2005 Air Emission Inventory

for King, Kitsap, Pierce, and Snohomish Counties

March 2008

pscleanair.org

Puget Sound Clean Air Agency

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INTRODUCTION

PURPOSE OF THE 2005 EMISSION INVENTORY

An emission inventory is a critical tool in assessing our region's air quality. In the most basic terms, an emission inventory is an estimation of the pollutants discharged into the air during a specified 12-month period. The Puget Sound Clean Air Agency (Agency) prepares a bottom-up inventory, which means that it has been prepared by collecting data from or about source categories and applying emission factors to the data to estimate emissions. The estimated emissions from sources and small categories are added together to give the total sum for the geographical inventory area. Bottom-up inventories are labor-intensive. In the future, the Agency intends to conduct bottom-up inventories for priority categories only (such as indoor burning, land-clearing debris burning, and categories that drive the Agency's programs). Although the U.S. Environmental Protection Agency (EPA) requires an emission inventory every three years, the Agency updates priority categories of the emission inventory every year.

EPA has set air quality standards for several pollutants, referred to as "criteria pollutants". Criteria pollutant concentrations are commonly considered an indication of overall air quality. Criteria pollutants (or their precursors) inventoried in this report are:

- Fine particulate matter ($PM_{2.5)}$ – also called fine particles
- Volatile organic compounds (VOC) – interact with other precursors in the presence of sunlight to produce ozone (a criteria pollutant)
- Nitrogen dioxide (NOx) – also called oxides of nitrogen, and is a precursor of ozone
- Sulfur dioxide (SOx) – also called oxides of sulfur
- Carbon monoxide (CO)

Historically, the Agency prepared separate inventories for criteria pollutants and greenhouse gases (GHG). The 2005 air emission inventory covers criteria pollutants as well as GHG. The GHG inventoried in this report includes carbon dioxide, methane, sulfur hexafluoride, nitrous oxide, and chlorofluorocarbons.

BACKGROUND OF THE 2005 EMISSION INVENTORY

The Agency has historical bottom-up criteria pollutant inventories[1] for 1990, 1996, 1999, and 2002. For this report, the 2005 air emission inventory combines the inventory for criteria pollutants as well as a GHG emission inventory.

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[1]Stationary Area Sources Emission Inventory for Carbon Monoxide and Precursors of Ozone for King, Pierce, and Snohomish Counties, Washington, Base Year 1990; prepared by Puget Sound Clean Air Agency, September 1994. Non Highway Mobile Sources Emission Inventory for Carbon Monoxide and Precursors of Ozone for King, Pierce, and Snohomish Counties, Washington, Year 1990; prepared by Puget Sound Clean Air Agency, September 1994. Central Puget Sound Nonattainment Area 1993-2010 Emissions Inventory Projections; prepared for Puget Sound Clean Air Agency by Sierra Research, Report No. SR95-04-03, March 23, 1995. The 1996, 1999, and 2002 Emission Inventories are not in bound report format but electronic copies of specific sections are available on request.

Several information sources contributed to the 2005 emission inventory. From this information, the Agency conducts calculations to arrive at the estimated tons of pollutants that are emitted into the air during the course of one year, in this case 2005.

An emission inventory is more than a static report about pollutants being emitted locally during a single calendar year. The Agency uses this information to guide ongoing air quality management programs and to allocate resources, propose new rules or delete existing ones, provide information to the public, and charge appropriate fees to registered businesses.

This report includes pollutant emissions generated by human activities, technically known as anthropogenic sources. This report does not include pollutant emissions from naturally occurring sources, known as biogenic emissions. The report presents emissions in eight categories:

- On-road mobile – cars, trucks, buses, and other vehicles using public roadways.
- Non-road mobile – mobile engines other than those on public roadways, such as trains, aircraft, ships, farm equipment, lawn & garden equipment, and construction equipment.
- Point sources – large stationary sources, such as industrial plants, that can emit large quantities of pollutants and are required to report their emissions and activity to the Agency.
- Stationary area combustion sources – small, individual sources such as fuel burned by small establishments, home energy use, indoor wood burning, and outdoor burning that, when combined, are significant contributors of air pollution.
- Stationary area solvent evaporative sources – activities such as metal cleaning, surface coating, loading and unloading of marine vessels, aircraft refueling, and asphalt paving.
- Fugitive dust sources – particulate matter from activities including dust from roads and construction, as well as emissions from industrial processes such as manufacturing.
- Greenhouse gases from non-combustion sources. All combustion sources and mobile sources emit GHG in addition to the criteria pollutants they emit. Solvent evaporative sources and fugitive dust sources do not produce GHG. Some non-combustion industrial processes and consumption produce GHG. The report presents GHG emissions produced by non-combustion separately.
- GHG from electricity production from burning of fossil fuels and GHG from electricity.

CONTRIBUTORS

An emission inventory of this scope is a significant undertaking and requires the cooperation of many individuals, agencies, and partners. The Agency wishes to recognize and thank StarCrest Consultants[2] and Sally Otterson, Air Quality Program, Department of Ecology (Ecology) for their contributions to the 2005 air emission inventory. The primary contact for this report is Kwame Agyei.[3]

[2]See Section 2.3 (Commercial Marine Vessels) of this report for contributions by StarCrest and contact information.

[3]Kwame Agyei, Engineer II, Puget Sound Clean Air Agency, (206) 689-4054 or kwamea@pscleanair.org.

SCOPE

The pollutants inventoried in this report include carbon monoxide (CO), oxides of nitrogen (NOx), particulate matter not exceeding 2.5 microns ($PM_{2.5}$), oxides of sulfur (SOx), volatile organic compounds (VOCs), and greenhouse gases as expressed in equivalents of carbon dioxide (CO_2). These greenhouse gases include carbon dioxide, methane, sulfur hexafluoride, nitrous oxide, and chlorofluorocarbons. Below is a brief explanation for each pollutant.

- CO – This colorless, odorless, poisonous gas is created when carbon-containing fuels are incompletely burned. On-road vehicles, such as cars and trucks, are the greatest contributor of carbon monoxide in our area. Carbon monoxide is no longer a pollutant prioritized for reduction strategies in the area under the Agency's jurisdiction, as CO levels have decreased substantially over the last two decades due to the implementation of stringent controls on new motor vehicles and the State's motor vehicle inspection and maintenance program.
- NOx – Similar to carbon monoxide, a large portion of nitrogen oxide emissions come from vehicles using public roadways. In addition to being a criteria air pollutant itself, NOx also contributes to ozone formation, another criteria pollutant.
- $PM_{2.5}$ – $PM_{2.5}$ clearly is associated with the most serious health effects, including respiratory disease, decreased lung function, heart attacks, and premature deaths. Wood burning contributes the greatest quantity of $PM_{2.5}$ to our region. In the winter, smoke from fireplaces and wood stoves is a major contributor to elevated PM levels. During the summer, vehicle exhaust, land-clearing burning, and backyard waste burning are the main sources.
- SOx – These colorless, corrosive gases are produced by burning sulfur-containing fuels, such as coal and oil, and by industrial processes, including smelters and paper mills. These gases are associated with several respiratory diseases. Stationary area sources burning fuel oil emit the largest amount of sulfur oxides in our area.
- VOCs – Volatile organic compounds play a key role in what eventually becomes ground-level ozone, commonly called smog. While ozone high in the atmosphere protects us from harmful levels of radiation, ground-level ozone has adverse heath consequences, such as impeding lung function and weakening the immune system.
- Greenhouse gases (GHG) – The major greenhouse gases (carbon dioxide, methane, sulfur hexafluoride, nitrous oxide, and chlorofluorocarbons) affect the portion of the sun's heat that is retained in the atmosphere around the Earth. This is referred to as global warming. Greenhouse gases come from both natural and human processes.

The 2005 air emission inventory procedure uses the methodologies and models recommended by the Emissions Inventory Improvement Project (EIIP). The EIIP goal is to improve the quality of emissions information and develop systems for collecting, calculating, and reporting emissions data. It is sponsored by the EPA and the National Association of Clean Air Agencies.

For categories that guide Agency priorities and programs, local information is often used in place of national or regional default data and parameters. To improve readability and reproducibility, references for the sources of data are listed on the pages where the information is used.

As with any emission inventory, the 2005 inventory has a level of uncertainty. This uncertainty comes from estimation of activity levels, such as how often people burn wood in a fireplace, or how far and often people drive their cars. Surveys designed to provide this data inevitably have limitations in sample size, population reached, and interpretation of results. In addition to uncertainty about activity levels, there is also the question of the emission factors themselves. Emission factors designate how much of a pollutant is released from a certain activity. They are typically developed by EPA in consultation with state and local air agencies and industry. Some of these emission factors are based on several studies, and some are based on only a few.

ESTIMATING METHODS AND DATA GATHERING

For specific categories, this emission inventory provides a brief description of the category, followed by the EPA source classification code, key assumptions, estimating equations, activity levels, data sources used, emissions factors, emissions, and references. With the exception of aircraft, the Agency inventory uses the same methods as the Washington Department of Community, Trade, & Economic Development (CTED) and Ecology. CTED uses all the aircraft bought in Washington State to estimate greenhouse gases from aircraft. The Agency follows the EIIP and IPCC guidelines, and inventories only the fuel burned during aircraft landing and takeoffs at the airport. Landing and takeoffs include approach to the airport, landing, takeoff, and climbout. Approach starts when aircraft get below 3,000 feet and climbout ends when aircraft get above 3,000 feet. For all other categories, CTED, Ecology, and Agency inventories use the same IPCC guidelines.

Some references are quoted so frequently their full citations are given here. Their bolded shortened references will be given whenever a methodology or emission factor cites them.

1. IPCC Guidelines

Intergovernmental Panel on Climate Change: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (Volume 3); http://www.ipcc-nggip.iges.or.jp/public/glinvs6.htm; accessed December 10, 2007. Page 12 of Chapter 1 (Energy) of the Revised 1996 Guidelines recommend excluding CO_2 emissions from combustion of biofuels and fuels bought in an area but not burned in the area.

IPCC published its latest guidelines in April 2007 as the: 2006 IPCC Guidelines for National Greenhouse Gas Inventories; http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm; accessed December 10, 2007. The foreword of the 2006 IPCC Guidelines states that "The 2006 Guidelines have built upon this body of work in an evolutionary manner to ensure that the transition from the previous guidelines to these new ones will be as straightforward as possible. These new guidelines include new sources and gases as well as updates to the previously published methods whenever scientific and technical knowledge have improved since the previous guidelines were issued."

2. U.S. GHG 2004

Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004, April 2006; EPA 430-R-06-002; http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissions.html; accessed September 27, 2007.

U.S. GHG 2005 is now available and quoted a few times. The full reference for U.S. GHG 2005 is: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005, EPA 430-R-07-002, April 15, 2007; http://www.epa.gov/climatechange/emissions/usinventoryreport.html; accessed December 13, 2007.

EPA relies on the latest available IPCC guidelines to prepare GHG inventories. Since EPA published U.S. GHG 2004 before the 2006 IPCC became available, the IPCC Guidelines quoted in this report is the revised 1996 version.

3. EIIP Guidelines

The Clearing House for Emission Inventories and Emission Factors; Emission Inventory Improvement Program (EIIP); Technical Report Series Volume 3: Area Sources; http://www.epa.gov/ttn/chief/eiip/techreport/volume03/index.html; accessed September 27, 2007. This document contains the latest available recommended methodologies and alternate methods for compiling air emission inventories for stationary area sources. There are ten EIIP volumes.

4. AP-42

The Clearing House for Emission Inventories and Emission Factors; AP-42 Fifth Edition; Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources; http://www.epa.gov/ttn/chief/ap-42/index.html; accessed September 27, 2007. This report frequently quotes the shortened versions of the full references.

SUMMARY TABLES

Table ES-1 summarizes the 2005 emission inventory for criteria pollutants and greenhouse gas emissions from anthropogenic activities in the geographical four-county jurisdiction of the Puget Sound Clean Air Agency. Table ES-1 does not include emissions from purchased electricity. In 2002, the Agency estimated 4.3 million tons of CO_2 equivalent of emissions from electricity produced elsewhere and consumed in the Puget Sound area.

Table ES-1 shows the summary of the criteria pollutants and GHG for the calendar year 2005. The combustion of fuels emits CO, NOx, $PM_{2.5}$, SOx, VOC, and GHG. The $PM_{2.5}$ from on-road vehicles includes particulate emissions from the exhaust, brake wear, and tire wear. Fugitive dust from roads, construction activities, and meat cooking contributed about 40% of $PM_{2.5}$ emissions. Solvent evaporation contributes about 34% of the total VOC emissions. In the Agency's jurisdiction, fuel combustion emitted 82% of the GHG; in Washington State, fuel combustion emitted 87%[4] of the GHG; and in the U.S., fuel combustion emitted 80%[5] of the GHG. GHG presented in the table includes carbon dioxide equivalents of carbon dioxide, nitrous oxide, and methane from combustion and industrial processes, as well as sulfur hexafluoride from power transmissions, and chlorofluorocarbons from industrial processes.

Table ES-1 presents criteria pollutant emissions to the nearest ten tons and GHG to the nearest thousand tons.

[4]Table ES-1, Draft Greenhouse Gas Inventory and Reference Case Projections, 1990-2020, Washington State Climate Advisory Team, Department of Ecology and Department of Community, Trade, & Economic Development, July 19, 2007.

[5]Table ES-2, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005, April 15, 2007, U.S. EPA http://www.epa.gov/climatechange/emissions/usinventoryreport.html; accessed December 13, 2007.

Table ES-1: 2005 Emissions for Puget Sound Clean Air Agency Geographic Area (tons)

General Category	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Diesel school buses	120	550	40	20	30	72,000
Other on-road diesel vehicles	9,060	34,410	940	860	1,660	3,928,000
Gasoline school buses	210	30	0	0	20	5,000
Other on-road gasoline vehicles	652,630	46,520	460	770	51,860	14,629,000
On-road liquefied petroleum gas (LPG) vehicles	0	20	0	0	0	15,000
On-road compressed natural gas (CNG) vehicles	100	220	20	0	10	288,000
Aircraft landings & takeoffs	5,990	1,840	30	160	1,580	644,000
Airport ground support equipment	12,630	550	30	30	470	55,000
Locomotives	510	3,840	90	280	190	176,000
Commercial marine vessels	1,530	10,980	570	3,760	430	704,000
Cargo handling equipment at ports	900	1,120	70	80	100	109,000
Misc. gasoline non-road mobile engines	235,060	2,370	390	100	13,770	539,000
Misc. LPG non-road mobile engines	14,400	3,080	20	0	840	190,000
Misc. CNG non-road mobile engines	1,480	270	0	0	0	133,000
Misc. diesel non-road mobile engines	6,670	12,920	1,070	370	1,450	1,215,000
Gasoline recreational boats	20,700	640	10	20	4,490	137,000
Diesel recreational boats	50	320	10	40	10	25,000
Large sources (reporting emissions to the Agency)	4,940	6,130	500	1,150	4,180	960,000
Electric power production at large sources	800	1,310	40	420	30	524,000
Natural gas burning by small sources	2,630	4,500	330	30	240	5,268,000
Distillate oil burning by small sources	310	1,310	90	450	20	1,384,000
LPG burning by small sources	60	410	10	0	10	339,000
Indoor wood burning*	27,980	560	3,760	70	13,280	93,000
Land-clearing debris burning	26,310	570	3,320	90	2,160	531,000
Other open burning*	4,870	140	1,040	20	830	28,000
Architectural coating	-	-	-	-	5,810	-
Original equipment surface coating	-	-	-	-	6,920	-
Other surface coating	-	-	-	-	3,410	-
Metal cleaning	-	-	-	-	6,540	-
Petroleum products distribution	-	-	-	-	5,880	-
Consumer products	-	-	-	-	13,570	-
Asphalt application	-	-	-	-	3,890	-
Printing & baking	-	-	-	-	3,360	-
Pesticides application & other evaporation	-	-	-	-	1,080	-
Road fugitive dust	-	-	4,270	-	-	-
Construction & quarrying fugitive dust	-	-	2,900	-	-	-
Commercial meat cooking	-	-	1,440	-	210	-
Enteric fermentation (livestock)	-	-	-	-	-	175,000
Manure management	-	-	-	-	-	482,000
Wastewater treatment	-	-	-	-	20	10,000
Natural gas distribution	-	-	-	-	-	327,000
Non-energy use of fuel	-	-	-	-	-	3,182,000
Nitrous oxide from soils	-	-	-	-	-	211,000
Landfill fugitive methane	-	-	-	-	-	850,000
Cement manufacturing	-	-	-	-	-	523,000
Direct use of nitrous oxide	-	-	-	-	-	52,000
Steel manufacturing & dry cleaning CO_2	-	-	-	-	-	4,000
Power transmission equipment	-	-	-	-	-	190,000
Miscellaneous manufacturing processes	-	-	-	-	-	879,000
Electricity consumption	-	-	-	-	-	8,947,000
Total	1,029,900	134,800	21,400	8,700	148,100	47,775,000

*CO_2 equivalent includes only methane & nitrous oxide emissions; it excludes carbon dioxide emissions.

Table ES-2 compares GHG in the Agency jurisdiction to GHG from other areas in the western U.S. and to U.S. emissions. Areas with many power plants have high per capita emissions. The Pacific Northwest gets most of its power from hydro and has relatively low per capita GHG emissions compared to other areas of the country. The per capita GHG emissions for the Agency jurisdiction compares well with per capita emissions from the Pacific Northwest and northern California. Washington State per capita emissions are almost 17 tons, compared to 14 tons for Puget Sound. Emissions from Centralia, a coal plant outside Agency jurisdiction, account for 80%[6] of Washington's power generation emissions.

The per capita vehicle miles traveled[7] for the Agency jurisdiction is 8,500 miles/year, while for Washington State it's 8,900 miles/year. The Washington report does not give the actual emissions from the Centralia plant, but does include emissions from all aircraft fuel loaded into planes in the State (as reported by the Energy Information Agency). The Agency report includes only emissions from aircraft landings and takeoffs (LTOs). The Centralia plant emissions, non-LTO emissions included in the Washington report, and the higher per capita travel rates explain why Washington has a higher per capita GHG rate than the Agency jurisdiction.

Table ES-2 Comparison of Puget Sound Area Gross GHG Emissions w/other areas of U.S.[8]

Jurisdiction	Year	Pop. (x 1,000)	Transportation Tons CO_2 Eqv	All Sources Tons CO_2 Eqv	% Emissions from Trans-portation	Tons CO_2 Eqv per capita from Transp'n	Tons CO_2 Eqv per capita from all Sources
Springfield, Oregon	2005	56	233,000	479,000	49	4	9
Eugene, Oregon	2005	146	708,000	1,388,000	51	5	10
Multnomah Co. Oregon	2004	674	4,114,000	10,684,000	39	6	16
Seattle, Washington	2000	563	3,950,000	7,013,000	56	7	12
King Co. Washington	2003	1,779	11,941,000	22,962,000	52	7	13
Puget Sound (geographic)	2005	3,460	20,461,000	38,828,000	53	6	11
Puget Sound (w/electricity)	2005	3,460	20,461,000	47,775,000	43	6	14
Washington State	2005	6,256	49,833,000	105,289,000	47	8	17
Bay Area, California	2002	6,772	43,200,000	85,400,000	51	6	13
California State	2004	36,591	214,524,000	550,236,000	39	6	15
U.S.	2005	296,507	2,090,000,000	8,000,000,000	26	7	27

Appendix D shows the geographic criteria pollutant emissions and greenhouse gas emissions from electricity consumption for the four counties in the Agency's jurisdiction.

[6] Appendix A, Draft Greenhouse Gas Inventory and Reference Case Projections, 1990-2020, Washington State Climate Advisory Team, Department of Ecology and the Department of Community, Trade, & Economic Development, July 19, 2007.

[7] Estimated with VMT from the"2005 HPMS Miles and VMT by County", published by Washington Department of Transportation available from Pat Whittaker (360) 570-2370 or whittap@wsdot.wa.gov; and Human Population from the "2005 Population Trends" published by the Washington Office of Financial Management.

