 $CO_{2\text{-eq}}$
Annual Operations	43,256	444,630 (SEA)/ 359,626 (BFI)	164,805	566,036
Annual Enplanements	180,519	13,853,299 (SEA)/ 11,526 (BFI)	4,671,560	20,675,380
Notes	Method designed to address local conditions	Includes Sea-Tac and King County Airport. 1996 IPCC methods and WRI used. For SEA, includes only passengers originating from Seattle locations.	Emissions are noted for CH4 and N_20, but not included in the above. Used 2006 IPCC Tier 2 LTO emissions only.	2006 IPCC Tier 1 for aircraft, airport ground fleet, facilities and GAV. Does not appear to include airline GSE

Source: ***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. Annual Operations and Enplanements: **FAA Terminal Area Forecast** August 2007 for respective airports and years.

For example, the City of Aspen prepared a citywide emissions inventory. Aspen-Pitkin County Airport is located in Aspen, and is operated by the Pitkin County. The inventory for Aspen accounted for aircraft emissions based on the average distance to the destination city for round trip travel. At Aspen, while airport fuel sales were available, the method used consisted of the following steps:

- Identifying the number of domestic passenger and international passengers.

- Estimate the average domestic and average international travel distances to enable quantifying the overall passenger travel distance
- Estimate the fuel consumed based on the average national aircraft fuel consumption per passenger mile traveled.
- Using known conversion factors, estimate the CO2 equivalent based on fuel consumed.

The net effect is that the emissions associated with the large assumed travel distance produced emissions substantially greater than the emissions associated with the fuel dispensed from Aspen. As a result, the Aspen approach found that over 40% of the city-wide emissions were associated with aircraft in 2004.

The City of Seattle 2000 emissions inventory identifies airport emissions associated with Sea-Tac 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 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 61percent. Growth in air travel, however, has resulted in energy use by commercial aircraft nearly doubling in the same period[9] - 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 (Port of Seattle 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. Similar to the Washington State Environmental Policy Act (SEPA), California projects are subject to the California Environmental Quality Act (CEQA). The City of Sacramento 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. The emissions inventory was 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. 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 Sacramento inventory did not include emissions associated with infrastructure use, other than emissions from the airport fuel tanks.

Finally, 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,

[9] Rocky Mountain Institute, Colorado.

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.

I.4.4 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 Washington prepared a greenhouse gas emissions inventory representing source emissions within the state. **Table I-2** 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 and their mitigation by each party.

The State of Washington greenhouse gas inventory indicates that in 2004, state-wide emissions were approximately 84 million tons of CO2-eq. The inventory was prepared by the State Dept. of Community, Trade & Economic Development. That report indicate that it were "… calculated based on methodology outlined in the *State Tool for Greenhouse Gas Inventory Development*, a series of worksheets developed by the U.S. Environmental Protection Agency" The Ecology documentation available on the web does not indicate the source of the aviation portion of transportation emissions. As noted in the **Table I-2,** transportation-related emissions statewide reflect about 50% of all emissions.

King County inventory: King County has assembled an emissions inventory for County owned resources, as well as community-wide emissions. **Table I-2** lists the 2004 county-wide emissions. King County is a participant in the International Council for Local Environmental Initiatives (ICLEI) Cities for Climate Protection program (CCP). CCP recognizes two GHG inventory types: government and geographic. The government inventory accounts all emissions that can be attributed to the actions of King County government in the course of normal business activity. For its government inventory, King County follows a hierarchy of four guidance documents: WRI, ICLE/STAPPA, US EPA, and IPCC. The county obtained its geographic community inventory from the Puget Sound Clean Air Agency (PSCAA).

TABLE I-2
US, STATE, COUNTY AND CITY GREENHOUSE GAS EMISSIONS (CO2eq)

Source	United States (2004)	State of Washington (2004)	King County (2004)	City of Seattle & Community (2000)
Total Tons $CO_{2\text{-eq}}$	7,100 million	84 million	23 million	7.7 million
Source Distribution				
Transport	32%	50%	60%	54%
Industrial	18%	21%	10%	36%
Electricity	39%	17%	10%	6%
Other	10%	12%	20%	5%
Aviation (if identified)	3%	8-9% est.	NA	15%

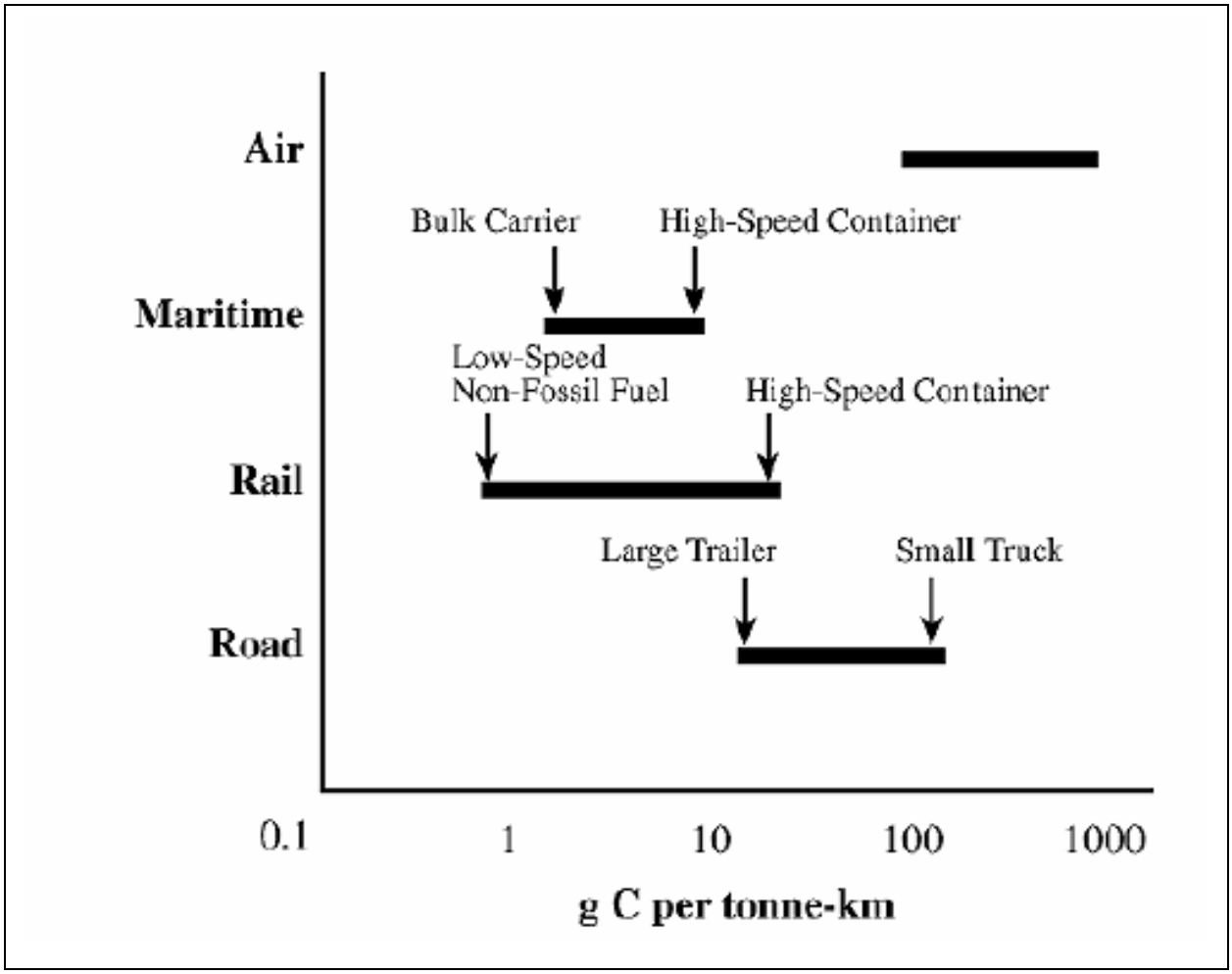
Source: *DRAFT Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004*, USEPA, February 2006; King County Plan, and City of Seattle (includes community and city emissions)

City emissions inventories. An exhaustive list of cities have begun or completed preparation of greenhouse gas emission inventories. In 2002, the City of Seattle completed an emissions inventory.[10] That inventory anticipated that transportation (including aviation) currently represents about 56% of citywide emissions. A category "airports" represented 14.8% of the total and is expected to increase to 16.3% of the citywide total by 2010. The method used in the Seattle inventory is similar to the IPCC Tier 1 method; emissions are based on fuel sales/dispensed at both Sea-Tac and Boeing Field. In the case of Sea-Tac Airport, the City of Seattle chose to include in its calculation 29% of the jet fuel dispensed at the Airport. This assumption is based on the percent of passengers originating from Seattle locations.

Comparison of Emissions from Various Mobile Sources: A frequently asked question about fuel efficiency and greenhouse gases relates to which mode of travel produces the least greenhouse gases. The answer to this requires an extensive list of assumptions concerning the vehicle and its efficiency. **Figure I-4,** from the IPCC, provides a general comparison reflecting the variability of fuel efficiency in ground and air vehicles.

[10] *Inventory and Report: Seattle's Greenhouse Gas Emissions*, City of Seattle, April 2002. http://www.seattle.gov/environment/Documents/GHG_Report.pdf#search='Seattle%20Greenhouse%20gas%20inventory'

FIGURE I-4
Carbon Efficiency of Mobile Sources



Source: IPCC, *Aviation and The Global Atmosphere*, Chapter 8.3.3 "Intermodality", 1999.

II. INVENTORY PROTOCOL

This chapter documents the methodologies used to prepare the 2006 greenhouse gas emissions inventory for Seattle-Tacoma International Airport. This chapter discusses:

- Port of Seattle Airport organization and operational boundaries
- Methods to quantify airport-related sources
- Uncertainties and Data Cautions

II.1 PORT OF SEATTLE AIRPORT ORGANIZATION AND OPERATIONAL BOUNDARIES

While a 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 sources of greenhouse gases and the identification of measures to reduce those emissions. To be useful requires consideration of an appropriate inventory boundary that reflects "the substance and economic reality of the entities activities" and responsibilities. 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, 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 Port's Aviation Division activities and associated emissions. This approach will enable the Port to combine, if it desires, the emissions associated with the airport organizational structure, with those of other elements of the Port.