[8] Springfield, OR: GHG of Springfield, Oregon, January 2007. Produced by the Climate Leadership Initiative Institute for a Sustainable Environment, University of Oregon, (541) 346-0786 or http://climlead.uoregon.edu. Eugene, OR: Eugene Community GHG Emissions Report, July 2007, Eugene Central Services, Facility Management Div., 210 Cheshire Ave, Eugene, OR 97401; prepared by Lynne Eichner-Kelley & Glen Svendsen. Multnomah County, OR: A Progress Report on the City of Portland and Multnomah County, Local Action Plan on Global Warming, June 2005, www.co.multnomah.or.os/dbcs/sustainbility; www.sustainableportland.org. Seattle, WA: Table B, Inventory and Report, Seattle's Greenhouse Gas Emissions, September 2002. King County, WA: Figure ES6, 2003 King County Air Emissions, December 2004, King County Department of Natural Resources. Puget Sound: Table ES-1 of this report. Washington State: Draft GHG and Reference Case Projections, 1990-2020, July 19, 2007, published by Washington State Department of Ecology and Washington State Department of Community, Trade, & Economic Development. Bay Area, CA: Source Inventory of Bay Area GHG Emissions, Base Year 2002, November 2006; published by the Bay Area Air Quality Management District, 939 Ellis St., San Francisco, CA 94109. California State: Air Resources Board, Statewide GHG Emissions Inventory, August 23, 2007 (available at http://www.arb.ca.gov/cc/ccei/emsinv/emsinv.htm). U.S.: Table ES-2, U.S. GHG 2005 (Inventory of U.S. GHG Emissions and Sinks: 1990-2005, April 2007; published by EPA). 2005 U.S. population is from www.census.gov/popest/states/tables/NST-EST2006-01.csv.

1 On-Road Vehicles

1.1 Category Description

This category covers emissions emitted by vehicles that travel on public roads. The particulate emissions include emissions from the exhaust, tire wear, and brake wear. Mobile on-road vehicle sources include cars, trucks, and buses that operate on public roadways. They are powered by gasoline, diesel, liquefied petroleum gas (LPG), or compressed natural gas (CNG). For this inventory, the Agency has adopted the criteria pollutant and carbon dioxide estimates developed by the Washington State Department of Ecology (Ecology)[9] based on the EPA MOBILE6.2 emission factor model and Vehicle Miles Traveled (VMT) from Washington State Department of Transportation Highway Performance Monitoring System (HPMS).[10] Ecology estimates include carbon monoxide (CO), nitrogen oxide (NOx), particulate matter not exceeding 2.5 microns ($PM_{2.5}$), sulfur oxide (SOx), volatile organic compounds (VOC), and carbon dioxide (CO_2) emissions for gasoline and diesel vehicles.

MOBILE6.2 is the model EPA recommends jurisdictions use to estimate on-road vehicle emission factors. The model does not estimate emissions; it only estimates emission factors that the modeler can apply to VMT for the vehicle category to estimate emissions. The model can estimate emission factors for 28 vehicle categories for any specified month of any specified year. MOBILE6.2 is not interactive (that is the modeler cannot edit data in the model itself); it requires the modeler to prepare an input file (with information relevant to the inventory area) in a DOS (ASCII) format with a text editor, such as Notepad. An example of information relevant to the inventory area includes distribution of vehicles by age, vehicle inspection programs, characteristics of fuel, and meteorology.

In its most basic form, a MOBILE6.2 input file consists of three sections: *header*, *run*, and *scenario*. Certain commands can only be placed in one of these sections. For example the model requires the fuel RVP and temperature inputs and these must go into the *run* section. The modeling year must go into the *scenario* section. If the modeler only wants emission factors for specific pollutants or vehicle types, such information must go into the *header* section.

The Agency used the Intergovernmental Panel on Climate Change (IPCC) guidelines to estimate the methane (CH_4) and nitrous oxide (N_2O) components of greenhouse gases. The IPCC guidelines apply methane and nitrous oxide emission factors to vehicle miles traveled to produce emissions. Ecology used MOBILE6.2 to estimate the carbon dioxide (CO_2) portion of the greenhouse gases. MOBILE6.2 applies CO_2 emission factors to vehicle miles traveled to produce emissions. The Agency applied external combustion factors in AP-42 to fuel burned by vehicles running on LPG and natural gas to estimate criteria pollutants emitted by such vehicles.

The EPA source classification codes (SCC) for on-road vehicles are shown below. The EPA National Emission Inventory includes SCCs in the national emission inventory reports. This helps jurisdictions enter emissions correctly into the national database.

SCC	Description of Vehicle
22 01 000 000	On-road gasoline vehicles
22 30 000 000	On-road diesel vehicles
22 67 000 000	On-road liquefied petroleum gas (LPG) vehicles
22 68 000 000	On-road compressed natural gas (CNG) vehicles

[9]Sally Otterson, Air Quality Program, WA Dept of Ecology, sott461@ecy.wa.gov.

[10]DVMT05COrpt.xls, 2005 HPMS Miles and VMT by County, June 21, 2006; e-mail December 4, 2006 from Pat Whittaker, HPMS Manager, WSDOT, whittap@wsdot.wa.gov or (360) 570-2370.

1.2 Summary of Emissions from On-road Vehicles

Table 1-1 shows the estimated tons of carbon monoxide, nitrogen dioxide, fine particles, sulfur dioxide, volatile organic compounds, and carbon dioxide equivalent emitted from vehicles using public roadways in the Agency's jurisdiction during 2005.

Table 1-1: 2005 Total On-road Mobile Emissions for Puget Sound Four-County Area (in tons)

Vehicle Type	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Diesel school buses	115	548	35	16	33	72,240
Other diesel vehicles	9,062	34,413	936	857	1,658	3,928,363
Gas school buses	212	26	0	0	16	4,525
Other gas vehicles	652,628	46,519	462	773	51,859	14,629,285
LPG vehicles	2	16	1	2	0	14,809
CNG vehicles	95	224	18	1	13	288,169
Total on-road vehicles	662,116	81,747	1,452	1,650	53,579	18,937,482

1.3 Key Assumptions

Total Vehicle Miles Traveled (VMT) as published by Washington State Department of Transportation is representative of actual miles traveled. Ecology used the 2005 HPMS vehicle miles traveled as published by the Washington State Department of Transportation to estimate the emissions. Ecology modeled percentage distribution of VMT among the vehicle categories with MOBILE6.2. EPA guidelines require that the total VMT for the county must agree with the VMT published in the county's HPMS system.

School Bus VMT provided by Washington Office of Superintendent of Public Instruction (WA OSPI) is representative of actual miles traveled. School bus emissions are of special interest to the Agency because the Agency has an on-going program to reduce emissions from diesel school buses. The Agency replaced the school bus VMT predicted by MOBILE6.2 with VMT derived from data provided by WA OSPI.

Carbon Dioxide Emissions are estimated using the VMT Method. The IPCC guidelines recommend inventory compilers use either the vehicle fuel consumption method or vehicle miles traveled (VMT) method to estimate carbon dioxide emissions.[11] Compilers can either estimate emissions by multiplying emission factors (expressed as grams per unit of fuel consumed) by the fuel consumed, or by multiplying emission factors (expressed as grams per VMT) by VMT. The fuel consumption method estimating equation is:

Emissions = (fuel consumed in the area) × (grams of CO_2 per unit of fuel burned)

The 2005 Washington State and the U.S. GHG 2004 inventories used the fuels sales method to estimate carbon dioxide emissions and used VMT to estimate the other GHG emissions. The VMT method estimating equation is:

Emissions = (VMT in the area) × (grams of CO_2 per mile traveled)

[11] U.S. GHG 2004; Annex 2.1: Methodology for Estimating Emissions of CO_2 from Fossil Fuel Combustion. Annex 3.1: Methodology for Estimating Emissions of CH_4 and N_2O from Mobile Combustion. IPCC Guidelines 2006: Volume 2, Section 3.2.1.1: Choice of Method (for estimating road transportation CO_2).

The Agency chose the VMT method over the fuel sales method because vehicle users can buy the fuel in one location and burn the fuel elsewhere. Therefore, the smaller the inventory area, the less accurate the fuel sales method becomes. The larger the inventory area, the more accurate the fuel sales method becomes. The IPCC guidelines say in general the fuel sold method is appropriate for carbon dioxide emissions and the VMT method is appropriate for the nitrous oxide and methane emissions. IPCC guidelines, Washington State, and U.S. GHG 2004 inventories do not compare and contrast the fuel sales method with the VMT method.

The VMT method is appropriate for the Puget Sound Clean Air Agency area because the area is relatively small compared to Washington State and the U.S. Also the VMT method more accurately depicts the emissions where they occur and the compiler can easily separate the emissions into the various vehicle categories without having to make assumptions about fuel economy (miles per gallon).

1.4 Estimating Equations

For a vehicle category:

VMT = (VMT fraction as modeled with MOBILE6.2) × (total VMT) Emissions = (VMT) × (grams of pollutant per mile)

For school buses, VMT was calculated from the equation:

VMT = (number of buses) × (54 VMT per bus/day) × (180 school days/year)

1.5 Activity Levels

Table 1-2 presents activity level data for school buses as estimated with information provided by the Washington State Office of Superintendent of Public Instruction (WA OSPI). WA OSPI provided the number of buses, number of school days per year, and the average number of miles a typical school bus traveled per school day.

Table 1-2: Number of School Buses and School Bus Miles Traveled, 2005[12]

County	# of Diesel School Buses	# of Gasoline School Buses	Diesel School Buses (1,000 VMT)	Gasoline School Buses (1,000 VMT)
King	1,850	158	17,903	1,529
Kitsap	307	23	2,971	223
Pierce	1,063	79	10,287	765
Snohomish	905	25	8,758	242

Table 1-3 presents total VMT per county as provided by the Washington State Department of Transportation. The total VMT comes from the 2005 Highway Performance Monitoring System (HPMS) database.

[12]Beth Carper, Puget Sound Clean Air Agency, bethc@pscaleanair.org or (206) 689-4957 provided the number of diesel school buses. Number of gasoline buses obtained from 2002 database provided by WA OSPI. Daily VMT per bus obtained from OSPI website http://www.k12.wa.us/transportation/default.aspx, accessed July 12, 2007. Shaylah Seymour (360) 725-6120, pupil transportation section of WA OSPI provided the 180 school days/year.

Table 1-3: Annual Vehicle Miles Traveled (AVMT) in Thousands, 2005[13]

County	1,000 VMT
King	16,500,283
Kitsap	1,604,175
Pierce	6,060,184
Snohomish	5,266,845

MOBILE6.2 estimates the fraction of total miles traveled by a vehicle category. Tables 1-4 and 1-5 show the MOBILE6.2 vehicle codes, vehicle classifications, range of vehicle weights for vehicle classes, and percent of VMT for each vehicle class as modeled with MOBILE6.2. The percent of VMT adds up to 100.

Table 1-4: 2005 VMT Distribution among Diesel Vehicle Categories[14]

Diesel Vehicle	Vehicle Description	Weight in Lbs	% of VMT
HDDBS	School buses	----	0.1900
HDDV2B	Class 2B heavy-duty	8,500-10,000	1.0900
HDDV3	Class 3 heavy-duty	10,000-14,000	0.3250
HDDV4	Class 4 heavy-duty	14,000-16,000	0.2600
HDDV5	Class 5 heavy-duty	16,000-19,500	0.1200
HDDV6	Class 6 heavy-duty	19,500-26,000	0.5375
HDDV7	Class 7 heavy-duty	26,000-33,000	0.6500
HDDV8a	Class 8a heavy-duty	33,000-60,000	0.7600
HDDV8b	Class 8b heavy-duty	>60,000	4.4125
LDDT12	Light-duty truck 1 and 2	<6,000	0.0425
LDDT34	Light-duty truck 3 and 4	6,000-8,500	0.1700
LDDV	Passenger cars	----	0.1725
HDDBT	Transit and urban buses	----	0.1175

Table 1-5: 2005 VMT Distribution among Gasoline Vehicle Categories[15]

Gasoline Vehicle	Vehicle Description	Weight in Lbs	% of VMT
HDGB	School, transit, and urban	----	0.0300
HDGV2B	Class 2B heavy-duty	8,500-10,000	3.5625
HDGV3	Class 3 heavy-duty	10,000-14,000	0.1275
HDGV4	Class 4 heavy-duty	14,000-16,000	0.0500
HDGV5	Class 5 heavy-duty	16,000-19,500	0.1100
HDGV6	Class 6 heavy-duty	19,500-26,000	0.2200
HDGV7	Class 7 heavy-duty	26,000-33,000	0.0900
LDGT1	Light-duty trucks 1	<4,000	7.4525
LDGT2	Light-duty trucks 2	4,000-6000	24.8080
LDGT3	Light-duty trucks 3	6-8,000 (4,000 empty)	8.4370
LDGT4	Light-duty trucks 4	6-8,000 (6,000 empty)	3.8800
LDGV	Passenger cars	----	41.9025
MC	Motorcycles	----	0.4825

[13]2005 HPMS VMT, Appendix Excel 1.1; from Pat Whittaker, WA DOT, Olympia, in hard copy and e-mail.
[14]Modeled with MOBILE6.2 by Sally Otterson, Department of Ecology, sott461@ecy.wa.gov.
[15]Modeled with MOBILE6.2 by Sally Otterson, Department of Ecology, sott461@ecy.wa.gov.

Tables 1-6 and 1-7 present VMT by vehicle class as estimated with the equation:

VMT for vehicle category = (VMT fraction for category) × (total VMT)

Table 1-6: 2005 AVMT (in thousands) for Diesel Vehicles as estimated with MOBILE6.2 VMT Fractions

Diesel Vehicle	King	Kitsap	Pierce	Snohomish
HDDBS	31,351	3,048	11,514	10,007
HDDV2B	179,863	17,486	66,056	57,409
HDDV3	53,626	5,214	19,696	17,117
HDDV4	42,901	4,171	15,756	13,694
HDDV5	19,800	1,925	7,272	6,320
HDDV6	88,689	8,622	32,573	28,309
HDDV7	107,252	10,427	39,391	34,234
HDDV8a	125,402	12,192	46,057	40,028
HDDV8b	728,075	70,784	267,406	232,400
LDDT12	7,013	682	2,576	2,238
LDDT34	28,050	2,727	10,302	8,954
LDDV	28,463	2,767	10,454	9,085
HDDBT	19,388	1,885	7,121	6,189
Total	1,459,863	141,929	536,175	465,984

Table 1-7: 2005 AVMT (in thousands) for Gas Vehicles as estimated with MOBILE6.2 VMT Fractions

Gasoline Vehicle	King	Kitsap	Pierce	Snohomish
HDGB	4,950	481	1,818	1,580
HDGV2B	586,823	57,149	215,894	187,631
HDGV3	21,038	2,045	7,727	6,715
HDGV4	8,250	802	3,030	2,633
HDGV5	18,150	1,765	6,666	5,794
HDGV6	36,301	3,529	13,332	11,587
HDGV7	14,850	1,444	5,454	4,740
LDGT1	1,229,684	119,551	451,635	392,512
LDGT2	4,093,390	397,964	1,503410	1,306,599
LDGT3	1,392,129	135,344	511,298	444,364
LDGT4	649,211	62,242	235,135	204,354
LDGV	6,914,031	672,189	2,539,369	2,206,940
MC	79,614	7,740	29,240	25,413
Total	15,040,420	1,462,246	5,524,009	4,800,861

1.6 Corrected School Bus VMT

The Agency considers the school bus VMT estimated with data provided by WA OSPI to be more accurate than estimates modeled with MOBILE6.2. The VMT for HDDBS, HDDBT, and HDGB modeled by Ecology with MOBILE6.2 (M6) as presented in Tables 1-6 and 1-7 are modified with the WA OSPI school bus VMT. The total AVMT must remain constant at the HPMS level.

Diesel school bus: HDDBS (modified) = HDDBS (WA OSPI) from Table 1-2
Gas school bus: HDGBS (modified) = HDGBS (WA OSPI) from Table 1-2
Diesel transit: HDDBT (modified) = HDDBT (M6) + [(HDDBS (M6) - HDDBS (WA OSPI)]
Gas transit & urban bus: HDGBT (modified) = HDGB (M6) - HDGBS (WA OSPI)

Tables 1-8 and 1-9 present the modified VMT for each vehicle class by county. The emission estimating equations use the modified VMTs.

Table 1-8: 2005 AVMT (in thousands) for Diesel Vehicles modified with WA OSPI VMT

Diesel Vehicle	King	Kitsap	Pierce	Snohomish
HDDBS	17,903	2,971	10,287	8,758
HDDV2B	179,863	17,486	66,056	57,409
HDDV3	53,626	5,214	19,696	17,117
HDDV4	42,901	4,171	15,756	13,694
HDDV5	19,800	1,925	7,272	6,320
HDDV6	88,689	8,622	32,573	28,309
HDDV7	107,252	10,427	39,391	34,234
HDDV8a	125,402	12,192	46,057	40,028
HDDV8b	728,075	70,784	267,406	232,400
LDDT12	7,013	682	2,576	2,238
LDDT34	28,050	2,727	10,302	8,954
LDDV	28,463	2,767	10,454	9,085
HDDBT	32,835	1,962	8,348	7,437
Total	1,459,863	141,929	536,175	465,984

Table 1-9: 2005 AVMT (in thousands) for Gasoline Vehicles modified with WA OSPI VMT

Gas Vehicle	King	Kitsap	Pierce	Snohomish
HDGBS	1,529	223	765	242
HDGBT	3,421	259	1,054	1,338
HDGV2B	586,823	57,149	215,894	187,631
HDGV3	21,038	2,045	7,727	6,715
HDGV4	8,250	802	3,030	2,633
HDGV5	18,150	1,765	6,666	5,794
HDGV6	36,301	3,529	13,332	11,587
HDGV7	14,850	1,444	5,454	4,740
LDGT1	1,229,684	119,551	451,635	392,512
LDGT2	4,093,390	397,964	1,503410	1,306,599
LDGT3	1,392,129	135,344	511,298	444,364
LDGT4	649,211	62,242	235,135	204,354
LDGV	6,914,031	672,189	2,539,369	2,206,940
MC	79,614	7,740	29,240	25,413
Total	15,040,420	1,462,246	5,524,009	4,800,861

1.7 Emission Factors for Diesel and Gasoline Vehicles

Tables 1-10, 1-11, and 1-12 present criteria pollutant emission factors[16] for on-road vehicles modeled with MOBILE6.2 by Sally Otterson of the Washington Department of Ecology.

Table 1-10: Emission Factors (milligrams per mile) for CO, NOx, and SOx as modeled with MOBILE6.2

Diesel Vehicle	CO	NOx	SOx
HDDBS	2,621	12,456	358
HDDV2B	1,019	3,797	173
HDDV3	1,183	4,136	192
HDDV4	1,380	5,544	220
HDDV5	1,421	5,734	226
HDDV6	2,159	8,716	258
HDDV7	3,232	11,704	297
HDDV8a	4,864	16,209	347
HDDV8b	3,985	15,960	359
LDDT12	4,539	2,726	79
LDDT34	1,106	1,324	131
LDDV	2,142	1,940	84
HDDBT	3,601	16,023	513
Gasoline Vehicle	**CO**	**NOx**	**SOx**
HDGBS	69,751	8,688	81
HDGBT	69,751	8,688	81
HDGV2B	13,204	3,992	50
HDGV3	33,090	4,912	55
HDGV4	56,392	6,649	58
HDGV5	32,192	5,805	64
HDGV6	38,106	6,098	65
HDGV7	61,100	8,127	71
LDGT1	24,051	1,289	27
LDGT2	24,612	1,604	27
LDGT3	25,731	1,734	35
LDGT4	25,974	2,149	35
LDGV	19,639	1,243	21
MC	16,874	1,793	10

[16]E-mail from Sally Otterson (sott461@ecy.wa.gov, (360) 407-6806) to Kwame Agyei, July 5, 2007: 2005 On-road Emissions for Puget Sound.

Table 1-11: Emission Factors (milligrams/mile) for $PM_{2.5}$ as modeled with MOBILE6.2

Diesel Vehicle	$PM_{2.5}$ (exhaust)	$PM_{2.5}$ (brakes)	$PM_{2.5}$ (tire)	$PM_{2.5}$ (total)
HDDBS	777	5.3	3.0	785
HDDV2B	119	5.3	2.0	126
HDDV3	114	5.3	3.0	122
HDDV4	136	5.3	3.0	144
HDDV5	120	5.3	3.0	129
HDDV6	321	5.3	3.0	329
HDDV7	437	5.3	3.0	445
HDDV8a	548	5.3	9.0	562
HDDV8b	357	5.3	9.0	371
LDDT12	291	5.3	2.0	298
LDDT34	123	5.3	2.0	130
LDDV	209	5.3	2.0	216
HDDBT	297	5.3	3.0	305
Gasoline Vehicle	**$PM_{2.5}$ (exhaust)**	**$PM_{2.5}$ (brakes)**	**$PM_{2.5}$ (tire)**	**$PM_{2.5}$ (total)**
HDGBS	106	5.3	3.0	114
HDGBT	106	5.3	3.0	114
HDGV2B	57	5.3	2.0	65
HDGV3	69	5.3	3.0	77
HDGV4	85	5.3	3.0	94
HDGV5	64	5.3	3.0	73
HDGV6	68	5.3	3.0	76
HDGV7	79	5.3	3.0	87
LDGT1	6	5.3	2.0	14
LDGT2	6	5.3	2.0	14
LDGT3	7	5.3	2.0	14
LDGT4	7	5.3	2.0	14
LDGV	5	5.3	2.0	12
MC	15	5.3	1.0	21

Table 1-12: Emission Factors (milligrams/mile) VOC as modeled with MOBILE6.2

Diesel Vehicle	VOC (evap)	VOC (exhaust)	VOC (total)
HDDBS		739	739
HDDV2B		213	213
HDDV3		236	236
HDDV4		319	319
HDDV5		327	327
HDDV6		533	533
HDDV7		756	756
HDDV8a		783	783
HDDV8b		650	650
LDDT12		2,594	2,594
LDDT34		658	658
LDDV		939	939
HDDBT		331	331
Gasoline Vehicle	**VOC (evap)**	**VOC (exhaust)**	**VOC (total)**
HDGBS	2,177	2,925	5,102
HDGBT	2,177	2,925	5,102
HDGV2B	435	546	981
HDGV3	829	1,321	2,150
HDGV4	2,421	2,349	4,770
HDGV5	1,323	1,364	2,687
HDGV6	1,512	1,603	3,115
HDGV7	2,215	2,610	4,826
LDGT1	707	1,057	1,764
LDGT2	707	1,104	1,812
LDGT3	703	1,265	1,968
LDGT4	703	1,321	2,025
LDGV	865	814	1,680
MC	637	2,265	2,902

MOBILE6.2 estimates carbon dioxide emission factors but it does not model nitrous oxide and methane emission factors. Table 1-13 presents GHG emission factors for on-road vehicles. The emission factor for carbon dioxide equivalent (CO_2 eqv) is estimated from the equation:

$$\text{mg } CO_2 \text{ Eqv} = (\text{mg } CO_2/\text{mile}) + (21 \times \text{mg } CH_4/\text{mile}) + (310 \times \text{mg } N_2O/\text{mile})$$

Table 1-13: Emission Factors (milligrams/mile) for Greenhouse Gases[17]

Diesel Vehicle	CO_2	CH_4	N_2O	CO_2 Eqv
HDDBS	1,640,125	5.1	4.8	1,641,720
HDDV2B	790,525	5.1	4.8	792,120
HDDV3	877,650	5.1	4.8	879,245
HDDV4	1,004,700	5.1	4.8	1,006,295
HDDV5	1,035,900	5.1	4.8	1,037,495
HDDV6	1,181,500	5.1	4.8	1,183,095
HDDV7	1,357,375	5.1	4.8	1,358,970
HDDV8a	1,586,800	5.1	4.8	1,588,395
HDDV8b	1,643,825	5.1	4.8	1,645,420
LDDT12	360,800	0.9	1.4	361,253
LDDT34	597,175	0.9	1.4	597,628
LDDV	380,725	0.5	1.0	381,046
HDDBT	2,349,175	5.1	4.8	2,350,770
Gasoline Vehicle	**CO_2**	**CH_4**	**N_2O**	**CO_2 Eqv**
HDGBS	1,416,750	263	214	1,488,458
HDGBT	1,416,750	263	214	1,488,458
HDGV2B	885,200	263	214	956,908
HDGV3	969,175	263	214	1,040,883
HDGV4	1,019,125	263	214	1,090,833
HDGV5	1.129,725	263	214	1,201,433
HDGV6	1,139,050	263	214	1,210,758
HDGV7	1,250,900	263	214	1,322,608
LDGT1	473,525	78	106	507,891
LDGT2	473,525	78	106	507,891
LDGT3	616,025	78	106	650,391
LDGT4	616,025	78	106	650,391
LDGV	371,425	70	65	392,960
MC	177,400	67	7	180,950

Emissions of a pollutant for a vehicle category were estimated from the VMT of the vehicle category and pollutant emission factors for the vehicle category, with the following equation:

$$\text{Tons emitted} = (1{,}000 \times \text{VMT}) \times (\text{mg/mile}) \div (1{,}000 \times 453.6 \times 2{,}000)$$

1.8 Emissions of Diesel and Gasoline Vehicles

Table 1-14 shows on-road vehicle emission estimates for the total four-county region, including both diesel and gasoline subcategories. County-level emissions are found in Appendices A1-A4.

[17] CO_2 emission factors modeled with MOBILE6.2 by Sally Otterson; CH_4 and N_2O factors taken from U.S. GHG: 2004 Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004, Annex 3.2, Tables A-94 and A-95.

Table 1-14: 2005 On-road Vehicle Emissions in Puget Sound Area (tons)

Diesel Vehicle	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
HDDBS	115	548	35	16	33	72.240
HDDV2B	360	1,343	45	61	75	280,109
HDDV3	125	436	13	20	25	92,705
HDDV4	116	468	12	19	27	84,880
HDDV5	55	223	5	9	13	40.390
HDDV6	376	1,520	57	45	93	206,304
HDDV7	682	2,568	94	63	159	286,571
HDDV8a	1,199	3,996	139	85	193	391,635
HDDV8b	5,704	22,847	531	514	930	2,355,433
LDDT12	63	38	4	1	36	4,981
LDDT34	61	73	7	7	36	32,960
LDDV	120	109	12	5	53	21,324
HDDBT	201	893	17	29	18	131,071
Subtotal	9,177	34,961	971	873	1,691	4,000,604
Gasoline Vehicle	**CO**	**NOx**	**$PM_{2.5}$**	**SOx**	**VOC**	**CO_2 Eqv**
HDGBS	212	26	0	0	16	4,525
HDGBT	467	58	1	1	34	9,961
HDGV2B	15,261	4,613	75	57	1,133	1,105,947
HDGV3	1,369	203	3	2	89	43,055
HDGV4	915	108	2	1	77	17,694
HDGV5	1,149	207	3	2	96	42,875
HDGV6	2,720	435	5	5	222	86,415
HDGV7	1,784	237	3	2	141	38,617
LDGT1	58,149	3,115	33	64	4,264	1,227,952
LDGT2	198.080	12,911	110	214	14,579	4,087,625
LDGT3	70,430	4,747	39	95	5,387	1,780,211
LDGT4	32.694	2,705	18	44	2,549	818,682
LDGV	266,970	16,897	169	284	22,832	5,341,926
MC	2,641	281	3	2	454	28,325
Subtotal	652,840	46,545	462	773	51,874	14,633,811
All Vehicles	662,018	81,506	1,433	1,647	53,565	18,634,414

1.9 Liquefied Petroleum Gas (LPG) and Compressed Natural Gas (CNG) Vehicles

Some on-road vehicles run on LPG or CNG. MOBILE6.2 does not have VMT distribution for on-road vehicles powered by LPG or CNG. From the 2005 vehicle registration data provided by the Washington State Department of Licensing, vehicles burning alternate fuel in Washington State constitute approximately 0.043% of the vehicle fleet.[18] Assuming alternate fuel, gasoline, and diesel vehicles have similar average travel rates (VMT per year), the VMT for alternate vehicles would be about 0.043% of the total VMT in Washington State.

[18] Motor Vehicle Registration by Class and County - Calendar 2005; https://fortress.wa.gov/vsFeeDistribution/reports.asp?rpt=2005C00-63.csv&intCountBit=1&bhcp=1, July 24, 2006. Special Fuel Vehicle Statistics: Judy Abern (jabern@dol.wa.gov, (360) 902-3726) mailed both reports to Kwame Agyei April 6, 2006. The Special Fuel Vehicle Statistics report is not available online.

Washington State transportation LPG and CNG fuel is apportioned to the counties by annual VMT as shown in Table 1-15.

Table 1-15: Fuel Consumption by LPG and CNG Vehicles[19]

Area	Annual Million VMT	1,000 Gallons of LPG	Million Cubic Feet of Natural Gas
King	16,500	1,299	2,676
Kitsap	1,604	126	260
Pierce	6,060	477	983
Snohomish	5,267	415	854
Washington State	55,487	4,368	9,000

Table 1-16 shows emission factors used for LPG and CNG vehicles. Currently, there are no emission factors for natural gas and propane fueled vehicles. The closest available factors are external combustion factors presented in Sections 1.4 and 1.5 of EPA's Compilation of Air Pollutant Emission Factors (AP-42). These factors are for external combustion of fuel (as in combustion of fuel in boilers).

Table 1-16: Emission factors for LPG and CNG Vehicles[20]

Pollutant	Lbs/1,000 Gallons of LPG	Lbs/Million Cubic Feet of Natural Gas
CO	1.9	40
NOx	14	94
$PM_{2.5}$	0.4	7.6
SOx	1.6	0.6
VOC	0.3	5.5
CO_2	12,500	120,000
CH_4	0.2	2.3
N_2O	0.9	2.2
CO_2 eqv	12,783	120,730

Emission factors from Table 1-16 are applied to LPG and CNG fuel burned (from Table 1-15) to obtain emissions presented in Tables 1-17 and 1-18.

Emissions = (quantity of fuel burned) × (lbs pollutant/unit quantity of fuel burned)

Table 1-17: Tons of Criteria Pollutants Emitted by LPG Vehicles, 2005

County	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
King	1.2	9.1	0.3	1.0	0.2	8,302
Kitsap	0.1	0.9	0.0	0.1	0.0	807
Pierce	0.5	3.3	0.1	0.4	0.1	3,049
Snohomish	0.4	2.9	0.1	0.3	0.1	2,650
Region	2.2	16.2	0.5	1.9	0.3	14,809

[19] Transportation Sector Energy Consumption Estimates, Washington 2004, Energy Information Agency, State Energy Data Report, Table 11; http://www.eia.doe.gov/emeu/states/sep_use/tra/use_tra_wa.html; July 19, 2007.

[20] AP-42, Sections 1.4 and 1.5 (External Combustion Factors). There are no factors for on-road vehicles running on LPG or CNG. The closest factors available are the AP-42 factors for LPG and CNG burning.

Table 1-18: Tons of Criteria Pollutants Emitted by CNG Vehicles, 2005

County	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
King	53.5	125.8	10.2	0.8	7.4	161,557
Kitsap	5.2	12.2	1.0	0.1	0.1	15,707
Pierce	19.7	46.2	3.7	0.3	0.3	59,336
Snohomish	17.1	40.2	3.2	0.3	0.3	51,569
Region	94.8	224.4	18.1	1.4	1.4	288,169

1.10 Comment on Biodiesel Emissions

Vehicles that use biodiesel are becoming available. Currently, credible data on the amount of biodiesel consumed at the county or even state level is not available. The Washington State Department of Revenue and Washington State Department of Licensing do not have data on biodiesel sales. The Energy Information Agency (the official energy data information in the U.S.) does not publish data on biodiesel consumption.

2 Non-Road Mobile Engines

Non-road mobile engines include aircraft, airport ground support equipment, locomotives, vessels, boats, and other miscellaneous mobile engines not used on public roadways. They can run on gasoline, diesel, LPG, CNG, or electricity.

Aircraft and airport ground support emissions are described in Section 2.1. Railroad emissions are included in Section 2.2. Commercial and recreational marine emissions are described in Sections 2.3 and 2.5, respectively. Section 2.4 describes miscellaneous non-road mobile emissions. Table 2-1 presents examples of non-road mobile engines.

Table 2-1: Examples of Non-Road Mobile Engines

Equipment	Examples of Equipment
Terrestrial recreation	Golf carts, all-terrain vehicles, dirt-bikes, specialty vehicles
Construction	Bull dozers, pavers, excavators, drills, surfacers, compactors, rammers, signals
Industrial	Aerial lifts, forklifts, sweepers, scrubbers, material handlers
Lawn and garden	Lawn mowers, trimmers, blowers, chippers, lawn tractors, aerators, chain saws
Agricultural	Tractors, combines, swathers, sprayers, balers, tillers
Commercial	Generators, pumps, compressors, welders, pressure washers
Logging	Shredders, chain saws, fellers, bunchers, debarkers
Airport ground support	Tractors, loaders, service trucks, deicers, forklifts, carts
Aircraft	Commercial, military, general aviation, and air taxies
Railroad	Line haul locomotives, switchyard locomotives, yard equipment
Recreational marine	Sailboats, Jet Skis, outboard motors, inboard motors, yachts
Commercial marine	Ocean-going vessels, ferries, fishing vessels, tugs, military boats

2.1 Airport-Related Equipment

Airport-related equipment includes both aircraft as well as the equipment that services the aircraft while on the tarmac.

2.1.1 Aircraft

2.1.1.1 Category Description

Aircraft fall into one of four categories:

- **military** includes aircraft used by the U.S. Armed Forces.
- **commercial** includes aircraft used for scheduled flights, and are operated by large airlines such as Northwest, Alaska, United, American, and British Airways.
- **general aviation** includes aircraft used by corporations and private citizens.
- **air taxi** includes aircraft used for shuttles and short routes such as Seattle to the San Juan Islands, Yakima, Bellingham, or Wenatchee. Air taxis are operated by short-route airlines such as Horizon, and are typically associated with a larger airline.

This category includes emissions from aircraft landings and takeoffs (LTOs) at the 30 airports located within the Agency's four-county jurisdiction. These airports include those most heavily used: Seattle-Tacoma International Airport (Sea-Tac), Snohomish County International Airport (Paine Field), and King County International Airport (Boeing Field), as well as military airports and the many smaller fields located in King, Kitsap, Pierce, and Snohomish counties. Shown below are the source classification codes (SCC) for aircraft.

SCC	Description of Aircraft
22 75 001 000	Military aircraft (F-16, C-130, Prowler, helicopters, etc.)
22 75 020 000	Commercial aircraft (used by airlines, i.e., Boeing 737, MD-80)
22 75 050 000	General aviation aircraft (corporate and private)
22 75 060 000	Air taxi (shuttles and short routes)

2.1.1.2 Key Assumptions

Landing and takeoff (LTO) information available is representative of actual landings and takeoffs. The LTO data in this section was provided by airport managers and the Federal Aviation Administration (FAA) Airport Master Records.[21] The FAA reports aircraft operations for the most recent 12-month period. For some of the small airports, the most recent 12 months do not coincide with calendar year 2005. The inventory assumes the most recently available 12-month LTO as 2005 LTO.

Emission estimates are based on the Emissions and Dispersion Modeling System 4.5 (EDMS 4.5). The FAA's EDMS 4.5, the latest available software for estimating airport emissions, was used for all the airports except Sea-Tac. The Inventory assumes Sea-Tac Airport meteorology for all the local airports. EDMS requires basic airport meteorology and characteristics. Sea-Tac data was used for all airports as presented in Table 2-3. Ecology inventories use Sea-Tac meteorology data to represent all areas of the Puget Sound region.

The basis for Sea-Tac's 2005 emissions is the 2000 Sea-Tac Airport Emissions. Sea-Tac Airport hired Camp Dresser & McKee Inc. (CDM) consultants to compile a comprehensive inventory for the airport for calendar year 2000 and projection years 2007 and 2015. This inventory adopts the 2000 inventory developed by Sea-Tac Airport and adjusts the 2000 emissions with the 2000 and 2005 LTO ratio.

LTOs for small airports are Cessna 150s and Beechjet 400s. The FAA provides LTO data for small airports by general aircraft category type (general aviation, air taxi, military, and commercial) not by specific aircraft type (B737, MD-80). The major general aviation airport in King County is Boeing Field, and in Snohomish County it's Paine Field. The Cessna 150 is the most common general aviation aircraft and the Beechjet 400 is the most common air taxi aircraft used at both Boeing and Paine Fields. Therefore, FAA-reported general aviation and air taxi LTOs for small airports are assumed to be Cessna 150 and Beechjet 400 LTOs, respectively.

The county estimates include only pollutants emitted during LTOs. The emissions presented in this report include only emissions from aircraft LTOs. The inventory does not include emissions from fuel burned by aircraft above 3,000 feet. This leaves a large percentage of aircraft emissions unaccounted for. EPA and FAA guidelines[22] recommend local aircraft emission estimates include only emissions from fuel burned during LTOs. The World Resource Institute does not have a clear policy on aircraft emission inventories. EPA and IPCC guidelines do not give reasons why local airport air emission inventories should count only LTO emissions. This inventory reports LTO emissions. The City of Seattle and King County aircraft emission inventories follow these guidelines and report only LTO emissions.

Comments on U.S. and Washington State Aircraft Emissions: U.S. and Washington State aircraft emission estimates include more than LTO emissions. Currently, national emission

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[21] Airport Master Records available at www.gcr1.com/5010web, September 14, 2007.

[22] Procedures for Emission Inventory Preparation, Volume IV, Mobile Sources, Chapter 5, 1992, EPA, Ann Arbor, MI; EDMS Reference Manual, page 3-1, prepared for FAA & U.S. Air Force by CSSI Inc., 2001, Washington DC.

totals do not include emissions from combustion of fuels used for international transport activities. The United Nations Framework Convention on Climate Change (UNFCCC) decided that nations should report emissions from fuel used for international transport separately from their national totals.[23] Nations should report international transport emissions for aircraft and ships based on the point of sale and should include the international transport emissions in their inventory write-up, but exclude it from their national total. The Revised 1996 IPCC Guidelines and the 2006 IPCC Guidelines reflect these decisions.

The end effect is that the U.S. should include cruising emissions from an aircraft flying from Seattle to Miami in its national totals, but exclude cruising emissions for aircraft flying from Seattle to Vancouver, Canada. Similarly, the U.S. should include emissions from ships traveling from Seattle to Los Angeles but exclude cruising emissions from ships traveling from Seattle to Melbourne, Australia. The annual U.S. GHG inventories follow these IPCC guidelines. For these reasons, one should not compare aircraft and ship emissions for a nation and a subset of the nation on a per capita basis. A nation counts cruise emissions and LTO emissions of non-international flights within the nation, but the subset area of the nation counts only LTO emissions.

The 2005 Washington State GHG emissions[24] follows IPCC guidelines except for aircraft. The Washington State GHG emissions includes emissions from all the aircraft fuel distributed in Washington State, as reported in the Energy Information Agency annual report for Washington State. For ships, it includes only emissions from fuel burned by ships while in Washington State waters, as recommended by the IPCC guidelines.

2.1.1.3 Characteristics of EDMS 4.5.

The EPA and FAA recommend modelers use the latest available version of the EDMS to estimate emissions from aircraft and associated ground support equipment.[25] The compiler must obtain detailed LTO information from the airport in order to run the model, and only a few airports can provide the level of LTO details required to run the model. An LTO includes four modes:

- **Approach** to the airport starts when aircraft get down to 3,000 feet and ends when they touch the tarmac. FAA calls the 3,000 feet mixing height. Mixing height can vary from airport-to-airport. The default is 3,000 feet, and this report uses the default.
- **Taxi/idle** includes touchdown on the tarmac, taxiing to the gate, maneuvering to the gate, idling at the gate (while passengers get off the plane), idling before pulling out of the gate, maneuvering out of the gate, and waiting at the edge of the runway for instructions from the air traffic controller to take off.
- **Takeoff** includes taxiing on the runway until leaving the tarmac.
- **Climb-out** from the airport starts when aircraft leave the tarmac and ends when they reach 3,000 feet.

Some airports report activity in operations. An operation is either a landing or a takeoff. For all practical purposes, the number of LTOs at an airport is the same as the number of landings (or

[23]Intergovernmental Negotiating Committee for a Framework Convention on Climate Change Report on the work of its ninth session, held at Geneva from February 7-18, 1994 (A/AC.237/55, Annex I, paragraph 1c).

[24]Appendix C1, page 54, Greenhouse Gas Inventory and Reference Case Projections, 1990-2020; prepared by the Washington State Climate Advisory Team, July 19, 2007; in consultation with WA State Dept of Ecology and Dept of Community, Trade, and Economic Development.

[25]Preface of EDMS Reference Manual, Year 2000: The official EPA-recommended procedure is the Procedures for Emission Inventory Preparation, Volume IV, Mobile Sources, Chapter 5, 1992, EPA, Ann Arbor, MI. This is a manual calculation. The FAA, U.S. Air Force, and EPA developed the manual calculations into the EDMS software.

the number of takeoffs). The number of landings and takeoffs together is called the number of operations. The number of LTOs is half the number of operations.