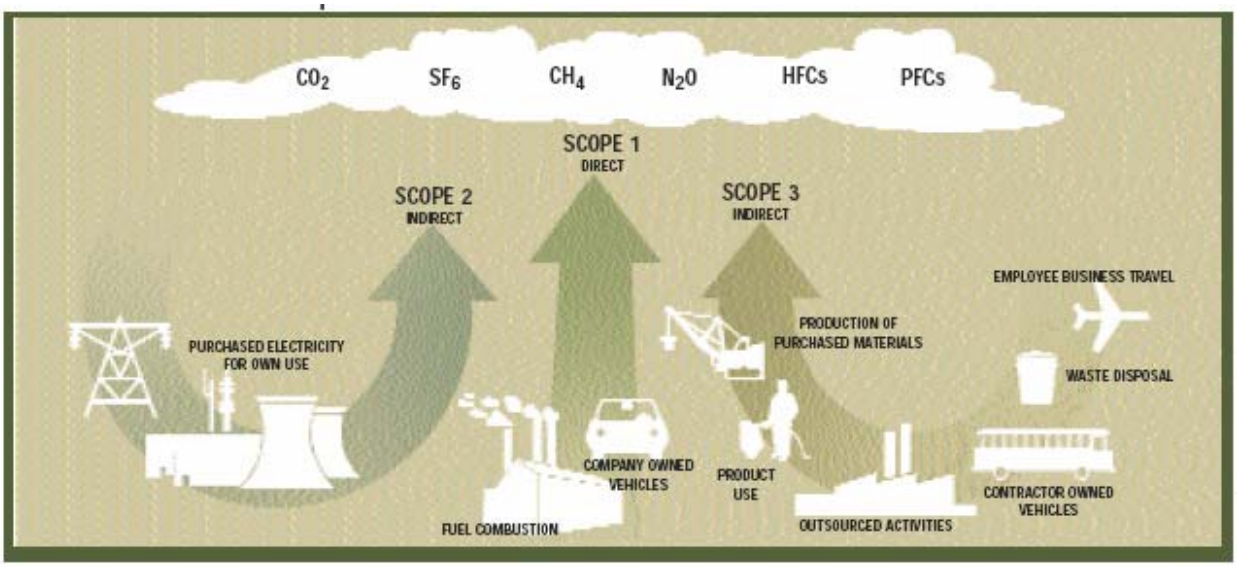
- **Operational boundaries**: Once an entity has determined its organizational boundaries in terms of the operations that it owns or controls, it then sets its operational boundaries. This involves identifying the emissions associated with its operations and categorizing them as *direct, indirect, and 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.

    - **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 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 Aviation Division was defined as the Port-owned land at Sea-Tac 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 or controlled by airlines/tenants. 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[11] "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."

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, most buildings and facilities are owned by the Port, 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 Port of Seattle Aviation Division inventory identifies sources of emissions and attempts to focus first on ownership and then control.

II.2 METHODS USED TO QUANITY GREENHOUSE GASES AT SEA-TAC AIRPORT

Based on the types of sources at Sea-Tac Airport, emissions from the following were quantified:

II.2.1. Aircraft Emissions

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

- The quantity of fuel dispensed at Sea-Tac to aircraft (jet fuel and aviation gas) was obtained by the Port of Seattle. Only Jet-A fuel is dispensed to aircraft at Sea-Tac. In 2006, a total of 441,039,267 gallons were dispensed. Fuel dispensed represents the amount of fuel that airlines acquired at Sea-Tac in order for departures to achieve their desired travel. It does not reflect the fuel acquired in origin cities that is necessary to enable travel to Sea-Tac (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 fuel consumption in the local setting and considers fuel consumed in the LTO approach mode. Fuel dispensed can be translated into CO_2

[11] *2006 IPCC Guidelines for Preparing National Greenhouse Gas Inventories , Volume I - General Guidance and Reporting*, IPCC, 2006, Page 1.4

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**.** Thus, aircraft fuel consumption at Sea-Tac generated about 4.2 million 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 Sea-Tac which consumed about 36.4 million gallons of Jet A fuel, and thus burned about 348,194 metric tons of CO_2.

  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 Sea-Tac 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*.
  - Time-in-mode: FAA's T1 data was also accessed to identify the specific time that aircraft operating at Sea-Tac 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. In accord with the IPCC Tier 2 method, emissions associated with flight in the cruise mode were identified based on subtracting the LTO based emissions from the fuel dispensed.

  In preparing the inventory for Sea-Tac, fuel consumption specifically associated with the Auxiliary Power Unit (APU) on aircraft could not easily be identified. However, similar to departure operations, such fuel use is reflected in the fuel dispensed. Therefore, unlike an emissions inventory for criteria pollutants, the greenhouse gas inventory for aircraft (cruise-related emissions) reflects fuel burn associated with the APU.

  As the Port of Seattle does not operate aircraft, the emissions associated with these sources are identified as Airline/Tenant-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, 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. 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 doe 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_2equivalent ($CO_{2\text{-}eq}$) is not evaluated in this report at this time**.

II.2.2 Ground Support Equipment (GSE)

This category refers to all of the airport and airline vehicles that support aircraft and airport activity. The method used to quantify GSE emissions was:

Port of Seattle GSE

Separate from airline/tenant GSE, the Port of Seattle operates GSE that include: fire fighting equipment, snow removal, airport administrative ground travel, and airport maintenance vehicles. In 2006, the Port purchased 144,268 gallons of gasoline, 179,710 equivalent gallons of CNG, and 16,745 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, and 120.593 lbs of CO_2 per 1,000 cubic feet of CNG).

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. Two scenarios were tested in the quantification of GSE emissions: 1) default data in EDMS, and 2) use of GSE operating times and fuel type from the 2000 survey. The primary differences in the two approaches are the amount of time that each GSE unit is used. The results of using the GSE survey time generate about 42,708 metric tons of CO_2. Use of the default EDMS GSE times indicates about 27,100 tons of CO_2. In light of the uncertainty concerning the emission factors, noted above, the higher (more conservative) emission level was used.
- 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 Sea-Tac Airport are primarily associated with passengers, employees, and cargo travel. It is not possible to capture in an inventory all GAV emissions with the data that is presently available, but rather this emissions inventory focused on capturing GAV emissions from passengers, parking and other surface movements, for which data is readily available. Thus, greenhouse gas emissions GAV were quantified in the following steps:

- In 2006, Sea-Tac Airport accommodated 29.9 million passengers. Passenger surveys conducted by the Port indicate that about 73% of the passengers begin or end their trip at

Sea-Tac and thus would use the roadway system.[12] This passenger survey further notes the mode by which passengers access the Airport: 47% by private vehicle, 21% by rental car, 12% by taxi/limo, 7% by other, and 13% by ShuttleExpress/Airporter. All vehicles are assumed to be gas except for ShuttleExpress/Airporter, which are assumed to be diesel. Some STIA taxi are CNG fueled, and some private vehicles are diesel. Therefore, it is likely that the estimate of passenger vehicle CO_2 emissions may be overstated with this evaluation.

The 2006 passenger survey indicates the general location of the origin/destination in the region of the passengers. Based on these locations, a Mapquest distance was obtained from the internet and a weighted average travel distance quantified. This data indicated an average one way trip of 49.5 miles to enter the Airport. It was expected that the limo/taxi distance is about 16.7 miles to enter the Airport. Once on-airport, these vehicles were estimated to travel an average distance of 2.29 miles. Fuel consumption associated with these vehicular trips was then calculated using a national fuel economy average for 2006 of 22.9 miles per gallon.

- Port of Seattle on-road vehicle use could not be separated from the Port-owned GSE as fueling records that separated the data were not available, and thus emissions from those sources are reported as GSE.
- Based on the Port's 2003 *Economic Impact Study*, the Port of Seattle employs approximately 1,171 people at Sea-Tac. Based on the tenant survey, employees at the Airport travel about 13.8 miles to work (27.6 miles round trip) at the national miles per gallon average of 22.9. For purposes of this evaluation, 90% of the Port employees are assumed to drive gas vehicles and 10% diesel. Using these statistics, the fuel consumption was calculated and CO_2 emissions based on the various fuel types.
- Similar to the Port employees, the 2003 *Economic Impact Study* identifies the number of employees reporting to work at airport tenant locations (17,847 employees). Based on the tenant survey, employees at the airport travel about 13.8 miles to work (27.6 miles round trip) at the national miles per gallon average of 22.9. For purposes of this evaluation, 90% of the tenant employees are assumed to drive gas vehicle and 10% diesel. Using these statistics, the fuel consumption was calculated and CO_2 emissions based on the various fuel types.
- The Port maintains an airport Automatic Vehicle Identification (AVI) system for use of the commercial vehicle lane. Through that system, the Port is able to report the number of trips that operators such as hotel shuttles, off-airport parking shuttles, etc. This data indicated that in 2006, hotel shuttles make 477,086 trips and about 1,171983 trips are made by off-airport parking organizations. The mileage to each location was calculated in order to identify the miles traveled. Calls to these companies indicate that a substantial portion of these vehicles are gas powered, enabling a calculation of gallons of fuel consumed and CO_2 emitted.
- The remaining quantify of vehicular trips were estimated based on actual vehicle counts collected in 2004. In 2004, approximately 15,914,000 vehicles entered the airport terminal area and 3,212,000 vehicles accessed the north cargo area. All of the vehicle travel noted above was subtracted from the vehicles entering the airport terminal area. This residual quantity was assumed to be vehicles recirculating in the terminal area -- representing about 681,215 trips. These vehicles were estimated to be 10% diesel and 90% gas. Vehicles entering the north cargo area were estimated to be half diesel and half gas.

[12] The remaining 27% of passengers connect through Sea-Tac to other cities, and thus do not use the airport roadway.

- Emissions were then grouped by user category.
  - Port-related ground access vehicle emissions reflect all emissions associated with travel on-airport roads, as well as all travel associated with Port-owned vehicles (regardless of the on- or off-airport roadway travel).
  - Airline/tenant-related ground access vehicles reflected the vehicles accessing the north cargo area, and tenant employee work commute on-airport.
  - A third category of ground access travel was noted representing Port and tenant employee commute off-airport, passenger vehicles off-airport, and hotel/parking shuttles off-airport. It is noted that data concerning tenant off-airport travel (such as cargo delivery and materials delivery off airport roads) is not available at this time and thus, is not represented in the inventory.