The modeler must enter the LTO by aircraft type such as B737, A320, or MD-80. For each type of aircraft, the modeler must select the type of engine on the aircraft (B737). A B737 operated by Northwest Airlines and a B737 operated by Alaska Airlines are similar in appearance only. A B737 may carry a GE, Pratt-Whitney, or Roll Royce engine. Each engine group has several variations that fit a B737. The engine may be a CFN, TFE, PT, or JT, etc. model. An aircraft is customized by the customer airline. Even airports that can provide detailed LTO data cannot provide these engine details.

The EDMS 4.5 recommends a default engine type for each aircraft type (shown in bold in the program). Unless the compiler knows that a particular aircraft type landing at the airport carries a specific engine type, the compiler must select the default. This report uses the default engine recommended by the software. Airports do not collect information on the type of engine on an aircraft LTO from the airport.

Table 2-2 presents the sources of LTO data. Table 2-3 shows input parameters used in the EDMS model. A short description of each parameter is provided after the table.

Table 2-2: Source of LTOs used in EDMS 4.5 Model

Airport/Aircraft	LTOs Input into EDMS 4.5
Boeing Field, Seattle	2000/2003 operations fleet mix, Table C3[26]
Paine Field, Everett	2004 LTOs[27]
McChord Air Force Base	2000 LTOs by aircraft (base LTOs only)[28]
Fort Lewis Army Base	2005 LTOs by aircraft type[29]
Sea-Tac International Airport	2000 and 2005 landing by aircraft type, December 2005[30]
General aviation aircraft	All LTOs are Cessna 150 (Agency assumption)[31]
Air taxi aircraft	All LTOs are Beechjet 400 (Agency assumption)

Table 2-3: Characteristics and Data Required for EDMS 4.5 Run

Characteristic	Description or Value of Characteristic
Airport name	Selects airport ID, latitude and longitude, elevation
Mixing height	3,000 feet (default), Agency selected the default for all airports
Average temperature	53°F (average annual temperature at Sea-Tac Airport)
Study year	2005 (even if LTO year is for a different year)
Diesel PPM sulfur	340 (does not affect aircraft emissions, affects on-road)
Mobile model	MOBILE6.2
Study type	Emissions only, performance-based, LTO-based

[26]King County, *King County International Airport Plan, Draft SEPA EIS/NEPA EA*, April 2004.
[27]Andrew Rardin, Environmental Manager, Paine Field, Everett, WA; e-mail October 12, 2005. LTO information.
[28]Kevin Shupe, Environmental Program Manager, McChord AFB, WA; e-mail July 14, 2003. LTO information.
[29]Terry Lee, Environmental & Natural Resources Division, HQ I Corps & Fort Lewis, WA; e-mail February 7, 2006. LTO information.
[30]Port of Seattle, Sea-Tac Airport statistics. Available at: www.portseattle.org/seatac/statistics; September 14, 2007.
[31]For small airports that lack detail on the types of aircraft landing at the airport, the Agency assigned Cessna and Beechjet default engines to LTOs for general aviation and air taxi, based on the mix of general aviation and air taxi aircraft landing at Boeing and Paine Fields.

Airport Name. Every airport has an assigned name and a code. For example, Sea-Tac Airport is officially called Seattle-Tacoma International Airport, and its code is SEA. EDMS 4.5 automatically assigns some characteristics such as, latitude, longitude, elevation, mixing height, length of runway, types of ground support equipment, and meteorology based on airport name.

Mixing Height. EDMS 4.5 automatically selects 3,000 feet as the default height at which the aircraft begins and ends LTO. The compiler may override this if the airport traffic controller has provided a mixing height specific for that airport. This inventory assumes the EDMS 4.5 default.

Average Temperature. The 2005 average annual temperature[32] for Sea-Tac Airport is used for all the airports in the Agency's jurisdiction. Meteorological data for Sea-Tac is available from the National Climatic Data Center in Asheville, North Carolina and from the Agency's Technical Services Department.

Study Year. The compiler selects a study year, which can affect the type and age of ground support equipment assigned to the airport by EDMS 4.5. This inventory is for 2005.

Diesel PPM Sulfur and Mobile Model. The default is 340 parts per million by weight (ppmw) of sulfur (S). This selection does not affect aircraft and ground support equipment emissions. EDMS 4.5 includes modules for modeling on-road vehicles arriving at or leaving the airport. The ppmw S is used in the MOBILE6.2, which a modeler can use to estimate emissions from the on-road vehicle activity around the airport. MOBILE6.2 is integrated with EDMS 4.5. The study type for this airport inventory does not require modeling on-road vehicle activity around airports. However, the software requires the modeler to provide the version of on-road emissions model and sulfur content that EDMS 4.5 should use to model on-road activity around the airport.

Study Type. EDMS 4.5 can perform several types of studies (i.e., model events, on-road vehicle contributions, and other scenarios at the airport). This inventory covers only LTO and ground support equipment (GSE) emissions. To model only LTO and GSE emissions, the modeler selects the "emissions only, performance-based, LTO-based" study type.

Following are the effects of the modeler's assumptions on aircraft LTO emissions:

Mixing Height: A mixing height greater than 3,000 feet increases the approach time and the emissions during the approach mode. The increase in emissions in the approach mode would be proportional to the increase in the time-in-mode for the approach mode. Time-in-mode is the number of minutes the aircraft spends in the mode.

Heavier Aircraft: A modeler enters LTO data into the software by aircraft type. The weight of the aircraft type (such as a B737) that corresponds with LTO data can vary depending on the number of passengers, freight, and even the type of engine the airline requested the manufacturer install on the B737. Heavier aircraft would have higher fuel consumption rates and hence higher emission rates. The modeler does not know the occupancy rate, tons of freight on board, type of engine on the aircraft, or which type of engine would make one B737 heavier than another. It is therefore difficult to compare the emission rates of a heavier B737 to that of a lighter B737. Since the modeler must enter the LTO data by aircraft type, the software cannot model differences in emission rates between lighter and heavier aircraft of the same kind. Appendices A9-A15 present differences in fuel consumption rates for several types of aircraft.

[32]2005 Local Climatological Data, annual summary with comparative data, Seattle, WA, Sea-Tac Airport, published by the National Climatic Data Center, Asheville, NC, www.ncdc.noaa.gov/oa/climateresearch.html. Copies available from Mary Hoffman, (206) 689-4006, maryh@pscleanair.org.

Longer Runway/Busier Airport: The taxiing/idle times vary with the airport. Once the modeler enters the airport code, EDMS assigns time-in-modes for that particular airport, and this inventory uses the default time-in-modes. Longer runways and idling times at busier airports will increase emissions. The increase is relative to the percent increase from the default time-in-modes.

Uncertainties of aircraft emissions: The estimated aircraft emissions for a large airport should be fairly accurate, since LTOs for the aircraft types are available. However, even for the large airports, an unknown percentage of landing aircraft of a particular type will have engines different from the default engines EDMS assigns to that type of aircraft. The EDMS selected the default engines based on existing aircraft population and characteristics. It is difficult to estimate the level of uncertainty for aircraft emissions because of the lack of information on the actual aircraft engines. For smaller airports, the level of uncertainty for the emission estimates could be significant because the FAA reports LTOs for small airports by aircraft group (military, general aviation, air taxi). The modeler has to make an assumption on the type of aircraft visiting the small airport. It is difficult to estimate the level of uncertainty for aircraft emissions at small airports because of lack of data on the types of aircraft landing at the small airport.

2.1.1.4 Activity Levels

The EDMS 4.5 model was run with the assumptions and inputs discussed in Section 2.1.1.2 and Table 2-3 of this report. The EDMS 4.5 software program estimated the LTO fuel and LTO emissions (in tonnes) for the various airports. Table 2-4 shows the summary of LTOs.

The activity levels were provided by the airports or obtained from the FAA's Airport Master Records (FAA AMR) online database.[33] Appendix A20 presents LTOs for the individual small airports as obtained from the FAA AMR website.

Table 2-4: LTOs Used to Run the EDMS 4.5

Airport/City/County	Year	# of LTOs	Modeling Airport
Sea-Tac, King County	2005	166,841	Sea-Tac
Sea-Tac, King County	2000	222,839	Sea-Tac
Boeing Field, Seattle, King County	2003	149,232	Boeing Field
Other King County Airports	2002	199,242	Boeing Field
Kitsap County Airports	2002	73,070	Bremerton
McChord Air Force Base, Pierce County	2000	5,773	McChord
Fort Lewis Army Base, Pierce County	2005	31,494	Fort Lewis
Small Pierce County Airports	2002	123,419	Tacoma Narrows
Paine Field, Everett, Snohomish County	2004	54,055	Paine Field
Small Snohomish County Airports	2002	148,936	Paine Field

Entering LTO data into the EDMS 4.5, results in metric tons of criteria pollutant emissions, fuel burned during each mode of the landing and takeoff cycle, and number, horsepower (hp), load factor, and type of ground support equipment used for landings and takeoffs.

Tables 2-5 and 2-6 present Sea-Tac Airport LTOs and emission estimates[34] developed by Camp Dresser & McKee Inc. (CDM) for Sea-Tac Airport with EDMS 4.11, an earlier version of EDMS.

[33] Airport Master Records http://www.gcr1.com/5010web, September 25, 2007.

[34] Tables 1 and 4, Final Report, Seattle-Tacoma International Airport Nonroad Mobile and Stationary Source Operational Emission Inventories for 2000, 2007, and 2015, June 7, 2002, prepared by Camp Dresser & McKee Inc., 18881 Von Karman Ave., #650, Irvine, CA 92612.

Table 2-5: 2000 and 2005 LTOs at Sea-Tac Airport

Type of Aircraft	Engine Selected by CDM	2000 LTOs	2005 LTOs
AN 12, 124, 42	TF39-GE-1	1	225
BAE 31, Beech 58P	TPE331-1	10	
Beech King 10, 30	PT6A-65AR	118	52
Cessna Series	PT6A-67B	7,365	
Piper PA-34	IO-360-B	15	
550 Citation	JT15D-4	12	
A300-600C	JT9D-20J	379	502
A318 and A319	CFM56-5A5	2,752	5,207
A320, 321,3 30, 340	CFM56-5A3	5,221	6,767
B727-200	JT8D-17	6,001	491
B737, 738	CFM56-3-B1	58,064	57,748
B747	CFC-50A	2,388	1,537
B757, 752, 75LR	RB211-535E4	13,971	12,712
B767, 762	JT9D-7R4D	2,979	2,373
B777-200	PW4077	1,325	900
BH-1900C, BH-C99	PT6A-65B	36	150
C-130, C-141 Hercules	T56 Series 1	4	1,114
Citation VII, and CRJ Series	TFE 731-2-2B	64	3,136
DA and DC Series	CFM56-2A	5,938	1,867
DHC-8-300	PW127-A	47,438	45,417
EMB-120	PW118	22,265	5,164
Fokker 27, Fokker 28	SPEY-MK555	15,691	120
Falcon Series, Il-96-300	TFE731-3	229	3
L-1011-500	RB211-525B4	125	118
Learjet Series 31, 35, 36, 188	TFE 731-2-2B	21	17
MD 10, MD 11	CF6-80CB42	1,479	873
MD 80-83, MD 90-30	JT8D-219	24,162	19,958
MD 90, MD 30	V2525-D5	1	
Navajo, Rockwell	TIO-540-J2B2	3,182	
Swearing Metro, other	TPE331-2	1,341	93
Total LTOs for Calendar Year		222,839	166,841

2.1.1.5 Aircraft Criteria Pollutant Emissions

The 2005 Sea-Tac aircraft emissions are estimated from the 2000 CDM EDMS 4.11 estimates using:

2005 Sea-Tac aircraft emissions = (2005 LTO)/(2000 LTO) × (2000 aircraft emissions)

The number of 2005 LTOs is less than the number of 2000 LTOs because of the slowdown in air traffic following the September 11, 2001 terrorist attack.

Table 2-6: 2000 Sea-Tac Emissions Estimated by CDM (tons)

Mode of LTO	CO	NOx	PM	SOx	VOC
Approach	148	270	4	32	12
Climb-out	62	520	7	24	4
Takeoff	38	650	9	25	3
Taxi	1,311	236	6	58	129
Auxiliary power units	29	21	0	3	2
Total	1,588	1,697	26	142	150

Table 2-7 shows 2005 emissions at Sea-Tac Airport as projected from the 2000 Sea-Tac Airport emissions.

Table 2-7: 2005 Sea-Tac Emissions projected from 2000 Sea-Tac Emissions (tons)

Mode of LTO	CO	NOx	PM	SOx	VOC
Approach	111	202	3	24	9
Climb-out	46	389	5	18	3
Takeoff	28	487	7	19	2
Taxi	982	177	4	43	97
Auxiliary Power Units	22	16	0	2	1
Total	1,189	1,271	19	106	112

Table 2-8 presents the summary of the aircraft emissions (in tonnes) by airport as estimated with EDMS 4.5. A tonne (metric ton) is 1,000 kilograms and equivalent to 2,205 pounds, or 1.1 tons.

Table 2-8: Tonnes of Pollutants Emitted from LTOs by Airport, 2005

Airport	CO	NOx	$PM_{2.5}$	SOx	VOC
Sea-Tac (from Table 2-7 above), King Co.	1,082	1,157	17	96	102
Boeing Field, King County	587	331	4	34	718
Other King County	1,193	14	1	1	164
Kitsap County	293	1	0	0	12
McChord AFB, Pierce County	408	108	1	8	313
Fort Lewis Army Base, Pierce County	28	7	0	0	14
Other Pierce County	516	3	0	0	29
Paine Field	603	46	0	3	44
Other Snohomish County	729	4	0	0	39

2.1.1.6 Fuel Burned by Aircraft

Sea-Tac Airport emissions prepared by CDM do not contain greenhouse gases. The Agency used EDMS 4.5 to estimate 2005 LTO fuel and greenhouse gases for all airports. Table 2-9 presents fuel burned during LTOs by weight and volume. See Appendices A9-A13 for details of the LTO fuel.

The conversion from kilograms of fuel to 1,000 gallons of fuel is:

$$1{,}000 \text{ gallons of fuel} = (\text{kg fuel} \times 2.205 \text{ lbs/kg}) \div [(7.05 \text{ lbs/gallon}) \times 1{,}000]$$

Table 2-9: Summary of Fuel Burned during LTOs at the Airports

Airport	Fuel Burned in LTOs (kg)	Fuel Burned in LTOs (1,000 gal)
McChord	12,023,903	3,761
Fort Lewis	787,101	246
Paine Field	3,762,851	1,177
Boeing Field	35,895,508	11,226
Sea-Tac	123,567,759	38,648
Other King Airports	3,244,110	1,015
Kitsap Airports	360,285	113
Other Pierce Airports	751,803	235
Other Snohomish Airports	1,035,102	324

A comparison of fuel loaded into aircraft and the quantity burned at the airport is presented below at the airports for which data is available. Column 2 of Table 2-10 is not used to estimate emissions; it is presented to emphasize that not all fuel loaded into aircraft at these airports is used to estimate emissions from aircraft LTOs at airports. EDMS 4.5 estimates LTO emissions from the fuel presented in column 3 of Table 2-10. The difference between the fuel loaded into aircraft at the airport and fuel burned during LTOs at the airport is the fuel burned at cruising height. (See earlier discussion on IPCC guidelines for international transportation emissions in Section 2.1.1.2 of this report.)

Table 2-10: Fuel Loaded into Aircraft and % Fuel Burned during LTOs at Airports

Airport	Loaded into Plane[35] (thousands of gallons) A	Burned in LTO[36] (thousands of gallons) B	Percent of Fuel (A) Burned during LTOs (B ÷ A) × 100
Sea-Tac	435,272	38,648	8.9
Boeing Field	22,000	11,227	51.0
Paine Field	2,656	1,177	44.3
McChord AFB	34,814	3,761	10.8
Fort Lewis	820	246	30.0

2.1.1.7 Emission Factors for Greenhouse Gas (GHG)

The emission factors shown in Table 2-11 were used to calculate the emissions of greenhouse gases as presented in Table 2-12.

Table 2-11: Greenhouse Gas Emission Factors for LTOs

Emission Factor	Lbs of CO_2/ 1,000 gallons[37]	Grams of CH_4/ kilogram of fuel[38]	Grams N_2O/ kilogram of fuel[39]
Emission Factor	22,468	0.087	0.1

[35]Provided by respective airports via e-mail or hard copy. See Table 2-2.

[36]EDMS 4.5 output. See Table 2-9.

[37]AP-42, Chapter 3, Table 3.3-1.

[38]U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004,* Annex A, Table 3-30.

[39]U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004,* Annex A, Table 3-30.

Table 2-12: Tonnes of LTO Fuel & Tonnes CO_2 Equiv from LTOs, 2005

Airport	Tonnes of LTO Fuel	LTO Fuel (1,000 gallons)	Tonnes CO_2 Eqv
McChord AFB, Pierce Co.	12,024	3,761	38,714
Fort Lewis AB, Pierce Co.	787	246	2,534
Other Pierce Co.	752	235	2,421
Kitsap Co.	360	113	1,160
Paine Field, Snohomish Co.	3,763	1,177	12,116
Other Snohomish Co.	1035	324	3,333
Sea-Tac, King Co.	123,568	38,648	397,861
Boeing Field, King Co.	35,896	11,227	115,576
Other King Co.	3,244	1,015	10,445

2.1.1.8 Summary of Emissions

Table 2-13 shows estimated emissions from LTOs at airports in the Puget Sound region in 2005.

Table 2-13: 2005 Landing and Takeoff Emissions, tons

County	CO	NOx	PM	SOx	VOC	CO_2 Eqv
King	3,151	1,652	24	145	1,085	577,5**80**
Kitsap	323	1	0	0	13	1,279
Pierce	1,049	129	2	9	392	48,145
Snohomish	1,468	55	1	4	91	17,032
Region	5,992	1,837	26	158	1,581	644,036

2.1.2 Airport Ground Support Equipment (GSE)

2.1.2.1 Category Description

Airlines use GSE to service aircraft at or near the gate. Motorized equipment, such as tractors, trucks, loaders, lifts, sweepers, and deicers service aircraft between flights. While gasoline and diesel engines are predominantly used, propane, natural gas, and electric equipment are quickly becoming popular options. EDMS 4.5 automatically assigns GSE for an airport. A modeler can accept the EDMS default estimates based on the airport code entered into the software if an actual count of equipment, rated horsepower, load factors, and hours of use are unknown. Shown below are the source classification codes (SCC) for the broad categories of GSE.

SCC	GSE Description
22 60 008 000	2-stroke GSE
22 65 008 000	4-stroke GSE
22 67 008 000	LPG GSE
22 68 008 000	Natural gas GSE
22 70 008 000	Diesel GSE
22 75 070 000	Auxiliary and alternate power units (APU) on aircraft

2.1.2.2. Key Assumption

The Agency estimated the efficiency of non-road engines with outputs of the NONROAD 2005 model. The Agency estimated the efficiency of non-road engines using the equation:

Efficiency = (output energy in Btu) ÷ (input energy in Btu)

A = (B × E) ÷ (C × D)

where

A = efficiency of engine category
B = output hp-hrs as estimated by EDMS for the GSE engine
C = input gallons for the category engine as estimated using the NONROAD 2005 model
D = Btu per gallon for the fuel
E = 2,547 Btu per hp-hr

Conversion factors are used to convert the non-road equipment gallons of fuel input modeled by the NONROAD 2005 model to hp-hrs of energy input. The factors[40] are:

- 130,000 Btu/gallon of gasoline
- 137,000 Btu/gallon of diesel
- 94,000 Btu/gallon of LPG
- 1,050 Btu/cubic feet of natural gas
- 2,547 Btu/horsepower-hour

Table 2-14 presents the input gallons of non-road engines and output hp-hrs of the engines as estimated with the NONROAD 2005 model. The efficiency is estimated with the output and input energy as explained above. Section 2.4 presents a fuller discussion of non-road equipment efficiencies and fuel consumption.

Table 2-14: Energy Input/Output of Miscellaneous Non-Road Equipment[41]

Non-Road Equipment	1,000 Gallons Input	1,000 Hp-Hrs Output	Efficiency (%)
4-stroke gasoline	48,065	412,178	16%
Diesel	107,165	1,952,343	34%
LPG (propane)	29,175	277,833	26%

The Agency assumed efficiencies of GSE are similar to miscellaneous non-road equipment and used the efficiencies to estimate input gallons for GSE. EDMS 4.5 estimates output and criteria pollutant emissions for GSE. However it does not estimate greenhouse gas emissions. To estimate greenhouse gas emissions for GSE, the Agency converted the EDMS output horsepower-hours to input gallons in order to apply pounds per gallon emission factors.