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. Port of Seattle records indicate that about 149,691,000 kilowatt hours (kWh) of electricity was purchased by the Port from Puget Sound Energy (PSE) in 2006. Using the Seattle Climate Partnership CO_2 generation for electrical power from PSE of 0.39 pounds of CO_2 per kWh, Port controlled airport facilities generate about 40,636 metric tons of electricity based CO_2.
- In addition to electricity, the Port purchases natural gas for purposes of heating various airport-related facilities. In 2006, 2,657,740 therms of natural gas were purchased, which generated about 14,156 metric tons of CO_2.
- The Port also consumes diesel fuel to power stationary sources, such as generators. Because the fuel consumed by the generators is not separately reported, the emissions from those sources are reflected in the Port-owned GSE noted above.

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 Port of Seattle 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. One is expected in late 2008/early 2009. 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. First, GSE greenhouse gas emission factors are not available from FAA or EPA models. Second, the default data from EDMS produced results that are 35% lower than that that were quantified using a 2000 Port survey of GSE use.

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. This inventory, however, represents the next step to improve the inventory prepared by the City of Seattle and should assist the Port of Seattle, and airport tenants and users, with examining and possibly reducing their contribution to greenhouse gases and the effects of these gases on climate change. 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. As the table notes, nearly 5.1 million metric tons of CO_2 were emitted in 2006, not including the non-CO_2 greenhouse gases. Relative to this total, 4.8% are associated with Port of Seattle Aviation Division activities, 83.8% of the emissions are associated with tenant activities, and 11.4% by public access activities.

TABLE III-1
SUMMARY OF GREENHOUSE GAS EMISSIONS ASSOCIATED WITH SEA-TAC AIRPORT ACTIVITY (2006)

User/Source Category	CO2 (tons/year)	Percent of User	Percent of Total
Port of Seattle-owned/controlled			
Facilities/Stationary Sources	40,636	16.7%	0.8%
Ground Support Equipment (on- and off-road)	2,730	1.1%	0.1%
Ground Access Vehicles			
Passenger Vehicles (airport roads)*	21,233	8.7%	0.4%
Hotel & Parking Shuttles (airport roads)	178,341	73.3%	3.5%
Port Employee Commute (on-airport)	263	0.1%	0.0%
Port-owned Vehicles (all roads)	0	0.0%	0.0%
Ground Access Vehicles Total	**199,837**	**82.2%**	**3.9%**
Port of Seattle-owned/controlled Total	**243,203**	**100.0%**	**4.8%**
Airlines/Tenants-owned/controlled*			
Aircraft			
Approach	49,722	1.2%	1.0%
Taxi/Idle/Delay	168,812	4.0%	3.3%
Takeoff	81,806	1.9%	1.6%
Climbout	47,854	1.1%	0.9%
Residual/Cruise/APU	3,871,903	90.7%	76.0%
Aircraft Total	**4,220,098**	**98.8%**	**82.8%**
Ground Support Equipment	**42,708**	**1.0%**	**0.8%**
Ground Access Vehicles (on-airport)			
Tenant Ground Access Vehicles	4,843	0.1%	0.1%
Tenant Employee Commute	2,353	0.1%	0.0%
Ground Access Vehicles Total	**7,196**	**0.2%**	**0.1%**
Stationary Sources	**0**	**0.0%**	**0.0%**
Airline/Tenant-owned/controlled Total	**4,270,002**	**100.0%**	**83.8%**
Public-owned/controlled*			
Port and Tenant Employee Commute (off-airport)	46,122	7.9%	0.9%
Passenger Vehicles (off-airport roads)	323,644	55.7%	6.4%
Hotel & Parking Shuttles (off airport roads)	211,017	36.3%	4.1%
Public-owned-controlled Total	**580,783**	**100.0%**	**11.4%**
Total Metric Tons	**5,093,989**		**100%**

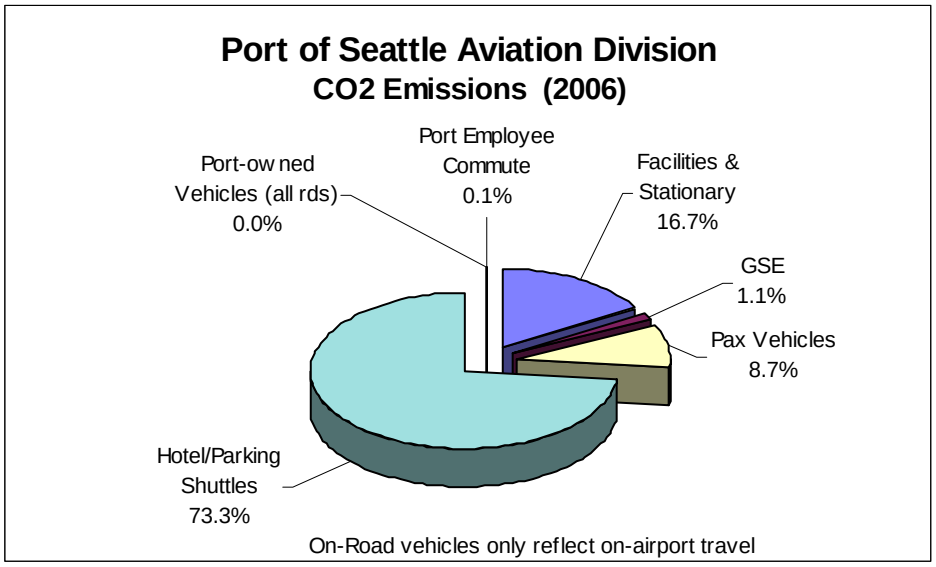
Updated 10-30-07 * includes an estimate of vehicle re-circulating on the terminal curb roadway.
** does not include off-airport travel for non-passenger traffic (i.e., cargo).
*** Note that Port owned vehicles traveling on public roads are noted in the GSE, due to fuel format.
Note: At this time, only CO_2 emissions are reflected, as factors for other GHG are not available for all sources.

The total airport-related emissions are about 22% of King County community emissions (as noted in **Table I-2)**. Further, the methodologies are not consistent, and that caution is advised when comparing the above inventory to that of the City, County, or State. The approach taken in the inventory, while not precise, represents the most thorough consideration of aviation emissions to date for Sea-Tac.

III.1 PORT OF SEATTLE OWNED/CONTROLLED EMISSIONS

As noted in **Table III-1**, Port of Seattle Aviation Division-related emissions represent 243,203 metric tons of CO_2 in 2006. **Figure III-1** shows the proportion of emissions associated with the Port of Seattle Aviation Division.

FIGURE III-1

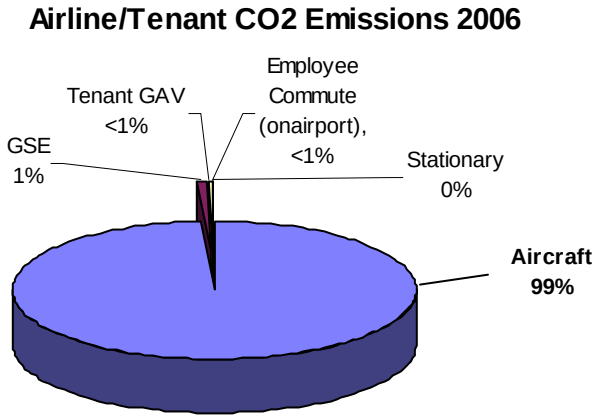


As this chart notes, the largest portion of greenhouse gas emissions that the Port either owns or has substantial control, is that associated with hotel and parking lot shuttles accessing the Airport, followed by the emissions associated with lighting and heating airport facilities. These two sources (facilities and Hotel/Parking shuttles) represent 90% of Aviation Division emissions.

III.2 AIRLINE/TENANT OWNED/CONTROLLED EMISSIONS

Airline/tenant-owned and controlled emissions represent 83.8% of airport-related emissions are noted in **Table III-1** or nearly 4.3 million metric tons of CO_2 in 2006. As would be expected, aircraft represent the single largest source of CO_2 emissions at nearly 99% (4.2 million tons of CO_2). GSE represent the second largest source of airline/tenant emissions at 1%. No tenant information was pursued concerning facility of stationary source emissions. 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.

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. As data is not available concerning cargo surface travel off-airport, it is omitted from this evaluation. Of airport-related emissions this user group represents 11.4% of all emissions or 580,783 metric tons of CO_2 in 2006. Passenger roadway travel is estimated to the largest source of emissions at nearly 56% followed by the shuttles by hotels/parking lot companies at 36%. Port and tenant employee off-airport commute represents about 8% of public-owned and controlled emissions.

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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 City of Seattle. However, as noted through the documentation of the methodologies deployed on other inventories, as well this version, improvements could be made in the data and 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. Fuel dispensed at the airport is a reliable source and the conversion of fuel burn to CO_2 emissions is relatively well understood. Given the current format of fuel data, it is not possible to separate out the emissions associated with Auxiliary Power Unit (APU).
- 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, the Port's 2000 GSE survey was used to identify the amount of time that each GSE vehicle is used. It is expected that many of the airlines have begun to convert their GSE to alternative fuel vehicles, such as electric and propane. Thus, an updated survey of tenant GSE use would improve the accuracy of the GSE data. Because the proportion of vehicles by fuel type relied upon the 2000 survey, it is possible that the GSE emissions are overstated. Port of Seattle GSE use is accurate, as it reflects actual fuel burn associated with those sources.
- Ground Access Vehicles (GAV): Hotel and parking shuttle vehicle travel is well documented at Sea-Tac due to the AVI system in place. However, while the Port collects extensive quantities of surface vehicle travel, the data is currently not segregated by users (i.e., Tenant, and public nor by vehicle types). Thus, the evaluation of GAV emissions is an estimate at this time.
- Facilities/Stationary Sources: The Port retains data concerning fuel use by airport facilities. This enables a clear identification of CO_2 emissions.

IV.2 FUTURE DATA COLLECTION

The Port has a tremendous data collection basis for Sea-Tac Airport. This information process has been designed to assist the Port 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 users groups, and thus their greenhouse gas emissions. Such examples could include:

- Passenger survey: The Port conducts an extensive passenger survey every few years. Consideration should be given to further defining the following passenger and travel characteristics:

- Type of vehicle transporting the passenger to/from SEA (auto, SUV, pickup truck, van, bus)
- Distance that each passenger traveled to and/or from SEA

- Surface Vehicle Travel: The Port has collected a wealth of information concerning the number of vehicles entering and exiting the airport. The following could be undertaken in the future:
  - Categorizing the types of vehicles (i.e., auto, SUV, pickup truck, delivery truck, heavy truck, etc.) would improve the analysis, as would the facility that each vehicle visited to (i.e., cargo, passenger, governmental, etc). The analysis reported in this inventory assumed that all vehicles accessing the North Cargo area are by tenant activities (versus that of the general public). The next time that that Port conducts 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 Port could consider conducting a survey 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. This survey could also, separately be conducted for off-airport rental car firms that have courtesy shuttles accessing the Airport.

  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 Port owned facilities. Consideration should be given to stratifying this power demand by resource (terminal, support facilities, airfield, etc).
- Ground Support Equipment (GSE):
  - The Port maintains information about is fleet of airport GSE. Future data should strive to segregate this fuel purchase by: 1) construction equipment, 2) snow removal equipment, 3) regular airfield/airport maintenance, 4) airport fire; 5) airport police, and 6) administrative. This type of stratification would enable consideration of greenhouse gas emissions and possible mitigation avenues. It would also enable the Port to track changes over time.
  - A limited survey of GSE use was conducted in 2000. Based on a comparison of the EDMS default data and that of the survey, it appears that GSE use was either not fully surveyed in 2000 or underreported. A full survey of GSE and their use would improve the accuracy of the inventory. It is expected that airlines at Sea-Tac have a much greater number of electric powered vehicles than reflected in the data collected 7 years ago.
  - Additional confirmation with the airlines could be conducted concerning the fuel burn associated with GSE to assure that the CO2 emissions associated with the vehicles are a high as noted in this analysis.

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
AVI - Automatic Vehicle Identification

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

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

SCP - Seattle Climate Partnership
SEA - Sea-Tac Airport
SEPA - Washington State 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 (CCl_2F_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.

COGENERATION: Production of two useful forms of energy, such as high temperature heat and electricity, from the same process.

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

COMMERCIAL SECTOR: An area consisting of non-housing units such as non-manufacturing business establishments (e.g., wholesale and retail businesses), health and educational institutions, and government offices.

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).

CRUDE OIL: A mixture of hydrocarbons that exist in liquid phase in underground reservoirs and remain liquid at atmospheric pressure after passing through surface separating facilities.

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.

FREON: See chlorofluorocarbon.

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.

GASOHOL: Vehicle fuel consisting of a mixture of gasoline and ethyl or methyl alcohol; typically 10 to 23 percent ethanol by volume.

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).

HALOCARBONS: Chemicals consisting of carbon, sometimes hydrogen, and either chlorine, fluorine, bromine or iodine.

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.

KEROGEN: Solid, waxy mixture of hydrocarbons found in oil shale, with a fine grained sedimentary rock. When the rock is heated to high temperatures, the kerogen is vaporized. The vapor is condensed and then sent to a refinery to produce gasoline, heating oil, and other products.

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.

NAPHTHA: A generic term applied to a petroleum fraction with an approximate boiling range between 122 and 400 degrees Fahrenheit.

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 (NOx): 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.

OIL SHALE: Underground formation of a fine-grained sedimentary rock containing varying amounts of kerogen, a solid, waxy mixture of hydrocarbon compounds. Heating the rock to high temperatures converts the kerogen to a vapor, which can be condensed to form a slow flowing heavy oil called shale oil.

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.

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

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.

PETROLEUM: A generic term applied to oil and oil products in all forms, such as crude oil, lease condensate, unfinished oils, petroleum products, natural gas plant liquids, and non-hydrocarbon compounds blended into finished petroleum products.

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.

RAIL: Includes "heavy" and "light" transit rail. Heavy transit rail is characterized by exclusive rights-of-way, multi-car trains, high speed rapid acceleration, sophisticated signaling, and high platform loading. Also known as subway, elevated railway, or metropolitan railway (metro). Light transit rail may be on exclusive or shared rights of way, high or low platform, multi-car trains or single cars, automated or manually operated. In generic usage, light rail includes streetcars, trolley cars, and tramways.

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.

RESIDENTIAL SECTOR: An area or portion consisting only of housing units.

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).

SHALE OIL: Slow-flowing, dark brown, heavy oil obtained when kerogen in oil shale is vaporized at high temperatures and then condensed. Shale oil can be refined to yield gasoline, heating oil, and other petroleum products.

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.

SPECIAL NAPHTHA: All finished products within the naphtha boiling range that are used as paint thinners, cleaners, or solvents. Those products are refined to a specified flash point.

STILL GAS: Any form or mixture of gases produced in refineries by distillation, cracking, reforming, and other processes. Principal constituents are methane, ethane, ethylene, normal butane, butylene, propane, propylene, etc. Used as a refinery fuel and as a petrochemical feedstock.

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.

SYNTHETIC NATURAL GAS (SNG): A manufactured product chemically similar in most respects to natural gas, resulting from the conversion or reforming of petroleum hydrocarbons. It may easily be substituted for, or interchanged with, pipeline quality natural gas.

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

Sea-Tac Airport Greenhouse Gas Calculations

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Seattle-Tacoma International Airport-related CO2 Emissions 2006

User/Source Category	Fuel Data	Fuel Units	CO2 (tons/year)	Percent of User	Percent of Total
Port of Seattle-owned/controlled					
Facilities/Stationary Sources	776,520	Million BTU	40,636	16.7%	0.8%
Ground Support Equipment (on- and off-road)	20,512	Million BTU	2,730	1.1%	0.1%
Ground Access Vehicles					
Passenger Vehicles (airport roads)*	295,591	Million BTU	21,233	8.7%	0.4%
Hotel & Parking Shuttles (airport roads)	2,198,892	Million BTU	178,341	73.3%	3.5%
Port Employee Commute (on-airport)	3,658	Million BTU	263	0.1%	0.0%
Port-owned Vehicles (all roads)	0	Million BTU	0	0.0%	0.0%
Ground Access Vehicles Total	**2,498,140**	Million BTU	**199,837**	**82.2%**	**3.9%**
Port of Seattle-owned/controlled Total	**3,295,172**	Million BTU	**243,203**	**100.0%**	**4.8%**
Airlines/Tenants-owned/controlled*					
Aircraft					
Approach	701,519	Million BTU	49,722	1.2%	1.0%
Taxi/Idle/Delay	2,381,727	Million BTU	168,812	4.0%	3.3%
Takeoff	1,154,177	Million BTU	81,806	1.9%	1.6%
Climbout	675,166	Million BTU	47,854	1.1%	0.9%
Residual/Cruise/APU	54,627,712	Million BTU	3,871,903	90.7%	76.0%
Aircraft Total	**59,540,301**	Million BTU	**4,220,098**	**98.8%**	**82.8%**
Ground Support Equipment	**985,316**	Million BTU	**42,708**	**1.0%**	**0.8%**
Ground Access Vehicles (on-airport)					
Tenant Ground Access Vehicles	110,595	Million BTU	4,843	0.1%	0.1%
Tenant Employee Commute	36,901	Million BTU	2,353	0.1%	0.0%
Ground Access Vehicles Total	**147,495**	Million BTU	**7,196**	**0.2%**	**0.1%**
Stationary Sources	**0**	Million BTU	**0**	**0.0%**	**0.0%**
Airline/Tenant-owned/controlled Total	**60,673,113**	Million BTU	**4,270,002**	**100.0%**	**83.8%**
Public-owned/controlled*					
Port and Tenant Employee Commute (off-airport)	723,081	Million BTU	46,122	7.9%	0.9%
Passenger Vehicles (off-airport roads)	4,575,911	Million BTU	323,644	55.7%	6.4%
Hotel & Parking Shuttles (off airport roads)	2,968,175	Million BTU	211,017	36.3%	4.1%
Public-owned-controlled Total	**8,267,167**	Million BTU	**580,783**	**100.0%**	**11.4%**
Total Metric Tons			**5,093,989**		**100%**

* includes an estimate of vehicle recirculating on the terminal curb roadway

** does not include off-airport travel for non-passenger traffic (ie, cargo)

10/30/2007

Seattle-Tacoma International Airport

Power Type	Use	Units	Use	Source	CO2 Emission Rate (lb/unit)	Conver	Unit Conv	CO2 (tons)	M BTU
Electrical	149,691,000	Kwh	Total airport	Seattle Light	0.60	0.000453592	lbs to ton	0	-
				PSE	0.39	0.000453592	lbs to ton	26,480	510,745.69
				GreenPwr	0.00	0.000453592	lbs to ton	0	-
Natural Gas	2,657,740	Therms	Heating	NG (kg/therm)	5.33	0.001	kg to ton	14,156	265,774.00
	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	-
Source: Russ Simonson from Stacey Fox					Total			40,636	776,519.69

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	-
					Total			0	0.0

Reported in Metric Ton See worksheet "Energydata" for sources Note that Port Diesel is listed in the GAV as fuel dispensed

BTU Conversion - electric: 3412 BTU per Kwh
Natural Gas: 100,000 BTU per Therm
Diesel - 137,700 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 1000
	0.4536	convert lb/kg 1 lb=0.4536 kg
	0.054701	kg/ft3
	97.37	1 therm = (100,000/1027)=97.37ft3
	5.33	kg/therm

Ground Support Equipment - GSE

Airline GSE -- See GSE_2006

Sea-Tac Airport - Port Owned

Power Type	Use	Units	Use	Conversion Factors	Converted	CO2 factor	Units CO2	CO2 (tons)	BTUs
Gasoline	144,268	gal	on and off rd	none	None	19.564	Lbs/gal	1,280.25	18,033,500,000
CNG	179,710	gal equiv		Convert to ft3	23,398.2	120.593	lb/ft3	1,279.9	172,521,600
CNG	-	ft3		none	None	120.593	lb/ft3	-	-
Diesel	16,745	Gal	on and off rd	none	None	22.384	lbs/gal	170.0	2,305,786,500
						Total		2,730.1	20,511,808,100