The generic conversion equation is:

A = [(B × C) ÷ (D × E)]

where

A = gallons input for GSE engine
B = output hp-hr as estimated by EDMS 4.5 for the GSE engine
C = 2,547 Btu per hp-hr
D = Btu per gallon for the fuel category (diesel, gasoline, propane)
E = efficiency of category of engine as derived from the non-road engine model

From the NONROAD 2005 model input gallons and output hp-hr, the Agency estimated miscellaneous non-road diesel equipment to be 34% efficient and miscellaneous non-road gasoline engines to be 16% efficient (see Table 2-14 above).

[40] AP-42, Appendix A, Miscellaneous Conversion Factors.

[41] U.S. EPA NONROAD 2005 model. Information is from the output results of the NONROAD 2005 model run for the Puget Sound region. See Section 2.4 of this report (Miscellaneous Non-Road Vehicles).

2.1.2.3 Estimating Method

EDMS 4.5 estimates GSE emissions on an LTO basis. It assumes that certain types of GSE service certain types of aircraft for known durations. EDMS 4.5 assigns the GSE and the usage characteristics per LTO automatically when the LTO by aircraft type is entered. Sea-Tac compiled an inventory of GSE emissions in 2000 and based its inventory on actual equipment population. The 2000 Sea-Tac GSE Inventory[42] is presented here and adjusted with 2000 and 2005 LTOs. Table 2-15 presents the type of GSE used at Sea-Tac Airport.

Table 2-15: GSE Population at Sea-Tac Airport, 2000

Type of GSE	Diesel	Gasoline	Propane	Electric
Air conditioner	5	1		
Air start unit	17	0		
Aircraft tractor	44	9		
Baggage tractor	11	195	47	
Belt loader	10	65	29	
Bobtail	0	11		
Cargo loader	29	18		
Cargo tractor	5	9		
Catering truck	1	4		
Deicer	0	17		
Forklift	7	6	38	16
Fuel truck	36	5		
Generator	4	8		
Ground power unit	33	2		
Hydrant truck	0	2		
Lavatory cart	0	14		16
Lavatory truck	0	15		
Lift	5	19	2	
Other	17	78		
Passenger stand	2	8		
Service truck	1	27		
Sweeper		3	5	
Water truck		15		
Tug				13
Total	227	531	121	45

Table 2-16 presents the 2000 emissions from GSE as estimated by CDM for Sea-Tac Airport.

Table 2-16: 2000 Emissions from Sea-Tac GSE[43] (in tons)

Type of GSE	CO	NOx	PM	SOx	VOC
Diesel	177	240	27	8	41
Gasoline	12,909	244	4	9	435
Propane	224	5	0	not available	14
Total	13,310	489	31	17	490

[42] Tables 3 and 4 of Final Report: Seattle-Tacoma International Airport Non-Road Mobile and Stationary Source Operational Emission Inventories for 2000, 2007 and 2015, June 7, 2002; prepared for the Port of Seattle by CDM, 18881 Von Karman Ave., #650, Irvine, CA 92612.

[43] Table 4 of Final Report: Seattle-Tacoma International Airport Non-Road Mobile and Stationary Source Operational Emission Inventories for 2000, 2007 and 2015, June 7, 2002; prepared for the Port of Seattle by CDM, 18881 Von Karman Ave. #650, Irvine, CA 92612.

2.1.2.4 Sea-Tac Airport Emissions

2005 Sea-Tac GSE emissions are estimated from the equation:

2005 Emissions = [(LTOs in 2005)/(LTOs in 2000)] x (GSE emissions in 2000)
2005 Emissions = (166,842/222,839) x (GSE emissions in 2000)

Table 2-17 shows 2005 emissions from GSE at Sea-Tac Airport.

Table 2-17: 2005 Emissions from Sea-Tac GSE (in tons)

Type of GSE	CO	NOx	PM	SOx	VOC
Diesel	133	180	20	6	31
Gasoline	9,665	183	3	7	326
Propane	168	4	0	not available	10
Total	9,965	366	23	13	367

For criteria pollutants, the EDMS 4.5 model estimates horsepower-hours for the GSE from LTO data and applies grams per horsepower-hour (g/hp-hr) emission factors to produce criteria pollutant emissions. For GHG, the Agency estimated the emissions by applying the GHG emission factors in Table 2-19 to the input gallons in Table 2-18.

2.1.2.5 Gallons of Fuel Burned by Ground Support Equipment (GSE)

Table 2-18 presents estimated fuel burned by GSE. See Appendices A16 through A18 for steps used to estimate the GSE fuel.

Table 2-18: 1,000 Gallons of Fuel Burned by GSE (2005)

Airport	Diesel at 34% Efficiency	Gasoline at 16% Efficiency
Sea-Tac	1,439	1,939
Boeing Field	313	945
Fort Lewis	103	30
McChord Air Force Base	128	10
Paine Field	56	36
Other King County airports	61	87
Kitsap County airports	2	3
Civilian Pierce County airports	7	10
Other Snohomish County airports	9	13

2.1.2.6 Emission Factors

Emission factors are emissions per unit quantity of fuel burned. Table 2-19 presents GHG emission factors for gasoline and diesel fuels. EDMS outputs did not include GSE running on LPG or natural gas. The actual 2000 Sea-Tac equipment count gave 227 diesel GSE, 531 gasoline GSE, 121 propane GSE, and 45 electric GSE.

Table 2-19: Emission Factors[44] for GHG (lbs/1,000 gallons of fuel input)

Type of Fuel	CO_2	CH_4	N_2O
Gasoline	20,020	1.1	0.5
Diesel	22,468	1.3	0.6

[44] Emission factor for CO_2 is from the *AP-42 Compilation of Air Pollutant Emission Factors*, Table 3.3-1 (internal combustion engines). Emission factors for N_2O and CH_4 are from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2004*, Annex A, Table 3-30.

2.1.2.7 Summary of Emissions

The emission factors (Table 2-19) are applied to the fuel burned (Table 2-18) to obtain GHG emissions shown in Table 2-20.

Table 2-20: Tons GHG Emitted by GSE (2005)

Airport	Diesel GSE	Gasoline GSE
Sea-Tac, King County	16,315	19,589
Boeing Field, King County	3,546	9,590
Fort Lewis Army Base, Pierce County	1,172	302
McChord Air Force Base, Pierce County	1,447	97
Paine Field, Snohomish County	631	360
Other King County airports	694	875
Kitsap County airports	21	27
Civilian Pierce County airports	78	98
Other Snohomish County airports	100	126

The EDMS 4.5 estimates criteria pollutants emitted by GSE. Table 2-21 presents tonnes of criteria pollutant emission estimates by airport and Table 2-22 presents the tons of criteria pollutant emission estimates by county (1 tonne equals 1.1 tons).

Table 2-21: Estimated Criteria Pollutants from Airport GSE as estimated by EDMS 4.5 (tonnes/2005)

Airport	CO	NOx	PM	SOx	VOC
Sea-Tac, King Co. (Table 2-17 above)	9,060	166	21	12	334
Boeing Field, King Co.	1,978	99	3	7	77
Other King County Airports	174	20	1	2	7
Kitsap County Airports	5	1			
McChord Air Force Base, Pierce Co.	36	18	2	2	3
Fort Lewis, Pierce Co.	83	15	1	2	4
Other Pierce County Airports	19	2			1
Paine Field, Snohomish Co.	97	8		1	4
Other Snohomish County Airports	25	3			1

Table 2-22: Emissions from Airport GSE by County (tons/2005)

County	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
King	12,337	496	26	23	459	50,606
Kitsap	6	1	0	0	0	48
Pierce	153	39	3	4	9	3,193
Snohomish	134	12	0	2	5	1217
Region	12,630	548	30	28	474	55,064

2.2 Railroad Locomotive Engines

2.2.1 Category Description

This category estimates emissions from locomotives used in the Agency's four-county jurisdiction. These include interstate and regional hauling lines, interstate and commuter rail lines, and locomotives used only within the rail yard. Equipment used to maintain rail yards is modeled with the U.S. EPA NONROAD 2005 model. Source classification codes (SCC) for rail equipment are shown below. Line haul locomotives operate over long distances. Switchyard locomotives operate in or near ports and train yards.

SCC	Description
22 85 002 006	Line haul class 1 (interstate lines - BNSF and Union Pacific)
22 85 002 007	Line haul class 2 and 3 (Tacoma Rail)
22 85 002 008	Interstate passenger rail (Amtrak)
22 85 002 009	Commuter rail (Sound Transit)
22 85 002 010	Switchyard locomotives (locomotives used within the yard)

2.2.2 Key Assumptions

Kitsap County has no rail activity. The Navy operates some trains in Kitsap County to move military equipment, however information about Navy rail activity is classified. Therefore no emissions were estimated for Kitsap County.

Fuel consumption data provided by the railroad companies is representative of rail activity in 2005. The Agency collected fuel consumption data from the railroads that operate in the Agency's jurisdiction. Union Pacific and Burlington Northern Santa Fe obtained their estimates from their national headquarters. The short line and regional railroad companies compile their fuel consumption from their own inventories. The Agency assumed the data the companies provided represented what they burned.

The Agency assigned Tacoma Rail fuel consumption to switchyard. Tacoma Rail did not separate the fuel consumption data provided to the Agency into line haul and switchyard. Since Tacoma Rail locomotives stay close to their bases in Tacoma or Olympia, the Agency assigned all Tacoma Rail fuel consumption to the switchyard category.

2.2.3 Estimating Equations

Emissions = (1,000 gal fuel burned) x (lbs of pollutant emitted per 1,000 gal fuel burned)
Total rail emissions = (line haul emissions) + (switchyard emissions)

2.2.4 Activity Levels

Table 2-23 presents the latest available data for rail line haul activity.

Table 2-23: Thousands of Gallons of Fuel Used by Line Haul Locomotives, 2005

Rail Company	King	Pierce	Snohomish
Union Pacific[45]	596	303	
BNSF[46]	4,921	2,825	3,963
Sound Transit[47]	500	150	50
Amtrak[48]	100	50	50
Total for line haul	6,117	3,328	4,063

[45] Jon Germer; Environmental Manager at Union Pacific Corporation, e-mail December 4, 2006.

[46] Jennifer Anderson, Environmental Manager at Burlington Northern Santa Fe Railway, e-mail & hard copy, jennifer.anderson@bnsf.com; (206) 625-6034, 2454 Occidental Ave. So., #1A, Seattle, WA 98134, December 4, 2006.

[47] Martin Young, Environmental Manager at Sound Transit, verbal communication (206) 398-5115, October 2006.

[48] Agency estimation based on Amtrak's schedule. Amtrak makes 3 round trips/day from Vancouver to Portland. Estimate assumes 3,000 hp engine, 28% load factor, each trip spends 1 hour in King Co., ½ hour in Pierce Co., and ½ hour in Snohomish Co., 6 days a week, 210 gallons of fuel/hp-hr, 7.05 lbs/gallon of fuel, Amtrak burns about 103,000 gallons in King Co., 52,000 in Pierce Co., and 52,000 in Snohomish Co. Fuel consumption rounded off to 100,000 gallons in King Co., 50,000 gallons in Pierce Co., and 50,000 gallons in Snohomish Co.

Table 2-24 presents fuel consumed by switchyard locomotives.

Table 2-24: Thousands of Gallons of Fuel Used by Switchyard Locomotives, 2005

Rail Company	King	Pierce	Snohomish
Union Pacific	110	99	
BNSF	500	400	200
Washington Dinner Train[49]	62		
Tacoma Rail[50]		500	
TEMCO[51]		100	
Pacific Rail[52]		30	
Ballard Rail	1		
Puyallup Rail[53]		2	
Total for Yard	673	1,131	200

2.2.5 Emission Factors

Table 2-25 presents emission factors.

Table 2-25: Emission Factors for Locomotives (lbs per 1,000 gallons)[54]

Pollutant	Line Haul	Switchyard
CO	62.6	89.4
NOx	493.1	504.4
$PM_{2.5}$	11.6	13.8
SOx	36.0	36.0
VOC	21.1	50.6
CO_2	22,468.0	22,468.0
CH_4	1.76	1.76
N_2O	0.56	0.56

2.2.6 Summary of Emissions

The Puget Sound Maritime Air Emissions Inventory (Maritime Inventory) compiled port-related emissions from locomotives. Table 2-26 presents the maritime-related emission estimates for rail. The maritime-related emissions are a subset of the emissions presented in Table 2-27.

Table 2-26: 2005 Maritime (Port-Related) Emissions from Locomotives[55] (tons)

Area	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
4-Co. Region	293	2,264	59	173	114	98,640

[49] Doug Bacon, Mgr, WA Dinner Train, Renton, WA, verbal & e-mail communication, dbacon@swdtrain.com.

[50] Alan Hardy, Technical Supervisor, Tacoma Rail, verbal & e-mail communication, September 2006.

[51] Terry Johnson, TEMCO, 11 Schuster Pkwy, Tacoma, WA 98402, verbal comm. December 4, 2006, (253) 572-3511; & Cindy Lin, Env. Coordinator, Port of Tacoma, clin@portoftacoma.com, (253) 838-0142 x142, September 2006.

[52] Cindy Lin, Port of Tacoma, verbal communication, (253) 838-0142 x142.

[53] Byron Cole, Yard Manager, Puyallup Rail, verbal communication December 4, 2006, (206) 782-1447.

[54] Criteria Pollutants: Jennifer Anderson, e-mail & hard copy, jennifer.anderson@bnsf.com, (206) 625-6034, Burlington Northern and Santa Fe Railway, *BNSF Railway Data Report, October 2006*. Carbon Dioxide: AP-42, Table 3.3-2. Methane and Nitrous Oxide: U.S. GHG 2004, Annex A, Table 3-30.

[55] Puget Sound Maritime Air Emissions Inventory, Table ES.6, prepared for the Puget Sound Maritime Air Forum by StarCrest Consulting Group, LLC; 5386 NE Falcon Ridge Lane, Poulsbo, WA 98370, April 2007.

Table 2-27 presents the total locomotive emissions obtained by applying the emission factors to the fuel burned by locomotives while in the Agency's jurisdiction.

Table 2-27: 2005 Estimated Emissions from Locomotives (tons)

County	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
King	222	1,678	40	122	82	77,005
Pierce	155	1,106	27	80	64	50,561
Snohomish	136	1,052	25	77	48	48,342
Region	512	3,836	92	279	193	175,909

2.3 Commercial Marine Vessels

2.3.1 Category Description

This category includes emissions from ocean-going vessels, ferries, tugs, and other commercial vessels. Ocean-going vessels include cruise vessels and merchant ships. Washington State Department of Transportation operates an extensive network of ferries in the Puget Sound region. Ferries such as the Victoria Clipper run between Seattle and Victoria, BC, Canada. Tugs guide ships to their berths and also tow ships. The U.S. Coast Guard operates vessels in the Puget Sound area both for police services and rescue missions. The estimates for commercial marine vessels come from the Puget Sound Maritime Air Emissions Inventory (Maritime Inventory). The Agency adopted the estimates developed by StarCrest Consulting Group for the Puget Sound Maritime Air Forum.[56] Emissions from recreational boats are shown in Section 2.5 of this report.

The inventory uses the power demand method to estimate emissions from commercial vessels. The fundamental equations in the power demand method are:

$$\text{Energy output in kW-hrs} = (\text{rated horsepower}) \times (\text{load factor}) \times (\text{hours spent in area})$$
$$\text{Kilograms emitted} = (\text{energy output in kW-hrs}) \times (\text{grams per kW-hr}) \div 1000$$

The major problem with the power demand method is obtaining the rated horsepower of visiting vessels. The U.S. Coast Guard databases list tonnage and draft (feet of water displaced by the vessel). Even if rated horsepower is known, the modeler has to estimate the load factor (fraction of rated horsepower used by a vessel while in Puget Sound waters). StarCrest Consulting obtained the rated horsepower from other commercial databases and estimated the load factor from vessel speed while in the Puget Sound area. For more details on the power demand method, see the Maritime Inventory.

The Agency estimated previous vessel emissions for this category with the fuel consumption method. In the last few years, the power demand method has eclipsed the fuel consumption method. StarCrest has used the power demand method to compile several port emission inventories around the country. The fundamental equations for the fuel consumption method are:

$$\text{Quantity of fuel burned} = (\text{gallons of fuel burned per hour}) \times (\text{hours spent in area})$$
$$\text{Kilograms emitted} = (\text{quantity of fuel}) \times (\text{grams per unit quantity of fuel}) \div 1000$$

[56] Puget Sound Maritime Air Emissions Inventory, prepared for the Puget Sound Maritime Air Forum by StarCrest Consulting Group, LLC; 5386 NE Falcon Ridge Lane, Poulsbo, WA 98370, April 2007.

The major problem with the fuel consumption method is obtaining the hourly fuel consumption rate for the vessels operating in the Puget Sound area. Either method presents challenges. Both methods obtain "hours spent in the area" from the vessel speed and distances traveled in the various vessel movement modes. According to the maritime inventory, the power demand method is more representative of the vessel movements and therefore produces better estimates.

The emissions from commercial marine vessels are taken from the Maritime Inventory. Commercial marine vessels include:

- Tugs — towing or guiding ships in and out of berths and harbors
- Tours — local and non-local cruises for passengers
- Ferries — Washington State Ferries, Victoria-Seattle (Victoria Clipper, etc.)
- OGV — ocean-going vessels (merchant marine and cruise ships)
- Fishing — fishing vessels
- Military — coast guard cutters, navy frigates, police boats, etc.

Source classification codes (SCC) for commercial marine vessels are shown below.

SCC	Description for Diesel-Powered Marine Vessels
22 80 002 020	Harbor vessels (tugs, tours, and ferries)
22 80 002 010	Ocean-going vessels, (OGV)
22 80 002 030	Fishing
22 80 002 040	Military (coast guard, navy)

2.3.2 Key Assumption

Only emissions from vessels while in the geographical boundaries of Puget Sound are included in this inventory. The inventory covers emissions of the vessels while the vessels are south of Buoy J, Port Angeles, Jefferson County. At Buoy J, a local pilot then takes command of the vessel. Following the IPCC guidelines, the maritime inventory did not inventory emissions from fuel burned when the vessels are out of the Puget Sound area. The 2005 Washington State GHG inventory[57] also inventoried emissions only when the vessel is in Washington State waters.

2.3.3 Emissions as Estimated by the Maritime Inventory

Emissions from ocean-going vessels were taken from Tables 3.41 and 3.42 of the Maritime Inventory and are shown in Table 2-28. Emissions from harbor vessels were taken from Tables 4.15 and 4.16 of the Maritime Inventory and are shown in Table 2-29. The commercial vessel emissions are presented as they appear in the Maritime Inventory. The total for the region may be off slightly due to rounding.

Table 2-28: 2005 Emissions from Ocean-Going Vessels (tons)

County	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
King	138	1,641	100	1,556	61	98,563
Kitsap	95	1,166	57	787	40	49,431
Pierce	67	793	54	975	27	65,081
Snohomish	8	97	6	105	3	6,484
Region	308	3,697	217	3,422	132	219,558

[57] Greenhouse Gas Inventory and Reference Case Projections, 1990-2020, prepared by WA State Climate Advisory Team, WA State Dept of Ecology, and Dept of Community, Trade, and Economic Development, July 19, 2007.

Table 2-29: 2005 Emissions from Harbor Vessels (tons)

County	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
King	502	2,954	146	113	130	198,771
Kitsap	167	985	49	38	44	66,257
Pierce	160	884	35	86	27	56,302
Snohomish	395	2,463	119	101	99	162,989
Region	1,224	7,285	349	337	300	484,319

2.4 Miscellaneous Non-Road Vehicles

2.4.1 Category Description

Miscellaneous non-road vehicles include motorized equipment used off public roadways for construction, logging, farming, yard work, material handling, and other activities. Table 2-30 lists activities and types of equipment included in the miscellaneous non-road emission inventory.