Source: Russ Simonson from Stacey Fox 10-8-07 email

Reported in Metric Ton See worksheet "Energydata" for sources

Note that Port Diesel and gas includes on and off-road use - as fuel dispensed
Fire, snow, and all POS vehicles fueling at SEA

CO2 Factor Source: See worksheet EnergyData

to calculate the energy eqivalent of CNG to gallons

Diesel	137,700	BTU/gal	
CNG	960	BTU/ft3	Transportation Data Energy Book
Motor Gas	125,000	BTU/gal	
CNG gal equiv	130.2083	ft3/gal	@sum(125,000/960)
CNG	120.593	lb CO2/1000 ft3	

0.00045359237 Lbs/ton

Airline GSE

Emissions Calculation (CO2 lbs)			
Lbs CO2 Diesel	Lbs CO2 Gas	Lbs CO2 Prop	Lbs CO2 Electric
12,346	27,338	3,024	-

Tons CO2	
Total Tons	42,708
Total M BTU	985,316

Port 2000 Survey

			Survey				Fuel Type Distribution (2000 CDM survey)				CO2 Emissions Rate (NONROAD2005)				
GSE Type	REFERENCE	Fuel	Survey Hp	Load Factor	Annual Hours	Min/LTO	Diesel %	Gas %	Prop %	Elect %	Diesel g/hp-hr	Gas g/hp-hr	CNG g/hp-hr	Prop g/hp-hr	Elect g/hp-hr
Air conditioner	None.	Diesel	154.5	0.75	4,040	1.426	100.0%	0.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Air Start	ACE 180	Diesel	383.9	0.70	5,661	1.998	100.0%	0.0%	0.0%	0.0%	543.26	848.39	494.29	644.99	0
Aircraft Tractor	ACE 300/400	Diesel	213.1	0.80	28,204	9.953	100.0%	0.0%	0.0%	0.0%	542.41	830.48	488.64	640.30	0
Baggage Tractor	Stewart & Stevens	Diesel	70.9	0.55	17,864	6.304	100.0%	0.0%	0.0%	0.0%	608.68	868.69	488.20	643.02	0
Belt Loader	Stewart & Stevens	Diesel	54.3	0.50	10,380	3.663	100.0%	0.0%	0.0%	0.0%	608.68	868.69	488.20	643.02	0
Bobtail	Stewart & Stevens	Diesel	112.7	0.55	-	0.000	100.0%	0.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Cargo Loader	Stewart & Stevens	Diesel	100.7	0.50	26,158	9.231	100.0%	0.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Cargo Tractor	Stewart & Stevens	Diesel	88.0	0.54	505	0.178	100.0%	0.0%	0.0%	0.0%	607.99	886.52	478.08	640.38	0
Cart	Stewart & Stevens	Diesel	55.0	0.50	-	0.000	100.0%	0.0%	0.0%	0.0%	608.68	868.69	488.20	643.02	0
Catering Truck	Stewart & Stevens	Diesel	240.0	0.53	1,600	0.565	100.0%	0.0%	0.0%	0.0%	542.41	830.48	488.64	640.30	0
Deicer	Hi-Way / TUG 660	Diesel	117.5	0.95	-	0.000	100.0%	0.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Forklift	Hi-Way F650	Diesel	155.5	0.30	5,124	1.808	100.0%	0.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Fuel truck	FMC Commander 1	Diesel	188.6	0.25	125,604	44.323	100.0%	0.0%	0.0%	0.0%	542.41	830.48	488.64	640.30	0
Generator	FMC Commander 3	Diesel	158.3	0.82	6,520	2.301	100.0%	0.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
GPU	Taylor Dunn	Diesel	163.1	0.75	31,944	11.272	100.0%	0.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Hydrant Truck	Hi-Way / TUG 660	Diesel	175.0	0.70	-	0.000	100.0%	0.0%	0.0%	0.0%	542.41	830.48	488.64	640.30	0
Lavatory Cart	Hi-Way F650	Diesel	55.0	0.50	-	0.000	100.0%	0.0%	0.0%	0.0%	608.68	868.69	488.20	643.02	0
Lavatory Truck	F750, Dukes Trans	Diesel	167.5	0.25	-	0.000	100.0%	0.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Lift	Dukes Transportati	Diesel	115.1	0.50	4,585	1.618	100.0%	0.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Other	(None specified. EF	Diesel	140.4	0.50	27,982	9.874	100.0%	0.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Passenger Stand	TLD, 28 VDC	Diesel	100.3	0.57	140	0.049	100.0%	0.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Service Truck	TLD	Diesel	173.6	0.20	1,931	0.681	100.0%	0.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Sweeper	F250 / F350	Diesel	53.3	0.51	-	0.000	100.0%	0.0%	0.0%	0.0%	608.68	868.69	488.20	643.02	0
Water Service	Gate Service	Diesel	158.6	0.20	-	0.000	100.0%	0.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Air conditioner	None.	Gas	154.5	0.75	808	0.285	0.0%	100.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Air Start	ACE 180	Gas	178.8	0.90	-	0.000	0.0%	100.0%	0.0%	0.0%	542.41	830.48	488.64	640.30	0
Aircraft Tractor	ACE 300/400	Gas	138.9	0.80	6,534	2.306	0.0%	100.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Baggage Tractor	Stewart & Stevens	Gas	100.1	0.55	277,485	97.919	0.0%	100.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Belt Loader	Stewart & Stevens	Gas	97.4	0.50	64,285	22.685	0.0%	100.0%	0.0%	0.0%	607.99	886.52	478.08	640.38	0
Bobtail	Stewart & Stevens	Gas	152.2	0.55	18,667	6.587	0.0%	100.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Cargo Loader	Stewart & Stevens	Gas	105.0	0.50	13,446	4.745	0.0%	100.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Cargo Tractor	Stewart & Stevens	Gas	95.0	0.54	12,141	4.284	0.0%	100.0%	0.0%	0.0%	607.99	886.52	478.08	640.38	0
Cart	Stewart & Stevens	Gas	55.0	0.50	-	0.000	0.0%	100.0%	0.0%	0.0%	608.68	868.69	488.20	643.02	0
Catering Truck	Stewart & Stevens	Gas	203.9	0.53	4,060	1.433	0.0%	100.0%	0.0%	0.0%	542.41	830.48	488.64	640.30	0
Deicer	Hi-Way / TUG 660	Gas	117.5	0.95	2,329	0.822	0.0%	100.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Forklift	Hi-Way F650	Gas	81.1	0.30	3,210	1.133	0.0%	100.0%	0.0%	0.0%	607.99	886.52	478.08	640.38	0
Fuel truck	FMC Commander 1	Gas	119.8	0.25	8,705	3.072	0.0%	100.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Generator	FMC Commander 3	Gas	107.0	0.82	7,200	2.541	0.0%	100.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
GPU	Taylor Dunn	Gas	99.3	0.75	3,482	1.229	0.0%	100.0%	0.0%	0.0%	607.99	886.52	478.08	640.38	0

			Survey				Fuel Type Distribution (2000 CDM survey)				CO2 Emissions Rate (NONROAD2005)				
GSE Type	REFERENCE	Fuel	Survey Hp	Load Factor	Annual Hours	Min/LTO	Diesel %	Gas %	Prop %	Elect %	Diesel g/hp-hr	Gas g/hp-hr	CNG g/hp-hr	Prop g/hp-hr	Elect g/hp-hr
Hydrant Truck	Hi-Way / TUG 660	Gas	121.5	0.70	3,054	1.078	0.0%	100.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Lavatory Cart	Hi-Way F650	Gas	55.0	0.50	644	0.227	0.0%	100.0%	0.0%	0.0%	608.68	868.69	488.20	643.02	0
Lavatory Truck	F750, Dukes Trans	Gas	143.9	0.25	22,380	7.897	0.0%	100.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Lift	Dukes Transportati	Gas	104.9	0.50	14,288	5.042	0.0%	100.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Other	(None specified. EF	Gas	126.2	0.50	67,704	23.891	0.0%	100.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Passenger Stand	TLD, 28 VDC	Gas	125.1	0.57	1,504	0.531	0.0%	100.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Service Truck	TLD	Gas	131.4	0.20	22,680	8.003	0.0%	100.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Sweeper	F250 / F350	Gas	53.3	0.51	1,086	0.383	0.0%	100.0%	0.0%	0.0%	608.68	868.69	488.20	643.02	0
Water Service	Gate Service	Gas	158.6	0.20	13,860	4.891	0.0%	100.0%	0.0%	0.0%	547.93	871.10	490.24	643.86	0
Air conditioner	None.	Prop	154.5	0.75	-	0.000	0.0%	0.0%	100.0%	0.0%	547.93	871.10	490.24	643.86	0
Air Start	ACE 180	Prop	178.8	0.70	-	0.000	0.0%	0.0%	100.0%	0.0%	542.41	830.48	488.64	640.30	0
Aircraft Tractor	ACE 300/400	Prop	138.9	0.80	-	0.000	0.0%	0.0%	100.0%	0.0%	547.93	871.10	490.24	643.86	0
Baggage Tractor	Stewart & Stevens	Prop	118.8	0.55	38,963	13.749	0.0%	0.0%	100.0%	0.0%	547.93	871.10	490.24	643.86	0
Belt Loader	Stewart & Stevens	Prop	165.0	0.50	15,979	5.639	0.0%	0.0%	100.0%	0.0%	547.93	871.10	490.24	643.86	0
Bobtail	Stewart & Stevens	Prop	152.2	0.55	-	0.000	0.0%	0.0%	100.0%	0.0%	547.93	871.10	490.24	643.86	0
Cargo Loader	Stewart & Stevens	Prop	102.8	0.50	-	0.000	0.0%	0.0%	100.0%	0.0%	547.93	871.10	490.24	643.86	0
Cargo Tractor	Stewart & Stevens	Prop	155.6	0.54	-	0.000	0.0%	0.0%	100.0%	0.0%	547.93	871.10	490.24	643.86	0
Cart	Stewart & Stevens	Prop	55.0	0.50	-	0.000	0.0%	0.0%	100.0%	0.0%	608.68	868.69	488.20	643.02	0
Catering Truck	Stewart & Stevens	Prop	205.0	0.53	-	0.000	0.0%	0.0%	100.0%	0.0%	542.41	830.48	488.64	640.30	0
Deicer	Hi-Way / TUG 660	Prop	117.5	0.95	-	0.000	0.0%	0.0%	100.0%	0.0%	547.93	871.10	490.24	643.86	0
Forklift	Hi-Way F650	Prop	68.0	0.30	37,088	13.088	0.0%	0.0%	100.0%	0.0%	608.68	868.69	488.20	643.02	0
Fuel truck	FMC Commander 1	Prop	140.0	0.25	-	0.000	0.0%	0.0%	100.0%	0.0%	547.93	871.10	490.24	643.86	0
Generator	FMC Commander 3	Prop	107.0	0.82	-	0.000	0.0%	0.0%	100.0%	0.0%	547.93	871.10	490.24	643.86	0
GPU	Taylor Dunn	Prop	99.3	0.75	-	0.000	0.0%	0.0%	100.0%	0.0%	607.99	886.52	478.08	640.38	0
Hydrant Truck	Hi-Way / TUG 660	Prop	121.5	0.70	-	0.000	0.0%	0.0%	100.0%	0.0%	547.93	871.10	490.24	643.86	0
Lavatory Cart	Hi-Way F650	Prop	55.0	0.50	-	0.000	0.0%	0.0%	100.0%	0.0%	608.68	868.69	488.20	643.02	0
Lavatory Truck	F750, Dukes Trans	Prop	163.3	0.25	-	0.000	0.0%	0.0%	100.0%	0.0%	547.93	871.10	490.24	643.86	0
Lift	Dukes Transportati	Prop	132.2	0.50	682	0.241	0.0%	0.0%	100.0%	0.0%	547.93	871.10	490.24	643.86	0
Other	(None specified. EF	Prop	173.3	0.50	-	0.000	0.0%	0.0%	100.0%	0.0%	547.93	871.10	490.24	643.86	0
Passenger Stand	TLD, 28 VDC	Prop	165.0	0.57	-	0.000	0.0%	0.0%	100.0%	0.0%	547.93	871.10	490.24	643.86	0
Service Truck	TLD	Prop	149.3	0.20	-	0.000	0.0%	0.0%	100.0%	0.0%	547.93	871.10	490.24	643.86	0
Sweeper	F250 / F350	Prop	45.0	0.51	1,390	0.491	0.0%	0.0%	100.0%	0.0%	608.04	1,002.02	471.54	626.35	0
Water Service	Gate Service	Prop	158.6	0.20	-	0.000	0.0%	0.0%	100.0%	0.0%	547.93	871.10	490.24	643.86	0

Tot Lbs
Tons CO2
Tons CO2
M BTU

All Default GSE usage time and equipment

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

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

0.002205 conversion of grams to lbs

0.0004536200 Conversion of lbs to metric tons

Sea-Tac Airport Ground Access Vehicles

Sea-Tac Airport Passenger Travel

Passenger On Road Travel	%	Pax	MPG	Dist (mi)	Fuel (Gallons)	CO2 lbs/gal	CO2 (lbs)	BTU
Annual Passengers								
Total Passengers		29,979,097						
O&D Percent/Pax	73%	21,974,678						
Mode split (2006 POS Pax Survey)								
On-Airport Roads								
Private vehicle (Gas)	47%	10,328,099	22.9	2.289	1,032,359	19.5640	20,197,068.8	129,044,857,759
Rental Car (gas)	21%	4,614,682	22.9	2.289	461,267	19.5640	9,024,222.2	57,658,340,701
Taxi/Limo (gas)	6%	1,318,481	22.9	2.289	131,790	19.5640	2,578,349.2	16,473,811,629
Taxi/Limo (CNG)	6%	1,318,481	22.9	2.289	131,790	120.5930	2,069,401.9	16,473,807,411
Other (gas)	7%	1,538,227	22.9	2.289	153,756	19.5640	3,008,074.1	19,219,446,900
Airporter/SuperShuttle (Diesel)	13%	2,856,708	16.0	2.289	408,688	22.384	9,148,067.9	56,276,311,459
	100.00%		Subtotal		2,319,650	Tons -->	20,876.7	289,956,244,887
Off-Airport								-
Private vehicle Gas	47%	10,328,099	22.9	49.5	22,324,930	19.5640	436,764,921.1	2,790,616,190,064
Rental Car	21%	4,614,682	22.9	49.5	9,974,969	19.5640	195,150,283.9	1,246,871,063,646
Taxi/Limo (gas 1/2)	6%	1,318,481	22.9	16.7	961,512	19.5640	18,811,023.0	120,189,014,504
Taxi/Limo (CNG)	6%	1,318,481	22.9	16.7	961,512	120.5930	15,097,864.7	120,188,983,736
Other	7%	1,538,227	22.9	15	1,007,573	19.5640	19,712,149.9	125,946,572,085
Airporter/SuperShuttle (Diesel)	13%	2,856,708	16.0	7	1,249,810	22.384	27,975,742.9	172,098,811,800
Average Distance estimated			Subtotal		36,480,305	Tons -->	323,643.6	4,575,910,635,836
MPG - Transp Data Energy Book #26 Table				Total	38,799,955	Tons -->	344,520.3	4,865,866,880,723

BTU conversion below

O&D Passenger Survey 2006 (see to the right)

Port of Seattle 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 trave	NA	19.564	lb/gal	0	-
Fuel and Use CNG	0	ft3				120.593	lb/ft3	0	0
Fuel and Use CNG	0	gal equiv	gal eq to ft3	130.2083	ft3/gal	120.593	lb/ft3	0	0
Fuel and Use Diesel	0	gal	NA	OnRoad trave	NA	22.384	lb/gal	0	0
Port owned vehicles included in GSE as fuel is not currenty recorded in this format							Tons CO2	0.0	0

Port of Seattle Airport Employees Commute Travel

Employee On Road Travel		Employees	MPG	Rnd trip Dist (mi)	Fuel (Gallons)	CO2 lbs/gal	CO2 (lbs)	BTUs Fuel
Off-airport travel								
POS Employees gas (90% of employees)		1,054	22.9	27.6	317,551	19.5640	6,212,561	39,693,831,878
POS Diesel (10% of employees)		117	22.9	27.6	35,283	22.3840	789,784	4,858,525,022
(2003 Economic Impact Study) Miles = employees*miles*50 weeks*5 days		1,171			**Total Pounds**		7,002,345	
				Total	352,834	**Tons**	3,176	44,104,257,642
On-airport travel								
POS Employees gas (90% of employees)		1,054	22.9	2.289	26,336	19.5640	515,237	3,291,999,318
POS Diesel (10% of employees)		117	22.9	2.289	2,926	22.3840	65,501	402,940,716
(2003 Economic Impact Study) Miles = employees*miles*50 weeks*5 days					**Total Pounds**		580,738	
Assumed paring in main garage				**Total**	29,262	**Tons**	263	3,657,777,020

Tenant Employees Commute Travel

Employee On Road Travel		Employees	MPG	Rnd trip Dist (mi)	Fuel (Gallons)	CO2 lbs/gal	CO2 (lbs)	BTUs Fuel
Off-airport travel								
Tenant Employees gas (90% of employees)		16,061	22.9	27.6	4,839,461	19.5640	94,679,218	604,932,641,921
Tenant Diesel (10% of employees)		1,785	22.9	27.6	537,718	22.3840	12,036,278	74,043,755,371
(2003 Economic Impact Study)		17,846			**Total Pounds**		94,679,218	
Miles = employees*miles*50 weeks*5 days				**Total**	5,377,179	**Tons**	42,945.8	678,976,397,293
On-airport travel								
Tenant Employees gas (90% of employees)		16,061	22.9	1.5	263,014	19.5640	5,145,610	32,876,774,017
Tenant Diesel (10% of employees)		1,785	22.9	1.5	29,224	22.3840	654,146	4,024,117,140
(2003 Economic Impact Study)					**Total Pounds**		5,188,555	
Miles = employees*miles*50 weeks*5 days assumed SEPL/NEPL				**Total**	292,238	**Tons**	2,353.5	36,900,891,157

Tenant GAV All Roads

Fuel type	Amount	Units	Conversion	Use	Conversion	CO2 Factor	units	CO2 (lbs)	BTUs Fuel
For Data By Fuel Type									
Fuel and Use Gas	-	Gal	NA	OnRoad trave	NA	19.564	lb/gal	0	-
Fuel and Use CNG	0	ft3				120.593	lb/ft3	0	0
Fuel and Use CNG	0	gal equiv	gal eq to ft3	130.2083	ft3/gal	120.593	lb/ft3	0	0
Fuel and Use Diesel	0	gal	NA	OnRoad trave	NA	22.384	lb/gal	0	0
							Sub Tons	0.0	0

North Cargo Area Traffic (Tenant) - on airport travel

North Cargo Area - Off Airport Travel		North Cargo Area	MPG	Est Rnd trip Dist (mi)	Off-Airport travel Fuel (Gallons)	CO2 lbs/gal	CO2 (lbs)	BTUs Fuel
North Cargo Area (50% vehicles gas		1,606,000	22.9	4	280,524	19.5640	5,488,172	35,065,502,183
North Cargo Area (50% diesel)		1,606,000	22.9	4	280,524	22.3840	6,279,250	38,628,157,205
See traffic assumptions worksheet		3,212,000			Total Pounds		5,488,172	
				Total	561,048	Tons	2,489.4	73,693,659,389

Off-Airport Passenger Parking Travel (estimated) - off airport travel

Off-Airport Shuttles - Off Airport Travel		Shuttle trips	MPG	Est Rnd trip Dist (mi)	Off-Airport travel Fuel (Gallons)	CO2 lbs/gal	CO2 (lbs)	BTUs Fuel
Off Airport Shuttles Parking (90% vehicles gas		1,054,785	22.9	6	276,363	19.5640	5,406,762	34,545,350,437
Off-Airport Shuttles Parking (10% diesel)		117,198	22.9	6	30,707	22.3840	687,345	4,228,350,893
See traffic assumptions worksheet		1,171,983			Total Pounds		5,406,762	
				Total	307,070	Tons	2,452.47	38,773,701,330