This section also includes emissions from cargo handling equipment estimated by StarCrest Consulting for the Maritime Inventory. The other non-road vehicles are inventoried in the following sections:

- 2.1 Aircraft and airport ground support equipment
- 2.2 Rail equipment
- 2.3 Commercial marine vessels
- 2.5 Recreational boats

Table 2-30: Examples of Miscellaneous Non-Road Vehicles

General Category	Specific Examples of Equipment Type
Terrestrial recreational	Golf carts, mopeds, all-terrain vehicles, etc.
Construction	Crawlers, pavers, excavators, signal boards, drills, rammers, bull dozers, etc.
Industrial	Cranes, refrigeration units, material handling machinery, etc.
Lawn and garden	Mowers, small chain saws, trimmers, yard tractors, aerators, etc.
Farm machinery	Combines, sprayers, irrigators, hydro units, tractors, plows, etc.
Commercial	Forklifts, pumps, compressors, washers, small generators, etc.
Logging	Fellers, bunchers, large chain saws, etc.

The miscellaneous non-road vehicle category encompasses emission estimates from engines powered by gasoline, diesel, compressed natural gas (CNG), and liquefied petroleum gas (LPG). Shown below are the source classification codes (SCC) for miscellaneous non-road equipment.

SCC	Description
22 60 000 000	Miscellaneous 2-stroke gasoline non-road equipment
22 65 000 000	Miscellaneous 4-stroke gasoline non-road equipment
22 67 000 000	Miscellaneous LPG (propane) non-road equipment
22 68 000 000	Miscellaneous natural gas (CNG) non-road equipment
22 70 000 000	Miscellaneous diesel non-road equipment

Each SCC can be further broken down into specific category descriptions. For example, the SCC group for miscellaneous 4-stroke gasoline non-road equipment has subgroups including terrestrial, industrial, commercial, lawn & garden, and logging.

2.4.2 Key Assumptions

Sea-Tac Meteorological Data is representative for all four counties. The Agency used Sea-Tac Airport temperatures for all four counties because they are representative of the region. The temperature at the location where the equipment is used affects the NONROAD 2005 model outputs. Ecology used Sea-Tac temperatures to model the on-road emissions.

Non-Road 2005 model defaults are representative for the Puget Sound region. The Agency used the following parameters in the model. In addition to the RVP and Sea-Tac temperatures, all inputs were left at the model's suggested defaults.

- Reid vapor pressure (RVP) ....8.8 (annual)
- Average minimum temperature ....46°F (annual, Sea-Tac Airport)
- Average maximum temperature.........61°F (annual, Sea-Tac Airport)
- Average dry bulb temperature ....53°F (annual, Sea-Tac Airport)
- Sulfur content in gasoline ....339 ppm (default)
- Sulfur content in diesel ....500 ppm (default)
- Sulfur content in marine diesel ....5,000 ppm (default)
- Sulfur content in natural gas ....3 ppm (default)
- Stage II control % 0
- Other variables (if any) ....default (in NONROAD 2005 model)

Sulfur content in on-road gasoline and diesel fuel has declined to about 15 ppmw S in 2007. Future inventories will assume the 15 ppmw or lower for non-marine fuel. The Maritime Inventory estimated marine emissions as presented in Section 2.3 of this report.

The NONROAD 2005 model does not cover cargo handling equipment used at the ports. While the NONROAD 2005 model includes cargo handling equipment, an inspection of the equipment population developed by the model and the equipment population in the maritime inventory indicates the model does not cover cargo handling equipment at the ports. Table 2-34 presents emissions from cargo handling equipment (CHE) at the ports as estimated by StarCrest Consulting and presented in Table 5.14 of the Maritime Inventory. The emissions from CHE at the ports are separate from the emissions from miscellaneous non-road equipment estimated with the NONROAD 2005 model.

2.4.3 Estimating Equations

The NONROAD 2005 model estimates emissions of each type of equipment from the equations:

$$\text{Emissions} = \text{horsepower-hours} \times (\text{grams/horsepower-hour})$$
$$\text{Horsepower-hours} = (\text{pieces of equipment}) \times (\text{hours used/year}) \times (\text{load factor})$$

The model was run on a county basis. Tables 2-31 and 2-32 show summaries of gallons of fuel burned and energy demand in horsepower-hours as estimated with the NONROAD 2005 model. The model does not estimate CH_4 and N_2O emissions directly. To estimate these emissions, off-model calculations were performed by applying emission factors to the fuel burned.

$$N_2O \text{ emissions} = (1{,}000 \text{ gallons of fuel}) \times (\text{lbs of } N_2O \text{ per } 1{,}000 \text{ gallons of fuel})$$
$$CH_4 \text{ emissions} = (1{,}000 \text{ gallons of fuel}) \times (\text{lbs of } CH_4 \text{ per } 1{,}000 \text{ gallons of fuel})$$
$$CO_2 \text{ eqv} = CO_2 + (21 \times CH_4) + (310 \times N_2O)$$

Emissions from snowmobiles and residential snow removal equipment were not included because there is little-to-no activity with this equipment in the Agency's jurisdiction.

2.4.4 Activity Levels

Table 2-31: Fuel Burned by Non-Road Equipment (as estimated w/NONROAD 2005 model)

County	2-stroke Gas (1,000 gallons)	4-stroke Gas (1,000 gallons)	Diesel (1,000 gallons)	LPG (1,000 gallons)	CNG (million cf)
King	2,838	28,601	54,838	17,840	1,408
Kitsap	318	2,412	6,412	436	42
Pierce	1,088	8,789	28,509	3,171	246
Snohomish	1,086	8,289	17,403	8,267	512
Region	5,329	48,085	107,165	29,715	2,208

Table 2-32: 1,000 hp-hrs Output (as estimated w/NONROAD 2005 model)

County	2-stroke Gasoline	4-stroke Gasoline	Diesel	LPG (Propane)	CNG
King	25,576	239,795	997,110	166,593	18,629
Kitsap	3,421	21,898	116,976	4,069	566
Pierce	10,737	75,719	520,948	29,916	3,254
Snohomish	10,772	74,767	317,309	77,255	6,616
Region	50,506	412,178	1,952,343	277,833	29,064

2.4.5 Emission Factors

The emission factors for criteria pollutants are built into the NONROAD 2005 model. The model estimates the activity levels and emissions on a specific-equipment basis. Table 2-33 presents GHG emission factors.

Table 2-33: Greenhouse Gas Emission Factors of Miscellaneous Non-Road Equipment[58]

Category of Non-Road Equipment	CH_4	N_2O
Gasoline (lbs/1,000 gallons burned)	1.11	0.49
Diesel (lbs/1,000 gallons burned)	1.27	0.56
LPG (lbs/1,000 gallons burned)	0.2	0.9
CNG (lbs/million cubic feet burned)	2.3	2.2

2.4.6 Summary of Emissions

Table 2-34 gives emissions from cargo handling equipment at the ports as estimated by the Maritime Inventory. The Agency has on-going programs to reduce maritime emissions. Table 2-35 shows emissions from miscellaneous non-road mobile equipment within the Agency's jurisdiction. Appendices A21-A24 show the county level emission estimates for miscellaneous non-road equipment.

Table 2-34: Emissions from Cargo Handling Equipment at the Ports, tons 2005[59]

Port, County	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Seattle, King	648	514	34	67	58	47,085
Tacoma, Pierce	226	586	34	7	38	60,025
Everett, Snohomish	22	23	2	2	2	1,392
Region	896	1,123	71	77	98	108,502

[58] Gasoline and Diesel: Inventory of U.S.Greenhouse Gas Emissions and Sinks 2004, Annex A, Table 3-30; LPG: U.S. EPA, AP-42 Compilation of Air Pollutant Emission Factors, Table 1.5-1; CNG: AP-42, Table 1.4-2.

[59] Puget Sound Maritime Air Emissions Inventory, Table 5.14, April 2007.

Table 2-35: Emissions from Misc. Non-Road Equipment (estimated w/NONROAD 2005 model) tons, 2005

Type of Equipment	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Gasoline	235,059	2,371	393	99	13,773	539,350
LPG	14,400	3,079	18	4	841	189,924
CNG	1,485	270	2	0	5	133,274
Diesel	6,666	12,971	1,069	371	1,450	1,214,623

2.5 Recreational Boats

2.5.1 Category Description

This category includes emissions from recreational boats. The types of recreational boats used in the Puget Sound area include:

Jet Ski..........personal watercraft, PWC (small, fast, 2-stroke gasoline boats).

Outboard .....engine "clamped" onto the boat (usually 2-stroke stroke). Outboards usually power small boats. However, local boat registration data indicates that some larger boats have outboards. Also 4-stroke outboards are becoming popular.

Inboard ....engine integrated into boat construction.

Sailboat ....boat using sails (may still use small engines to augment sails).

Diesel ....boat burning diesel fuel.

The Washington Department of Licensing (DOL) issues boat registrations. A boat owner must obtain a license to use the boat during the year. DOL categorizes boats licensed to be used during the year as "registered boats". The EPA source classification codes (SCC) for recreational boats are shown below. Not all types of boats listed below exist in the Puget Sound area. For example, an extensive internet search reveals only one Australian company currently makes diesel outboard boats and there are no diesel outboard distributors in the U.S. 2006 DOL boat registration data shows that a few small boats use electricity, propane, and other unspecified fuel types.

SCC	Description
22 82 005 010	Gasoline 2-stroke outboard
22 82 005 015	Gasoline 2-stroke PWC (Jet Ski, personal watercraft)
22 82 005 025/010 025	Gasoline sailboats
22 82 010 010	Gasoline 4-stroke outboard
22 82 010 005	Gasoline 4-stroke inboard
22 82 020 005	Diesel inboard
22 82 020 010	Diesel outboard
22 82 020 020/025	Diesel sailboat

2.5.2 Key Assumptions

Average gallons of fuel consumed per boat in 1994-95 is similar to fuel used in 2005. The DOL conducted a Washington Marine Fuel Use Study in 1994-95.[60] The Agency assumed the

[60]WA Dept. of Licensing, 1994-1995 WA Marine Fuel Use Study, October 1, 1994 through September 30, 1995. Contact is Robert Plue, Economic Analyst.

annual fuel consumption per boat in a boat category as found by the 1994 survey is still true for 2005. For example, a 1994 Jet Ski and a 2005 Jet Ski burn fuel at the same rate (gallons/year).

Percent of registered boats used during 1994-95 is similar to registered boats used in 2005. The 1994-95 DOL study estimated the fraction of registered boats used. The Agency assumed that the fraction of 1994-95 registered boats used during 1994-95 is the same as the fraction of 2005 registered boats used during 2005. Boat owners must register a boat if they intend to use it during the year; similar to annual car registration tabs. Not all registered boats get used.

Recreational boats are mostly used in their county of moorage. Boat owners store boats in marinas and in driveways. The owners tow them to local ramps for launching. The Agency assumes the crossover between counties cancels the other out. The larger the inventory area, the more accurate the assumption becomes.

Washington State boat characteristics are similar to county boat characteristics. The Agency used statewide boat characteristics to separate county boat population into fuel types and propulsion types. DOL provided county boat population by boat length only. The Agency used statewide characteristics to separate county boat population.

All diesel boats are inboard. An extensive internet search reveals that only one Australian company currently makes diesel outboard boats and there are no diesel outboard distributors in the U.S. Local groundtruthing[61] indicates diesel outboard motors do not exist in the Puget Sound area. Local boat salesmen were not familiar with diesel outboards. Ryan of Woodinville Three Rivers Marine said manufacturers do not make them. A salesman at Bayside Marine said Tohatsu Company manufactures diesel outboards, but a search of the Tohatsu website lead to eBay websites, and even on eBay sites, no diesel outboards were found.

Jet Skis make up 32.7% of gasoline boats under 16 feet long. Keri-Anne Jetzer of DOL provided data that showed 30,200 (32.7%) of the 91,132 gasoline boats less than 16 feet long were Jet Skis. The 1994-95 DOL survey also found that 33% of boats less than 16 feet long were Jet Skis.

92% of sailboats burn gasoline if needed to augment the sails. The 1994-95 DOL survey estimated that 92% of sailboats had small gasoline engines used to augment sails when necessary. The Agency assumed the remaining sailboats burned diesel when necessary to augment sails.

2.5.3. Estimating Equations

The emissions from each category of boat is estimated as follows:

# of boats used = (# of registered boats) × (fraction used during year)
Gallons of fuel used/year = (# of boats used) × (gallons used per boat/year)
Lbs of pollutant emitted = (gallons of fuel used/year) × (lbs of pollutant/gallon)

2.5.4 Population of Recreational Boats

DOL registers boats by county of moorage, boat length, fuel type (diesel, gasoline, sail, etc.), and by propulsion (outboard, inboard, sail). DOL provided Washington State registered boat population by fuel type and boat length as of October 17, 2007. Table 2-36 presents statewide registered boat population by boat length and fuel type, and Table 2-37 shows the percent distribution by fuel type for each boat length.

[61] Local boat dealers said diesel outboards are not available; a few said manufacturers do not make them: Lynnwood Motoplex, 17900 Hwy 99, (425) 774-0505; Woodinville Three Rivers Marine, (425) 415-1575; Everett Bayside Marine, (425) 252-3088; Mercer West Marine, (206) 292-8663.

Table 2-36: Certificates Issued to WA State Boats as of October 17, 2007[62]

Fuel Type	<16'	16–20'	21–30'	31–40'	41–50'	51–60'	>60'	Total
Diesel	56	144	2,942	6,167	2,877	576	253	13,015
Gasoline	92,132	112,286	38,155	3,390	366	52	89	246,470
Sail, other	3,078	1,391	805	76	19	1	3	5,373
Total	95,266	113,821	41,902	9,633	3,262	629	345	264,858

Table 2-37: Percent Distribution of WA State Boats by Fuel Type as of October 17, 2007

Fuel Type	<16'	16–20'	21–30'	31–40'	41–50'	51–60'	>60'
Diesel	0.06%	0.13%	7.02%	64.02%	88.20%	91.57%	73.33%
Gasoline	96.71%	98.65%	91.06%	35.19%	11.22%	8.27%	25.80%
Sail, other	3.23%	1.22%	1.92%	0.79%	0.58%	0.16%	0.87%

Table 2-38 gives 2005 boat registration data[63] by length for counties in the Agency's jurisdiction.

Table 2-38: 2005 Registered Boats by County of Moorage

County	<16'	16–20'	21–30'	31–40'	41–50'	51–60'	>60'	Total
King	20,510	22,434	10,531	3,255	1,259	248	158	58,395
Kitsap	4,870	4,541	2,337	869	284	34	12	12,947
Pierce	11,373	12,621	3,952	1,074	340	49	30	29,439
Snohomish	10,806	11,073	4,495	789	178	31	24	27,396
Washington	100,759	112,946	39,553	9,895	3,234	594	467	267,448

The statewide boat distribution (Table 2-37) is used to separate county boats (Table 2-38) into boat fuel types as shown in Table 2-39. Only King County calculations and distributions are presented here, however the same methodology would be used for other counties. For a specified length category:

$\underline{A = (B \times C)}$

where

A = Number of King County boats of specified length range burning the type of fuel
B = Fraction of Washington State boats of that specified length category burning the fuel
C = Number of all King County boats of the specified length range

For example, for King County gasoline boats with lengths between 16 and 20 feet:

B = 98.65% (3rd row, 3rd column of Table 2-37)
C = 22,434 (2nd row, 3rd column of Table 2-38)

Table 2-39: 2005 Registered Boats in King Co., by fuel type and boat length

Fuel Type	<16'	16–20'	21–30'	31–40'	41–50'	51–60'	>60'	Total
Diesel	12	28	739	2,084	1,110	227	116	4,317
Gasoline	19,835	22,131	9,589	1,145	141	21	41	52,904
Sail, other	663	274	202	26	7	0	1	1,174
Total	20,510	22,434	10,531	3,255	1,259	248	158	58,395

[62] E-mail from WA Dept. of Licensing, Keri-Anne Jetzer, Research Analyst, kjetzer@dol.wa.gov and Judy Abern, (360) 902-3726, jabern@dol.wa.gov, October 17, 2007.

[63] E-mail from WA Dept. of Licensing, Keri-Anne Jetzer, Research Analyst, kjetzer@dol.wa.gov and Judy Abern, (360) 902- 3726, jabern@dol.wa.gov, October 17, 2007.

Assuming 33% of gas boats less than 16 feet long are Jet Skis and 92% of sailboats burn gas, King County boat distribution presented in Table 2-39 is further separated into the distribution presented in Table 2-40.

Table 2-40: 2005 Registered Boats in King Co., by fuel type and boat length

Boat Type	<16'	16–20'	21–30'	31–40'	41–50'	51–60'	>60'	Total
Jet Ski	6,506							6,506
Diesel inboard	12	28	739	2,084	1,110	227	116	4,317
Gasoline	13,329	22,131	9,589	1,145	141	21	41	46,398
Sail with diesel	53	22	16	2	1			94
Sail with gas	610	252	186	24	7		1	1,080
Total	20,510	22,434	10,531	3,255	1,259	248	158	58,395

Table 2-41 shows the percent distribution of 2005 Washington State boats by length and propulsion (outboard, inboard, and sail).

Table 2-41: 2005 Percent Distribution of Registered Boats in WA, by propulsion and length[64]

Propulsion Type	<16'	16–20'	21–25'	26–39'	40–65'	>65'	All Boats
Outboard	88.21%	56.09%	25.50%	6.18%	2.15%	36.64%	58.85%
Inboard	9.63%	42.32%	68.36%	74.23%	84.74%	60.62%	37.07%
Sailboat	2.16%	1.59%	6.14%	19.59%	13.12%	2.74%	4.08%

The percent distribution of outboards and inboards (Table 2-41) is used to separate gasoline boats (Table 2-40) into outboards and inboards as presented in Table 2-42.

Table 2-42: 2005 Registered Boats in King Co., by propulsion type, fuel type, and length

Boat Type	<16'	16–20'	21–30'	31–40'	41–50'	51–60'	>60'	Total
Jet Ski	6,506							6,506
Diesel inboard	12	28	739	2,084	1,110	227	116	4,317
Gas inboard	1,312	9,518	6,984	1,057	138	13	16	19,037
Gas outboard	12,018	12,613	2,605	88	3	8	25	27,361
Sail with diesel	53	22	16	2	1			94
Sail with gas	610	252	186	24	7		1	1,080
Total	20,510	22,434	10,531	3,255	1,259	248	158	58,395

The 1994-95 Washington Marine Fuel Use Study estimated the percent of registered boats used during the year. Table 2-43 shows the percent of boats used during the year.

Table 2-43: Percent of Registered WA State Boats Used in 1994-95 (& in 2005)

Jet Ski	Boats <16 feet	Boats 16-26 feet	Boats >26 feet	Sailboats
87%	72%	83%	88%	86%

Applying the percents (Table 2-43) to the registered King County boat population (Table 2-42) gives the number of active boats in King County during 2005. An active boat is defined here as

[64] Derived from Certificates Issued to Boats with 2005 Expiration, WA DOL report MMVCGR, provided by Judy Abern, (360) 902-3726, jabern@dol.wa.gov, October 17, 2007.

a registered boat that was used in 2005. Table 2-44 presents the number of active boats in King County in 2005.

Table 2-44: 2005 Registered Boats in King County by propulsion type, fuel type, and length

Boat Type	<16'	16–20'	21–30'	31–40'	41–50'	51–60'	>60'	Total
Jet Ski	5,660							5,660
Diesel inboard	9	24	651	1,834	977	200	102	3,796
Gas inboard	944	7,900	6,146	931	121	11	14	16,076
Gas outboard	8,653	10,469	2,293	77	3	7	22	21,524
Sail with diesel	46	19	14	2	1			81
Sail with gas	524	217	160	20	6		1	929
Total	15,836	18,628	9,263	2,864	1,108	218	139	48,056

2.5.5 Gallons of Fuel Consumed by an Average Boat

The 1994-95 Washington Marine Fuel Use Study estimated average fuel use per year per boat. These consumption rates, shown in Table 2-45, are assumed to be true for boats used in 2005 as well.

Table 2-45: Average Number of Gallons Burned/Boat/Year[65]

Boat Type	<16'	16–20'	21–30'	31–40'	41–50'	51–60'	>60'
Jet Ski	70						
Diesel	71	91	238	300	400	500	850
Gasoline	71	100	316	630	820	1,011	1,887
Sailboat	20	25	30	40	45	50	60

2.5.6 Fuel Consumed by Recreational Boats

Applying the fuel consumption rates (Table 2-45) to the number of boats used in the year (Table 2-44) gives the fuel consumed by recreational boats in King County in 2005. Table 2-46 shows the fuel consumed (to the nearest 1,000 gallons) by active boats moored in King County.

Table 2-46: Fuel Consumed per Year by King County Boats (1,000 Gallons)

Boat Type	<16'	16–20'	21–30'	31–40'	41–50'	51–60'	>60'	Total
Jet Ski	396							396
Diesel inboard	1	2	155	550	391	100	87	1,285
Gas inboard	67	790	1,942	586	99	11	26	3,522
Gas outboard	614	1,047	725	49	3	7	42	2,485
Sail with diesel	1	2						2
Sail with gasoline	10	5	5	1				22
Total gasoline	1,088	1,842	2,671	636	102	18	68	6,426
Total diesel	2	3	155	550	391	100	87	1,287

The steps described above were repeated for Kitsap, Pierce, and Snohomish Counties. Tables 2-47, 2-48, and 2-49 present active boat fuel consumption for these three counties.

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[65] WA Dept. of Licensing, 1994-95 WA Marine Fuel Use Study, October 1, 1994 through September 30, 1995. Contact is Robert Plue, Economic Analyst.

Table 2-47: Fuel Consumed per Year by Kitsap County Boats (1,000 Gallons)

Boat Type	<16'	16–20'	21–30'	31–40'	41–50'	51–60'	>60'	Total
Jet Ski	94							94
Diesel inboard			34	147	88	14	7	290
Gas inboard	16	160	431	157	22	2	2	789
Gas outboard	146	212	161	13	1	1	3	536
Sail with diesel								
Sail with gasoline	2	1	1					5
Total gasoline	258	373	593	170	23	3	5	1,425
Total diesel			34	147	88	14	7	291

Table 2-48: Fuel Consumed per Year by Pierce County Boats (1,000 Gallons)

Boat Type	<16'	16–20'	21–30'	31–40'	41–50'	51–60'	>60'	Total
Jet Ski	220							220
Diesel inboard		1	58	182	106	20	16	383
Gas inboard	37	444	729	193	27	2	5	1,438
Gas outboard	341	589	272	16	1	1	8	1,228
Sail with diesel	1							1
Sail with gasoline	6	3	2					11
Total gasoline	603	1,036	1,003	210	28	4	13	2,896
Total diesel	1	1	58	182	106	20	16	384

Table 2-49: Fuel Consumed per Year by Snohomish County Boats (1,000 Gallons)

Boat Type	<16'	16–20'	21–30'	31–40'	41–50'	51–60'	>60'	Total
Jet Ski	209							209
Diesel inboard		1	66	133	55	12	13	282
Gas inboard	35	390	829	142	14	1	4	1,416
Gas outboard	324	517	309	12		1	6	1,169
Sail with diesel								
Sail with gasoline	6	3	2					10
Total gasoline	573	909	1,140	154	14	2	10	2,804
Total diesel	1	1	66	133	55	12	13	283

2.5.7 Emission Factors and Summary of Fuel Consumption

Emission factors for boats were derived using the NONROAD 2005 model. Table 2-50 presents emission factors for recreational boats.

Table 2-50: Emission Factors for Recreational Boats Burning Fuel (lbs/1,000 gallons burned)[66]

Type of Boat	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2	CH_4	N_2O	CO_2 Eqv
Jet Ski	3,475.5	43.9	1.2	3.3	1,136.8	20,020	1.4	0.5	20,202
Gas outboard	3,001.6	35.3	1.2	3.3	1,240.5	20,020	1.4	0.5	20,202
Gas inboard	3,035.8	146.3	1.2	3.3	160.5	20,020	1.4	0.5	20,202
Diesel	45.4	287.3	7.3	31.7	10.7	22,468	1.6	0.6	22,676

Table 2-51 summarizes 2005 fuel consumption by county and boat type that matches emission factors presented in Table 2-50. The Agency assumed gas sailboats have outboard engines.

[66] CO, NOx, $PM_{2.5}$, SOx, and VOC: NONROAD 2005 model, lbs/gallon = (lbs emitted) ÷ (gallons burned); CO_2: AP-42, Table 3.3-1 Gasoline Internal Combustion Engine; CH_4 and N_2O: U.S. GHG 2004, Annex A, Table 3-30.

Table 2-51: 2005 Recreational Boat Fuel Consumption by county and boat type (1,000 gallons)

County	Jet Ski	Outboard Gas	Inboard Gas	Diesel (total)	Gas (total)
King	396	2,507	3,522	1,287	6,426
Kitsap	94	541	789	291	1,425
Pierce	220	1,239	1,438	384	2,896
Snohomish	209	1,180	1,416	283	2,804
Region	919	5,467	7,165	2,244	13,551

Washington State recreational boat fuel consumption is reported in 2005 Highway Statistics.[67] Table MF-24 in the 2005 Highway Statistics shows Washington State boats burned 27.2 million gallons of gasoline in 2005. The 13.6 million gallons of gasoline consumed in the 4-county region is about 50% of the statewide 27.2 million gallons consumed. Table 2-38, presented above, shows 48% of Washington's registered boats are moored in the Agency's jurisdiction.

2.5.8 Emissions from Recreational Boats

Emission factors (Table 2-50) were applied to fuel consumption (Table 2-51) to obtain the emissions presented in Tables 2-52 through 2-56.

Table 2-52: Tons of Pollutants Emitted by Recreational Boats in King Co., 2005

Type of Boat	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Jet Ski	688	9	0	1	225	4,002
Outboard gasoline	3,763	44	2	4	1,555	25,326
Inboard gasoline	5,347	258	2	6	283	35,579
Diesel	29	185	5	20	7	14,593
Total gasoline	9,797	311	4	11	2,063	64,907
Total (all boats)	9,826	496	9	31	2,070	79,500

Table 2-53: Tons of Pollutants Emitted by Recreational Boats in Kitsap Co., 2005

Type of Boat	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Jet Ski	163	2	0	0	53	950
Outboard gasoline	812	10	0	1	336	5,466
Inboard gasoline	1,198	58	0	1	63	7,973
Diesel	7	42	1	5	2	3,296
Total gasoline	2,174	69	1	2	452	14,389
Total (all boats)	2,181	111	2	7	454	17,685

Table 2-54: Tons of Pollutants Emitted by Recreational Boats in Pierce Co., 2005

Type of Boat	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Jet Ski	381	5	0	0	125	2,219
Outboard gasoline	1,859	22	1	2	768	12,511
Inboard gasoline	2,183	105	1	2	115	14,524
Diesel	9	55	1	6	2	4,353
Total gasoline	4,423	132	2	5	1,008	29,254
Total (all boats)	4,432	187	3	11	1,010	31,607

[67] U.S. Dept. of Transportation, *2005 Highway Statistics*, Table MF-24: Private and Commercial Non-Highway Use of Gasoline – 2005; www.fhwa.dot.gov/policy/ohim/hs05/htm/mf24.htm, accessed July 27, 2007.

Table 2-55: Tons of Pollutants Emitted by Recreational Boats in Snohomish Co., 2005

Type of Boat	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Jet Ski	362	5	0	0	119	2,109
Outboard gasoline	1,770	21	1	2	732	11,914
Inboard gasoline	2,149	104	1	2	114	14,300
Diesel	6	41	1	4	2	3,205
Total gasoline	4,282	129	2	5	964	28,323
Total (all boats)	4,288	170	3	9	966	31,528

Table 2-56: Tons of Pollutants Emitted by Recreational Boats in 4-County Region, 2005

Type of Boat	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Jet Ski	1,595	20	1	2	522	9,280
Outboard gasoline	8,204	96	3	9	3,391	55,217
Inboard gasoline	10,876	524	4	12	575	72,376
Diesel	51	322	8	36	12	25,446
Total gasoline	20,676	641	8	22	4,488	136,873
Total (all boats)	20,727	963	16	58	4,500	162,319

3 Point Sources

Point sources are stationary sources that report emissions and process quantities to the Puget Sound Clean Air Agency (Agency) and the Washington State Department of Ecology (Ecology). The point sources are assigned to specific Agency permit engineers who check the activity levels, emission factors, and criteria pollutant emissions reported by the sources for reasonableness.

3.1 Ecology Jurisdiction Sources

Pulp mills and aluminum smelters report their emissions directly to Ecology. Table 3-1 shows the fuel consumption and Table 3-2 presents emissions from two pulp mills as reported to Ecology.[68] Simpson-Tacoma is in Tacoma (Pierce County) and Kimberly-Clark is in Everett (Snohomish County).

Table 3-1: Fuel Consumption by Ecology Sources

Facility	Distillate Oil (1,000 gallons)	Natural Gas (million cubic feet)	Wood (tons)
Simpson-Tacoma	9,186	129	145,436
Kimberly Clark	15	180	573,813

Table 3-2: Tons of Criteria Pollutant Emitted by Ecology Sources, 2005

Facility	CO	NOx	$PM_{2.5}$	SOx	VOC
Simpson-Tacoma	1,402	610	93	378	35
Kimberly-Clark	893	767	36	360	283
Total	2,295	1,377	129	738	318

Point sources do not report greenhouse gases (GHG). GHG are estimated in Section 3.2, along with Agency point sources.

3.2 Agency Jurisdiction Sources

3.2.1 Category Description

The Agency's Regulation I, Sections 5.05(b) and 7.09(a) require sources that emit at or above the following thresholds to report their emissions to the Agency:

- Any single toxic air contaminant (TAC) emissions............................ 2 tons/year
- Facility-combined total of all TAC emissions.................................... 6 tons/year
- Emissions of any criteria air pollutant or criteria pollutant precursor (CO, NOx, SOx, VOC, PM_{10}, and $PM_{2.5}$)......................... 25 tons/year

These thresholds screen out smaller sources; only very large sources report their emissions and activity levels to the Agency. Section 4 of this report covers emissions from small sources. This report does not include toxic air pollutants.

3.2.2 Methodology

Reported emissions and activity levels were extracted from the Agency's compliance database, by reporting facility and then summarized by county.

[68] Washington Department of Ecology, Sally Otterson, sott461@ecy.wa.gov.

3.2.3 Key Assumptions

Point sources accurately report their emissions. This inventory report assumes the reporting sources accurately reported their fuel consumption, other activity levels, and emissions resulting from the activity. The Agency assigns a permit engineer to each point source. The engineer reviews the reported activity levels and emissions before entering them into the Agency compliance database.

Carbon dioxide emissions from biomass burned in boilers do not contribute to GHG. The Intergovernmental Panel on Climate Change (IPCC) guidelines recommend that greenhouse gas inventories exclude carbon dioxide emissions from combustion of charcoal, wood, and other biomass-based fuels such as ethanol derived from crop. This is based on a rationale that, over time, a new biomass will grow back and absorb an equivalent amount of carbon dioxide from the atmosphere.[69] Therefore, the emissions from wood and other biomass burning presented in this report include the CO_2 equivalent of CH_4 and N_2O only. Two point sources burn wood in their boilers: Simpson-Tacoma (145,000 tons) and Kimberly-Clark of Everett (574,000 tons).

The Agency is exploring whether or not to include carbon dioxide emissions from biomass burning in its inventories. For the 2005 emission inventory, the Agency assumed that carbon dioxide emissions from wood burning in facilities, homes, and outdoor vegetative matter that grows back do not contribute to GHG because the biomass will grow back and absorb an equivalent amount of carbon dioxide from the atmosphere.

3.24 Emissions Reported by Point Sources

Table 3-3 presents emissions as reported by sources to the Agency.

Table 3-3: Tons of Criteria Pollutants Emitted by Agency Sources, 2005

Inventory Area	CO	NOx	$PM_{2.5}$	SOx	VOC
King	3,072	5,551	239	700	2,017
Kitsap	42	91	85		152
Pierce	291	466	88	60	636
Snohomish	44	109		70	1,080
Region	3,450	6,217	411	831	3,885

The Agency does not require sources to report greenhouse gases (GHG). Sources that report emissions must report their fuel consumption. Table 3-4 presents fuel consumption reported by Agency and Ecology sources.

Table 3-4: Fuel Burned by Sources Reporting Emissions to the Agency and Ecology

County	Natural Gas (million cf)	Distillate Oil (1,000 gals)	Residual Oil (1,000 gallons)	Propane (1,000 gallons)	Coal (tons)	Wood (tons)
King	5,970	118	153		145,538	
Kitsap	970	144				
Pierce	6,193	10,473	56	10	25,397	145,436
Snohomish	1,210	28	1,526			573,813

[69]Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004, page 3-63, Section 3.12 Wood Biomass and Ethanol Consumption (IPCC Source Category 1A).

3.2.5 Emission Factors for GHG

Table 3-5 presents GHG factors for fuel burned by point sources.

Table 3-5: GHG Emission Factors for Fuel Burned

Type of Fuel	Units	CO_2	CH_4	N_2O	Ref: AP-42[70]
Natural Gas	mcf	120,000	2.3	2.2	Table 1.4-2
Distillate Oil	1,000 gallons	22,300	0.052	0.11	Section 1.3
Residual Oil	1,000 gallons	25,000	1.0	0.11	Section 1.3
Propane	1,000 gallons	12,500	0.2	0.9	Table 1.5-1
Coal	tons	4,810	0.04	0.03	Section 1.1
Wood	tons	not applicable	0.23	0.14	Table 1.6-3

3.2.6 GHG Estimating Equation and Summary of Emissions

Applying the emission factor to the fuel burned gives GHG emissions in CO_2 equivalent.

$$\text{Tons of } CO_2 \text{ eqv} = \text{tons of } CO_2 + (21 \times \text{tons of } CH_4) + (310 \times \text{tons of } N_2O)$$

Table 3-6 presents GHG emissions from fuel combustion at sources that report activities to the Agency and Ecology. The emissions presented in Table 3-6 do not include carbon dioxide emitted from industrial processes such as cement manufacturing, steel manufacturing, lime production, and other non-combustion industrial processes.

Table 3-6: 2005 GHG Emissions from Sources Reporting to the Agency and Ecology (tons of CO_2 eqv)

County	Natural Gas	Distillate Oil	Residual Oil	Propane	Coal	Wood	Total
King	360,380	1,318	1,917	0	350,757	0	714,371
Kitsap	58,554	1,608	0	0	0	0	60,162
Pierce	373,841	116,963	702	66	61,209	3,397	556,173
Snohomish	73,042	314	19,117	0	0	13,403	105,876
Region total	625, 060	120,203	21,736	66	411,966	16,800	1,436,582

3.2.7 Emissions from Electric Power Generation from Fossil Fuels

Activity levels and emissions from electric power production activities of point sources are discussed in Section 9 of this report. The emissions from electricity production activities are estimated separately and presented in Table 9-4, (repeated here as Table 3-7).

Table 3-7: Tons of Emissions from Electric Power Production Activity of Agency and Ecology Sources, 2005

County	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
King Co.	120	440	7	21	9	206,364
Pierce Co.	439	266	20	77	12	292,878
Snohomish Co.	244	603	11	324	4	24,437
Total	803	1,309	38	422	25	523,679

[70] AP-42: http://www.epa.gov/ttn/chief/ap42/ch01.

3.2.8 Emissions from all Point Sources (excluding power generation activity)

The electricity production emissions presented in Table 3-7 are included in Table 3-2 (criteria pollutants from Ecology sources), Table 3-3 (criteria pollutants from Agency sources), and Table 3-6 (GHG emissions from Agency and Ecology sources). Table 3-8 presents a summary of emissions from all point sources reporting emissions to the Agency and Ecology, excluding activities relating to electric power generation.

Table 3-8: Tons of Emissions from Sources Reporting to the Agency and Ecology (excluding electric power generation)

County or Area	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
King Co.	2,952	5,111	232	679	2,008	514,313
Kitsap Co.	42	91	85		152	60,162
Pierce Co.	1,254	810	161	361	659	304,138
Snohomish Co.	693	113	19	106	1,359	81,424
Total	4,941	6,125	497	1,146	4,178	960,037

4 Stationary Area Combustion Sources

An area source is a source of emissions that does not report emissions and activities to the Agency. These are smaller than the point sources presented in the previous section. A stationary area combustion source individually contributes a small quantity of emissions when it burns fuel. However, as a group, they contribute more to our airshed than the larger point sources. Examples include emissions from residential heating, and fuel burned by stationary equipment in facilities that do not report emissions to the Agency.

4.1 Combustion of Petroleum-Based Fuels

4.1.1 Category Description

This category covers emissions from petroleum-based fuels burned by households and facilities that do not report emissions and process quantities to the Agency. Households burn petroleum-based fuels for space heating, water heating, and cooking. These fuels include natural gas, propane, and distillate fuel oil. American community survey data from the U.S. Census Bureau indicate that households in the four-county jurisdiction of the Agency do not burn coal. Small industrial and commercial establishments burn petroleum-based fuels for space heating and other operations. Agency inspections also show that area sources in the Agency's jurisdiction do not burn coal and residual oil. Shown below are the source classification codes (SCC) for fuels burned by area sources in the Agency's jurisdiction.

Type of Fuel	Industrial SCC	Commercial SCC	Residential SCC
Distillate oil	21 02 004 000	21 03 004 000	21 04 004 000
Natural gas	21 02 006 000	21 03 006 000	21 04 006 000
Propane (LPG)	21 02 007 000	21 03 007 000	21 04 007 000

Propane is the common name for Liquefied Petroleum Gas (LPG).

4.1.2 Key Assumptions

Calculations in this category assume energy use is directly proportional to applicable surrogates. A surrogate, as used here, means an easily available quantity that can be used to estimate the value of another quantity that is not available or more difficult to obtain directly. The 2005 fuel consumption for area sources is estimated with surrogates. The quantity of distillate oil and propane burned was estimated with surrogates because consumption data is available at the state level but not available at the county level. Puget Sound Energy (PSE) and Cascade Natural Gas Company (CNGC) provided natural gas consumption data for the counties. Key assumptions are listed below.

Residential fuel consumption is directly proportional to households using the fuel. Emission Inventory Improvement Project guidelines recommend households as the surrogate to apportion state level residential fuel consumption to county level. The Agency therefore used households using the fuel as surrogates to apportion Washington State residential consumption to the counties.

Commercial and industrial fuel consumption is directly proportional to employment. Emission Inventory Improvement Project guidelines recommend employment as the surrogate to apportion state level commercial and industrial fuel consumption to county level. Industrial establishments are those facilities with a 2-digit North American Industrial Classification System (NAICS) level of 31, 32, or 33. Commercial establishments are facilities with a NAICS level greater than 33.

Household, commercial, and industrial area sources do not burn coal and residual oil. The 2000 U.S. Census results indicate that households do not burn coal or residual oil. Residual oil requires pre-heating before feeding to boilers for combustion. This makes it unsuitable for small boilers. Also, Agency inspectors anecdotally confirm that they do not encounter area sources that burn coal and residual oil.

Cascade Natural Gas Company (CNGC) and Puget Sound Energy (PSE) are the sole distributors of natural gas in the Puget Sound area. CNGC and PSE are the only utility companies that supply natural gas in the Agency's jurisdiction. CNGC is the sole supplier of natural gas in Kitsap County and northern Snohomish County; PSE is the sole supplier in King, Pierce, and southern Snohomish counties.

4.1.3 Fuel Consumption Estimating Equations

The Agency used the following equations to estimate activity levels for area source consumption of natural gas, propane, and distillate oil.

Residential Natural Gas: The quantity of natural gas consumed = the quantity of natural gas distributed by PSE and CNGC to households.

Residential Distillate Oil: $A = (B \div C) \times D$

where

- A = thousand gallons of distillate oil consumed by households in the county
- B = number of households using distillate oil in the county
- C = number of households using distillate oil in Washington State
- D = thousand gallons of fuel consumed by households in Washington State

Residential LPG: $A = (B \div C) \times D$

where

- A = thousand gallons of LPG consumed by households in the county
- B = number of households using LPG in the county
- C = number of households using LPG in Washington State
- D = thousand gallons of LPG consumed by households in Washington State

Commercial Area Natural Gas: $A = (B - C)$

where

- A = million cubic feet (mcf) of natural gas consumed by commercial area sources in the county
- B = mcf of natural gas distributed by natural gas companies to commercial sources in the county
- C = mcf of natural gas consumed by commercial point sources in the county as obtained from the Agency's compliance database

Commercial Area Distillate Oil: $A = [(B \div C) \times D] - E$

where

- A = thousand gallons of distillate oil consumed by commercial area sources in the county
- B = number of commercial employees in the county
- C = number of commercial employees in Washington State
- D = thousand gallons of distillate oil consumed by commercial sources in Washington State
- E = thousand gallons of distillate oil consumed by commercial point sources in the county as obtained from the Agency's compliance database

Commercial LPG: A = [(B ÷ C) × D] - E

where

A = thousand gallons of LPG consumed by commercial area sources in the county
B = number of commercial employees in the county
C = number of commercial employees in Washington State
D = thousand gallons of LPG consumed by commercial sources in Washington State
E = thousand gallons of LPG consumed by commercial point sources in the county as obtained from the Agency's compliance database

Industrial Area Natural Gas: A = (B - C)

where

A = mcf of natural gas consumed by industrial area sources in the county
B = mcf of natural gas distributed by natural gas companies to industrial sources in the county
C = mcf of natural gas consumed by industrial point sources in the county as obtained from the Agency's compliance database

Industrial Area Distillate Oil: A = [(B ÷ C) × D] - E

where

A = thousand gallons of distillate oil consumed by industrial area sources in the county
B = number of industrial employees in the county
C = number of industrial employees in Washington State
D = thousand gallons of distillate oil consumed by industrial sources in Washington State
E = thousand gallons of distillate oil consumed by industrial point sources in the county as obtained from the Agency's compliance database

Industrial LPG: A = [(B ÷ C) × D] - E

where

A = thousand gallons of LPG consumed by industrial area sources in the county
B = number of industrial employees in the county
C = number of industrial employees in Washington State
D = thousand gallons of LPG consumed by industrial sources in Washington State
E = thousand gallons of LPG consumed by industrial point sources in the county as obtained from the Agency's compliance database

4.1.4 Surrogates Used to Estimate Fuel Consumption

PSE and CNGC provided the natural gas consumption data presented in Table 4-1.