Off-Airport Passenger Parking Travel (estimated) - on airport travel

Off-Airport Shuttles - On Airport Travel		Shuttle Trips	MPG	Rnd trip Dist (mi)	On-Airport travel Fuel (Gallons)	CO2 lbs/gal	CO2 (lbs)	BTUs Fuel
Off Airport Shuttles Parking (90% vehicles gas		1,054,785	22.9	2.289	105,432	19.5640	2,062,680	13,179,051,192
Off-Airport Shuttles Parking (10% diesel)		117,198	22.9	2.289	11,715	22.3840	262,222	1,613,115,866
See traffic assumptions worksheet		1,171,983			Total Pounds		2,062,680	
				Total	117,147	Tons	935.6	14,792,167,057

Passenger Traffic Recirculating Terminal Curb (estimated) - on airport travel

Employee On Road Travel		Trips recir	MPG	Rnd trip Dist (mi)	On-Airport travel Fuel (Gallons)	CO2 lbs/gal	CO2 (lbs)	BTUs Fuel
Off Airport Shuttles Parking (90% vehicles gas		613,094	22.9	1.5	40,159	19.5640	785,670	5,019,870,360
Off-Airport Shuttles Parking (10% diesel)		68,122	22.9	1.5	4,462	22.3840	99,880	614,432,132
See traffic assumptions worksheet		681,215			Total Pounds		785,670	
				Total	44,621	Tons	356.37	5,634,302,492

Hotel Shuttles

Assume gas unless know Diesel

Hotel		Annual trips	MPG	Off Airport Dist (mi)	Fuel (Gallons)	CO2 Factor	CO2 ((lbs)
Best Value		64	16	26.8	54,886	19.5640	1,073,798
Val-U Inn Auburn (address not provided)		67	16	10	21,440	19.5640	419,452
Valu-U Inn Kent		73	16	8.3	19,389	19.5640	379,322
Garden Suites		138	16	3.61	15,942	19.5640	311,885
King Oscar Hotel - Pacific		158	16	14.02	70,885	19.5640	1,386,796
Holiday Inn Express Downtown		172	16	15.54	85,532	19.5640	1,673,351
Homestead Studio Suites Tukwila		566	16	2.7	48,902	19.5640	956,727
Holiday Inn Hotel & Suite Kent		652	16	4.8	100,147	19.5640	1,959,280
Kings Oscar Motel - Tacoma		677	16	24.64	533,801	19.5640	10,443,282
Best Western Fed Way		681	16	10.25	223,368	19.5640	4,369,972
Days Inn - Tukwila		926	16	2.8	82,970	19.5640	1,623,217
La Quinta Motor SeaTac		991	16	1.1	34,883	19.5640	682,455
Days Inn -- Kent		1,138	16	4.8	174,797	19.5640	3,419,725
Towneplace Suites Renton		1,230	16	6.47	254,659	19.5640	4,982,153
Homewood Stuites Tukwila		1,266	16	4.32	175,012	19.5640	3,423,932
SpringHill Suites		1,410	16	6.54	295,085	19.5640	5,773,039
Hawthorne Suites		1,450	16	4.43	205,552	19.5640	4,021,419
Comfort Suites - Tukwila		1,466	16	4.36	204,536	19.5640	4,001,549
Primestar Hotel/LaQuinta Fed Way		1,705	16	9.77	533,051	19.5640	10,428,614
Sutton Suites & Extended Stay		2,103	16	1.7	114,403	19.5640	2,238,184
Courtyard by Marriott - Fed Way		2,159	16	3.32	229,372	19.5640	4,487,437
Travellodget Renton		2,359	16	4.47	337,431	19.5640	6,601,507
Econolodge SeaTac North		2,461	16	2.1	165,379	19.5640	3,235,479
Towneplace Stonebrook Suites Kent		2,592	16	3.07	254,638	19.5640	4,981,739
Best Western Rivers Edge		3,914	16	2.7	338,170	19.5640	6,615,950
Ramada Inn SeaTac s.139th		4,296	16	2.1	288,691	19.5640	5,647,955
Courtyard by Marriott - Southcenter		4,350	16	4.8	668,160	19.5640	13,071,882
Hampton Inn Southcenter		4,470	16	0.98	140,179	19.5640	2,742,466
Hilton Garden Inn		4,626	16	3.9	577,325	19.5640	11,294,782
Holiday Inn Select - Renton		5,603	16	4.1	735,114	19.5640	14,381,762
Red Lion S Seattle		5,838	16	3.7	691,219	19.5640	13,523,012
CHA Southecenter/Doubletree		6,081	16	1.8	350,266	19.5640	6,852,596
Travellodge Airport North		6,171	16	2.19	432,464	19.5640	8,460,719
Courtyard by Mariott - Tukwila		6,439	16	9.81	2,021,331	19.5640	39,545,317
Red Roof Inn SeaTa		6,650	16	0.3	63,840	19.5640	1,248,966
Embassy Suites		6,726	16	2.7	581,126	19.5640	11,369,157
Columbia Hospitality/Cedarbrook		7,230	16	0.94	217,478	19.5640	4,254,747
Best Western Executel		7,369	16	2.4	565,939	19.5640	11,072,035

Roadway Inn			8,496	16	0.4	108,749	19.5640	2,127,562		
Days Inn SeaTac			8,537	16	1.2	327,821	19.5640	6,413,486		
Quality Inn SeaTac			10,273	16	1.3	427,357	19.5640	8,360,808		2.15%
Super 8 Motel			10,892	16	1.4	487,962	19.5640	9,546,481		2.28%
Ramada Inn & Suites SeaTac			11,474	16	0.3	110,150	19.5640	2,154,982		2.41%
Sleep Inn SeaTac			12,010	16	1.59	611,069	19.5640	11,954,950		2.52%
Best Value Inn SeaTac	All Gas		12,072	16	2.3	888,499	19.5640	17,382,598		2.53%
Sky Way Inn	Gas		12,343	16	1.9	750,454	19.5640	14,681,890		2.59%
SeaTac Crest Motor Inn	Gas		12,698	16	0.95	386,019	19.5640	7,552,080		2.66%
Raddison Hotel Gateway			13,318	16	0.7	298,323	19.5640	5,836,395		2.79%
Hampton Inn SeaTac			13,748	16	0.98	431,137	19.5640	8,434,770		2.88%
SeaTac Inn	Gas		14,781	16	0.87	411,503	19.5640	8,050,645		3.10%
Econolodge/Sandstone Inn	All are gas		15,284	16	1.16	567,342	19.5640	11,099,480		3.20%
Coast Gateway Hotel	All are gas		16,454	16	0.3	157,958	19.5640	3,090,298		3.45%
Comfort Inn & Suites	2 gas 1 diesel		16,823	16	1.04	559,869	19.5640	10,953,286		3.53%
Clarion Hotel	will call back		22,036	16	0.46	324,370	19.5640	6,345,973		4.62%
Jet Motel Airport Parking	All are gas		23,869	16	0.98	748,532	19.5640	14,644,277		5.00%
Holiday Inn Express /Farifield Sea	left message with mgr		24,275	16	1.57	1,219,576	19.5640	23,859,785		5.09%
Holiday Inn- SeaTac	All are gas		24,689	16	1.0	790,048	19.5640	15,456,499		5.17%
Hilton Seattle Airport	All are gas		26,614	16	1.1	936,813	19.5640	18,327,806		5.58%
Marriott Hotel Sea-Tac	All are gas		26,880	16	0.6	516,096	19.5640	10,096,902		5.63%
Doubletree SeaTac	Majority are Diesel		33,253	16	0.44	468,202	22.384	10,480,239		6.97%
Off-Airport Roads			477,086	Miles	Gal -->	23,435,214		**Tons --->**	208,565	
					M BTU	2,929,402				
On-Airport Roads	Miles -->	2.289	477,086	16		17,472,798		**Tons --->**	177,405	
					M BTU	2,184,100				

Miles doubled in gallon calculation to account for roundtrip
Assume vehicles to be gas unless noted
Airport miles not doubled -- as that is circulation in and out

Soruces of Distances
Mapquest
Orbitz
estimated

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

Diesel	137,700	BTU/gal	
CNG	960	BTU/ft3	Transportation Data Energy Book
Motor Gas	125,000	BTU/gal	
CNG gal equiv	130.2083	ft3/gal	@sum(125,000/960)
CNG	120.593	lb CO2/1000 ft3	

0.00045359237 Lbs/ton

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	16,075,336.8	2.2046	35,439,688	6.8200	5,196,435	21.095	109,618,799	49,722.3
Taxi-Idle-Delay	54,577,387.4	2.2046	120,321,308	6.8200	17,642,421	21.095	372,166,862	168,812.0
Takeoff	26,448,030.1	2.2046	58,307,327	6.8200	8,549,461	21.095	180,350,890	81,805.8
Climbout	15,471,464.1	2.2046	34,108,390	6.8200	5,001,230	21.095	105,500,950	47,854.4
Subtot	112,572,218.4		248,176,713		36,389,547		767,637,501	348,194.5
AvGas								
Approach	-	2.2046	-	6.0000	-	18.355	-	0.0
Taxi-Idle-Delay	-	2.2046	-	6.0000	-	18.355	-	0.0
Takeoff	-	2.2046	-	6.0000	-	18.355	-	0.0
Climbout	-	2.2046	-	6.0000	-	18.355	-	0.0
Subtot	-		-		-		-	0.0
Total LTO	112,572,218.4		248,176,713		36,389,547			348,194.5

Fuel Dispensed	**Jet A**	441,039,267	21.095	9,303,723,337	4,220,097.9
Email from Russ 10-8-07	**Av Gas**	-	18.355	-	0.0
	Total	441,039,267		9,303,723,337	4,220,097.9
Cruise (Fuel dispensed - LTO)	**Jet A**	404,649,720	21.095	8,536,085,837	3,871,903.4
	Av Gas	-	18.355	-	0.0
	Total	404,649,720		8,536,085,837	3,871,903.4

Carried over from AC_2006
User Input
0.00045359237 Lbs/ton

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

P&WA handbook http://www.airliners.net/discussions/tech_ops/read.main/47675
P&WA handbook http://www.airliners.net/discussions/tech_ops/read.main/47675

Jet A-1 is 0.812 density (a liter of Jet A-1 weighs .812 grams)
Now if you hate kilos so much, multiply these by 2.2048 to get lbs...
1 gallon of gasoline equals 5.8 to 6.5 lbs http://www.santacruzpl.org/readyref/files/g-l/gasoline.shtml
1 gallon of ethanol equals 6.59 lbs.

Sea-Tac Airport 2006 LTOs and Emissions

			EDMS Output				Jet A Fuel (EDMS Output)				
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)
Airbus A300F4-600 Series	CF6-80C2A5	437	11,558	697,483	1,596	JetA	130,624	101,222	186,352	205,490	73,797
Airbus A310-200 Series	CF6-80A3	154	3,120	195,793	1,271	JetA	41,128	26,563	47,588	57,912	22,604
Airbus A319-100 Series	V2522-A5	5,186	42,323	3,610,114	696	JetA	465,344	645,862	1,260,657	1,238,253	
Airbus A320-200 Series	V2527-A5	3,545	40,005	2,900,016	818	JetA	376,216	493,203	934,779	862,143	233,677
Airbus A321-100 Series	CFM56-5B3/P	597	9,238	487,199	816	JetA	63,638	75,369	141,434	163,353	43,406
Airbus A330-300 Series	PW4168A Talon II	723	22,965	1,423,958	1,970	JetA	194,236	203,327	372,358	516,993	137,044
Airbus A340-200 Series	CFM56-5B2/2 DAC	780	28,260	1,670,156	2,141	JetA	240,949	205,444	420,996	656,290	146,479
Boeing 727-100 Series	JT8D-7 series Reduced emissi	28	163	28,539	1,019	JetA	4,124	5,528	11,170	5,569	2,149
Boeing 727-200 Series	JT8D-15 Reduced emissions	187	1,432	222,471	1,190	JetA	26,679	41,877	85,349	49,135	19,433
Boeing 737-200 Series	JT8D-17 Smoke fix	587	3,886	480,976	819	JetA	68,505	90,424	177,762	103,643	40,644
Boeing 737-300 Series	CFM56-3C-1	11,098	72,428	7,869,912	709	JetA	982,547	1,446,199	2,834,973	1,443,576	1,162,617
Boeing 737-400 Series	CFM56-3C-1	16,086	143,625	12,842,599	798	JetA	1,737,663	2,156,352	4,109,153	2,951,358	1,888,074
Boeing 737-500 Series	CFM56-3C-1	977	4,129	587,611	601	JetA	56,439	122,457	249,574	76,420	82,723
Boeing 737-700 Series	CFM56-7B20	15,113	141,151	11,471,166	759	JetA	1,899,967	1,710,407	3,113,388	2,874,228	1,873,177
Boeing 737-800 Series	CFM56-7B27	8,277	116,978	7,180,693	868	JetA	1,397,637	1,052,026	1,977,942	2,286,039	467,049
Boeing 737-900 Series	CFM56-7B24	6,921	84,837	5,857,918	846	JetA	1,168,666	833,100	1,554,096	1,911,523	390,534
Boeing 747-200 Series	JT9D-7Q	55	4,053	225,086	4,092	JetA	33,326	26,186	53,706	81,774	30,094
Boeing 747-400 Series	PW4056	1,482	51,370	3,998,958	2,698	JetA	474,083	550,991	1,147,939	828,122	997,825
Boeing 757-200 Series	PW2037	8,670	90,120	8,136,055	938	JetA	1,065,659	1,388,986	2,714,846	1,499,702	1,466,862
Boeing 757-200 Series	RB211-535E4	7,137	76,364	7,184,084	1,007	JetA	861,569	1,339,491	2,646,493	1,189,114	1,147,417
Boeing 767-200 Series	JT9D-7R4D, -7R4D1	42	630	50,486	1,202	JetA	5,857	8,984	17,772	10,495	7,379
Boeing 767-300 Series	PW4060 Reduced emissions	2,428	67,059	3,947,976	1,626	JetA	661,393	576,848	1,065,396	1,062,738	581,602
Boeing 777-200 Series	PW4090	1,133	76,509	2,637,576	2,328	JetA	459,312	308,902	625,529	714,124	529,711
Boeing DC-8 Series 70	CFM56-2-C5	32	514	51,238	1,601	JetA	6,551	8,584	16,876	14,435	4,793
Boeing DC-9-50 Series	JT8D-17 Reduced emissions	24	222	22,266	928	JetA	3,219	3,738	7,288	5,332	2,689
Boeing MD-10-30	CF6-6D	1,205	68,320	2,790,094	2,315	JetA	388,433	317,458	643,435	1,057,181	383,587
Boeing MD-11	CF6-80C2D1F 1862M39	449	9,048	838,195	1,867	JetA	95,533	137,050	284,429	221,962	99,222
Boeing MD-83	JT8D-219 Environmental Kit (E	18,079	128,096	15,291,142	846	JetA	2,073,232	2,536,633	5,005,601	2,947,003	2,728,675
Boeing MD-90	V2525-D5	713	7,684	589,452	827	JetA	111,221	97,820	188,010	192,403	
Bombardier CRJ-200	CF34-3B	685	962	172,482	252	JetA	22,619	34,773	69,005	37,242	8,843
Bombardier CRJ-700	CF34-8C1	3,696	7,186	1,155,114	313	JetA	122,046	259,042	525,368	200,945	47,715
Bombardier de Havilland I	PW123D	31,503	34,699	4,726,406	150	JetA	469,479	1,010,584	2,120,233	555,506	570,606
Bombardier de Havilland I	PW150A	12,397	9,087	2,003,385	162	JetA	184,748	443,329	932,163	218,602	224,544
Bombardier Learjet 35	TFE731-2-2B	465	197	48,556	104	JetA	5,068	11,056	22,990	7,053	2,389
Cessna 208 Caravan	PT6A-114A	3,608	511	121,744	34	JetA	40,392	18,246	37,238	25,869	
Cessna 441 Conquest II	TPE331-10	211	56	12,014	57	JetA	687	3,337	7,129	863	
Cessna 550 Citation II	JT15D-4 series	421	184	50,659	120	JetA	6,814	10,879	22,636	5,688	4,642
Cessna 750 Citation X	AE3007C Type 2	327	1,403	113,619	347	JetA	38,861	13,055	25,396	36,308	
Embraer EMB120 Brasilia	PW118B	3,651	2,122	394,080	108	JetA	35,865	95,452	201,421	61,343	
Gulfstream II-B	SPEY Mk511 Transply IIH	34	119	20,202	594	JetA	1,939	4,340	8,895	2,115	2,913
Gulfstream IV-SP	TAY 611-8C Transply IIJ	348	1,234	179,879	517	JetA	22,043	37,596	75,275	21,476	23,489
Lockheed C-130 Hercules	T56-A-15	54	123	20,344	377	JetA	2,020	4,019	8,272	2,449	3,584
Lockheed L-1011 Tristar	RB211-524B series Phase 2	142	2,056	243,679	1,716	JetA	26,317	49,856	105,311	43,255	18,940
Beech 1900-D	PT6A-67D	268	44	18,949	71	JetA	1,972	4,424	9,397	2,865	292
Beech Baron 58	TIO-540-J2B2	74	1	1,842	25	JetA	716	264	480	138	245
	LTOs -->	**170,029**	**1,366,070**	**112,572,167**			**16,075,337**	**18,511,285**	**36,066,102**	**26,448,030**	**15,471,464**
	OPS -->	340,058									

Taxi in Time	Taxi out Time
7 Minutes	15 Minutes

EDMS output assigned to AvGas or JetA based on aircraft engine type
All Jets and TP are Jet A, Props are AvGas

10/30/2007

Sea-Tac Airport 2

Aircraft Name	AvGas (EDMS Output) Approach (kg)	Taxi-In (kg)	Taxi-Out (kg)	Takeoff (kg)	Climbout (kg)
Airbus A300F4-600 Series	-	-	-	-	-
Airbus A310-200 Series	-	-	-	-	-
Airbus A319-100 Series	-	-	-	-	-
Airbus A320-200 Series	-	-	-	-	-
Airbus A321-100 Series	-	-	-	-	-
Airbus A330-300 Series	-	-	-	-	-
Airbus A340-200 Series	-	-	-	-	-
Boeing 727-100 Series	-	-	-	-	-
Boeing 727-200 Series	-	-	-	-	-
Boeing 737-200 Series	-	-	-	-	-
Boeing 737-300 Series	-	-	-	-	-
Boeing 737-400 Series	-	-	-	-	-
Boeing 737-500 Series	-	-	-	-	-
Boeing 737-700 Series	-	-	-	-	-
Boeing 737-800 Series	-	-	-	-	-
Boeing 737-900 Series	-	-	-	-	-
Boeing 747-200 Series	-	-	-	-	-
Boeing 747-400 Series	-	-	-	-	-
Boeing 757-200 Series	-	-	-	-	-
Boeing 757-200 Series	-	-	-	-	-
Boeing 767-200 Series	-	-	-	-	-
Boeing 767-300 Series	-	-	-	-	-
Boeing 777-200 Series	-	-	-	-	-
Boeing DC-8 Series 70	-	-	-	-	-
Boeing DC-9-50 Series	-	-	-	-	-
Boeing MD-10-30	-	-	-	-	-
Boeing MD-11	-	-	-	-	-
Boeing MD-83	-	-	-	-	-
Boeing MD-90	-	-	-	-	-
Bombardier CRJ-200	-	-	-	-	-
Bombardier CRJ-700	-	-	-	-	-
Bombardier de Havilland D	-	-	-	-	-
Bombardier de Havilland D	-	-	-	-	-
Bombardier Learjet 35	-	-	-	-	-
Cessna 208 Caravan					
Cessna 441 Conquest II					
Cessna 550 Citation II					
Cessna 750 Citation X					
Embraer EMB120 Brasilia					
Gulfstream II-B					
Gulfstream IV-SP					
Lockheed C-130 Hercules					
Lockheed L-1011 Tristar					
Beech 1900-D					
Beech Baron 58					
	-	-	-	-	-

EDMS output assigned to A
All Jets and TP are Jet A, I