Table 4-1: Natural Gas Supplied by Natural Gas Companies, 2005 (million cubic feet)[71]

County	Residential	Commercial	Industrial
King	28,527	18,582	10,171
Kitsap	1,691	725	1,683
Pierce	9,079	5,862	4,939
Snohomish	7,780	3,807	3,813

Table 4-2 presents the number of households using distillate oil and LPG. The Agency used these surrogates to apportion Washington State residential fuel consumption to the county level.

[71] E-mail from Julie Waltari, Puget Sound Energy, Bellevue, WA, June 30, 2006. E-mail from L. Wilkins, Distribution Manager, and Beverly Baker Brooks, Director, Business Applications, Cascade Natural Gas Company, Seattle, WA, June 30, 2006.

Table 4-2: Households Using Fuel, 2005[72]

Area	Distillate Oil	LPG
King Co.	58,453	9,817
Kitsap Co.	8,141	4,520
Pierce Co.	11,069	5,571
Snohomish Co.	5,940	7.807
Washington State	126,740	69,591

Table 4-3 presents the number of employees in the commercial and industrial sectors. The Agency used employment as a surrogate to apportion Washington State commercial and industrial fuel consumption to the county level.

Table 4-3: Commercial and Industrial Employment,[73] **2005**

Area	Commercial (NAICS >33)	Industrial (NAICS 31, 32, 33)
King Co.	841,585	97,525
Kitsap Co.	49,682	1,972
Pierce Co.	181,981	20,300
Snohomish Co.	147,258	40,927
Washington State	1,873,071	256,563

4.1.5 Total Fuel Consumption Tables

Table 4-4 presents total residential fuel consumption. The natural gas companies provided the natural gas consumption. The Agency estimated the residential distillate oil and LPG consumption with the number of households as described in the above equations.

Table 4-4: Total Residential Fuel Consumption, 2005

County	Natural Gas (mcf)	Distillate Oil (1,000 gallons)	LPG (1,000 gallons)
King	28,527	27,564	10,475
Kitsap	1,691	3,839	4,823
Pierce	9,079	5,220	5,944
Snohomish	7,780	2,815	8,330

Table 4-5 presents total commercial fuel consumption. The natural gas companies provided the natural gas consumption. The Agency estimated the commercial distillate oil and LPG consumption with the number of employees in the commercial sector.

Table 4-5: Total Commercial Fuel Consumption, 2005

Area	Natural Gas (mcf)	Distillate Oil (1,000 gallons)	LPG (1,000 gallons)
King Co.	18,582	14,644	5,888
Kitsap Co.	725	864	348
Pierce Co.	5,862	3,167	1,273
Snohomish Co.	3,807	2,562	1,030
Washington State	48,458	32,592	13,104

[72] U.S. Census Bureau, *Profile of Selected Housing Characteristics: 2000*, Table DP-4. Available at: http://censtats.census.gov/data/wa/05053033.pdf. This web address gives access to King County data; replace 033 with 35 for Kitsap County data, 53 for Pierce County data, and 61 for Snohomish County data.

[73] U.S. Census Bureau, *County Business Patterns, WA, 2005, CBP/04-49*; *Manufacturing Employment: NAICS 31-33; Commercial Employment: NAICS >33,* http://censtats.census.gov/cgi-bin/cbpnaic/cbpsect.pl, July 26, 2007.

Table 4-6 presents total industrial fuel consumption. The natural gas companies provided the natural gas consumption. The Agency estimated the industrial distillate oil and LPG consumption with the number of employees in the industrial sector.

Table 4-6: Total Industrial Fuel Consumption, 2005

Area	Natural Gas (mcf)	Distillate Oil (1,000 gallons)	LPG (1,000 gallons)
King Co.	10,171	39,306	9,084
Kitsap Co.	1,683	795	184
Pierce Co.	4,939	8,182	1,891
Snohomish Co.	3,813	16,495	3,812
Washington State	68,000	103,404	23,898

To obtain stationary commercial area source combustion of fuel, the fuel burned by commercial sources that reported their fuel burning activity to the Agency is subtracted from the total commercial consumption. Table 4-7 shows commercial point source consumption as reported to the Agency.

Table 4-7: Commercial Point Source Fuel Consumption,[74] 2005

County	Natural Gas (mcf)	Distillate Oil (1,000 gallons)	LPG (1,000 gallons)
King	1,410	----	----
Kitsap	970	144	----
Pierce	1,312	1,252	10
Snohomish	---	----	----

To obtain stationary industrial area source combustion of fuel, the fuel burned by industrial sources that reported their fuel burning activity to the Agency is subtracted from the total industrial consumption. Table 4-8 shows industrial point source consumption as reported to the Agency.

Table 4-8: Industrial Point Source Fuel Consumption, 2005

County	Natural Gas (mcf)	Distillate Oil (1,000 gallons)	LPG (1,000 gallons)
King	4,560	118	----
Kitsap	----	----	----
Pierce	893	9,221	----
Snohomish	1,210	28	----

4.1.6 Adjustments for Kitsap County Commercial Natural Gas and Pierce County Industrial Distillate Oil

A generic equation used to estimate stationary area source fuel consumption is:

stationary area fuel use = (total fuel use) – (point source fuel use)

Unfortunately, in some instances, the equation produces confounding results. For example, CNGC provided data that commercial sources in Kitsap County burned 725 mcf of natural gas. However, the Agency database shows the U.S. Navy in Kitsap County burned 970 mcf. The Navy could be obtaining natural gas from elsewhere or Cascade did not include the Navy's consumption in the general commercial sources consumption. Similarly, according to Agency data, utilities in Pierce County burned 9,221 gallons of oil, but the county consumption as apportioned with industrial employment as a surrogate gives Pierce County's total fuel oil

[74]Commercial and industrial point source fuel consumption extracted from Agency compliance data with Microsoft Access. Accessed August 16, 2006.

consumption as 8,182 gallons. In such cases, the employment surrogate used does not accurately estimate the total fuel consumption in the county.

For Kitsap County commercial natural gas, subtracting the 970 mcf of natural gas burned by the Navy from the 725 mcf that CNGC said they supplied to commercial sources, produces negative area source natural gas consumption. Similarly, for Pierce County industrial distillate oil, subtracting the 9,221 gallons burned by utilities (as reported to the Agency) from the total county 8,812 gallon consumption estimated with the employment surrogate, results in negative industrial area oil consumption.

The Agency assumed Kitsap County commercial area source consumption of natural gas to be equal to the total reported by CNGC. This means CNGC supplied the 725 mcf to small commercial sources in addition to the 970 mcf it supplied to the Navy. The Navy consumption is accounted for in the point source section. In addition, the Agency assumed Pierce County industrial area source consumption of fuel oil to be equal to the total consumption estimated with the industrial employment surrogate. The 9 million gallons of distillate oil burned by the point sources is inventoried in the point source section. Point source emissions described in Section 3 cover the Navy's natural gas consumption and Pierce County's utilities distillate oil consumption.

4.1.7 Area Source Fuel Consumption

Table 4-9 presents residential consumption of natural gas, distillate oil, and LPG.

Table 4-9: Residential Fuel Consumption, 2005

County	Natural Gas (mcf)	Distillate Oil (1,000 gallons)	LPG (1,000 gallons)
King	28,527	27,564	10,475
Kitsap	1,691	3,839	4,823
Pierce	9,079	5,220	5,944
Snohomish	7,780	2,815	8,330

Table 4-10 presents commercial area consumption of natural gas, distillate oil, and LPG.

Table 4-10: Commercial Area Fuel Consumption, 2005

County	Natural Gas (mcf)	Distillate Oil (1,000 gallons)	LPG (1,000 gallons)
King	17,172	14,644	5,888
Kitsap	725	720	348
Pierce	4,550	1,914	1,263
Snohomish	3,807	2,562	1,030

Table 4-11 presents industrial area consumption of natural gas, distillate oil, and LPG.

Table 4-11: Industrial Area Fuel Consumption, 2005

County	Natural Gas (mcf)	Distillate Oil (1,000 gallons)	LPG (1,000 gallons)
King	5,611	39,188	9,084
Kitsap	1,683	795	184
Pierce	4,045	8,182	1,891
Snohomish	2,603	16,467	3,812

4.1.8 Emission Factors for Fossil Fuel Combustion[75]

Table 4-12 presents emissions factors for residential combustion of natural gas, LPG, and distillate oil.

Table 4-12: Emission Factors for Residential Combustion of Fossil Fuels

Pollutant	Natural Gas lbs/mcf	LPG lbs/1,000 gallons	Distillate Oil lbs/1,000 gallons
CO	40	1.9	5
NOx	94	14	18
$PM_{2.5}$	7.6	0.4	0.4
SOx	0.6	0.0	7.2
VOC	5.5	0.3	0.713
CO_2	120,000	12,500	22,300
N_2O	2.2	0.9	0.05
CH_4	2.3	0.2	1.78
CO_2 eqv	120,730	12,783	22,353

Table 4-13 presents emissions factors for combustion of natural gas, LPG, and distillate oil in commercial area source boilers.

Table 4-13: Emission Factors for Commercial Combustion of Fossil Fuels

Pollutant	Natural Gas lbs/mcf	LPG lbs/1,000 gallons	Distillate Oil lbs/1,000 gallons
CO	84	1.9	5
NOx	100	14	18
$PM_{2.5}$	7.6	0.4	2
SOx	0.6	0.0	7.2
VOC	5.5	0.3	0.34
CO_2	120,000	12,500	22,300
N_2O	2.2	0.9	0.11
CH_4	2.3	0.2	0.216
CO_2 eqv	120,730	12,783	22,339

Table 4-14 presents emissions factors for combustion of natural gas, LPG, and distillate oil in industrial area source boilers.

[75] U.S. EPA, *AP-42 Compilation of Air Pollutant Emission Factors*. Chapter 1, Section 1.3 (Fuel Oil), Tables 1.3-1, 1.3-2, 1.3-3, 1,3-8, 1,3-12; Section 1.4 (Natural Gas), Tables 1.4-1, 1.4-2; and Section 1.5 (LPG), Table 1.3-1. Available at: http://www.epa.gov/ttn/chief/ap42/ ch01/index.html; accessed October 23, 2006.

Table 4-14: Emission Factors for Industrial Combustion of Fossil Fuels

Pollution	Natural Gas lbs/mcf	LPG lbs/1,000 gallons	Distillate Oil lbs/1,000 gallons
CO	84	3.2	5
NOx	140	19	24
$PM_{2.5}$	7.6	0.6	2
SOx	0.6	0.0	7.2
VOC	5.5	0.3	0.2
CO_2	120,000	12,500	22,300
N_2O	2.2	0.9	0.11
CH_4	2.3	0.2	0.0.052
CO_2 eqv	120,730	12,783	22,335

Notes:

Sulfur content in LPG is 10 ppmw[76] of sulfur, or 0.001% Sulfur. AP-42 gives the SO_2 emission factor as 0.1(%S), or 0.0001 lbs of SOx per 1,000 gallons of LPG.

#2 distillate oil distributed in the Puget Sound area contains 500 ppmw (0.05%).[77] AP-42 gives the emission factor as 144(% S). This gives 7.2 lbs of SOx per 1,000 gallons.

CO_2 eqv = [tons CO_2 + (21 × tons CH_4) + (310 × tons N_2O)].

4.1.9 Summary of Emissions

A generic emission estimating equation is: A = B × C

where

A = lbs of pollutant emitted
B = quantity of fuel burned
C = lbs of pollutant emitted per unit quantity of fuel burned

Table 4-15 shows the emissions from residential burning of petroleum-derived fuel in the Agency's jurisdiction.

Table 4-15: Tons of Pollutants Emitted by Residential Sources in 4-County Region

Type of Fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	942	2,213	179	14	129	2,841,797
Distillate oil	99	355	8	142	14	440,780
LPG (propane)	28	207	6	0	4	189,018

Table 4-16 presents the emissions from commercial area sources burning petroleum-derived fuel in the Agency's jurisdiction.

Table 4-16: Tons of Pollutants Emitted by Commercial Area Sources in 4-County Region

Type of Fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	1,103	1,313	100	8	72	1,584,865
Distillate oil	50	179	20	71	3	221,608
LPG (propane)	8	60	2	0	1	54,510

[76]Propane Education & Research Council press release, November 8, 2002; available at http://www.propanecouncil.org/newsroom/press_releaseDetail.cfv?id=176.

[77]Ballard Oil: (206) 783-0241; Genesee Fuel: (206) 722-1545; Glendale Oil: (206) 243-7700 (Jerry Hoefer).

Table 4-17 presents the emissions from industrial area sources burning petroleum-derived fuel in the Agency's jurisdiction.

Table 4-17: Tons of Pollutants Emitted by Industrial Area Sources in 4-County Region

Type of Fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	586	976	53	4	38	841,674
Distillate oil	162	776	65	233	6	721,778
LPG (propane)	24	142	4	0	2	95,688

Table 4-18 presents the summary of emissions from all area sources burning petroleum-derived fuel in the Agency's jurisdiction.

Table 4-18: Tons of Pollutants Emitted by All Area Sources in 4-County Region

Type of Fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	2,630	4,501	332	26	240	5,268,336
Distillate oil	310	1,309	92	446	24	1,384,166
LPG (propane)	60	409	12	0	8	339,216

Appendices A27 through A42 show county-level emissions.

4.2 Indoor Wood Burning

4.2.1 Category Description

This category covers emissions from cord wood, firelogs, and wood pellets burned in household wood-burning appliances. Indoor wood-burning appliances include wood fireplaces, inserts, woodstoves, and pellet stoves. Wood pellets are made from ground wood chips and saw dust, a common waste material in the wood products industry. Fireplaces, inserts, and woodstoves mostly burn cord wood but can also burn manufactured logs, such as Duraflame. Firelogs are made from compacted recycled biomass products such as saw dust, nutshells, and recycled cardboard glued together with wax. The wax may be petroleum-based but to reduce organic emissions, some manufacturers, such as Duraflame[78] use non-petroleum wax. Duraflame, Inc. claims the logs have a heating value of 14,167 Btu per pound.

Households burn wood indoors usually for one of two reasons: (1) ambiance or (2) home heating. Because fireplaces do not heat homes effectively, the Agency assumed that people burn in fireplaces primarily for ambiance, while they burn in woodstoves primarily for heat. Shown below are the source classification codes (SCC) for residential wood-burning appliances.

SCC	Description
21 04 008 001	Wood fireplace
21 04 008 002	Uncertified fireplace insert
21 04 008 003	Certified non-catalytic fireplace insert
21 04 008 004	Certified catalytic fireplace insert
21 04 008 010	Uncertified woodstove
21 04 008 030	Catalytic woodstove
21 04 008 050	Certified non-catalytic woodstove
21 04 008 053	Pellet-fired stove
21 04 009 000	Firelog (fireplaces, fireplace inserts, woodstoves)

[78] www.duraflame.com.

EPA certifies woodstoves and fireplace inserts for compliance with national emission standards. Washington standards are stricter than the national standards. Many wood-burning appliances still in use predate these standards. The Agency has partnered with Northwest Hearth, Patio, and Barbeque Association (NWHPBA) and other interest groups to determine the population and types of wood-burning appliances and wood-burning characteristics in the Puget Sound area. Table 4-19 presents current national and Washington State particulate emission standards.[79]

Table 4-19: Particulate Matter Emission Standards for Wood Stoves (grams per hour)

Type of Stove	National (EPA) Standards (effective July 1, 1990)	Washington State Standards (effective January 1, 1995)
Non-catalytic	7.5	4.5
Catalytic	4.1	2.5

A fireplace is a recess, usually with a mantelpiece above it, with or without hinged or folding glass doors, built into a wall of a room as a place to light an open fire to heat the room. A woodstove is a free-standing appliance that burns wood or wood-derived fuel to heat a room. Inserts are essentially woodstoves that fit into fireplace cavities. Pellet-fired stoves are woodstoves or fireplace inserts designed to burn wood pellets.

Uncertified woodstoves were manufactured before 1988.[80] Stoves manufactured later were certified by EPA based upon a particulate emission test. Some of the certified stoves have catalysts. Catalysts reduce the emission rate of organic compounds and particulate matter if owners maintain the catalysts as recommended by the manufacturer. Over time, without proper maintenance, there is very little difference between catalytic and non-catalytic woodstoves.

4.2.2 Key Assumptions

The calculations for the tables in this section make the following assumptions about how much wood is burned per hour in each appliance as well as the length of each session. Five members of the Air Resources Department of the Puget Sound Clean Air Agency developed the assumptions used to estimate the quantity of wood burned in indoor-burning appliances in the Agency area,[81] based on a review of available information.

Results of the Pacific Rim Research (PRR) survey are representative of wood-burning behavior in the Agency 4-county area. The Agency contracted with PRR to perform a behavioral survey. The survey covered 300 households in each of the 4 counties and the Agency assumed the results of the survey are representative of the Puget Sound area.

Households use their fireplaces mostly for ambiance and burn for 4 hours. The Agency assumed households use fireplaces for ambiance. Duraflame, Inc. and other firelog manufacturers, sell firelogs that burn for 4 hours. Therefore, the Agency assumed that households burning for ambiance use their fireplaces for 4 hours per session.

Households using stoves and fireplace inserts burn for approximately 8 hours. For homes using stoves and fireplace inserts, the Agency assumed most of these households burn to heat their homes when they return home from work until they go to sleep. Thus stoves and inserts

[79]Washington State: WAC 173-433-100, Sections 3(a) and 3(b): Solid Fuel Burning Devices. EPA: http://www.epa.gov/compliance/resource/publications/monitoring/caa/woodstoves/certifiedwood.pdf.

[80]AP-42, Table 1.10-1: pre-Phase I residential wood-burning devices are those not certified to 1988 EPA emission standards; Phase I residential wood-burning devices are certified to 1988 EPA emission standards; Phase II residential wood-burning devices are certified to 1990 EPA emission standards shown in Table 4-36 of this report.

[81]The five members who contributed to the development of the assumptions are: Dave Kircher, John Anderson, Kwame Agyei , Naydene Maykut (now retired), and Amy Fowler.

burn for approximately 8 hours. The Agency has recently completed a survey to improve these assumptions and will incorporate the results into future emission inventory updates.

The Agency collects particulate matter concentration data with nephelometers and other instruments located in neighborhoods known to have high particulate matter concentrations. A nephelometer is an instrument that measures a surrogate (light scattering) for the concentration of particulate matter in the ambient air. This measurement correlates well with filter-based measurements that determine particulate mass in ambient air. The nephelometer data shows that on winter nights, particulate concentrations generally rise from 4:00 p.m. to midnight; after which the concentrations drop sharply. Appendix C shows how particulate concentrations vary with hour of day over a typical week in late December. Concentration levels start rising from 4:00 p.m. and start dropping after midnight. These data support the Agency's assumption that most burning in stoves and inserts is concentrated during the evening hours, although some households burn for longer durations and/or outside of evening hours.

Households that burn 6-lb firelogs burn one at a time and they last for 4 hours. Manufacturers claim firelogs last 4 hours and weigh 6 lbs. Because manufacturers advise burning one log at a time, the Agency assumed households burn firelogs one at a time (or 1.5 lbs of firelogs per hour). Thus, in an 8-hour session, a household will burn two 6-lb logs (1.5 per hour × 8 hours = 12 lbs of firelogs).

Pellet stove households burn for 8 hours at 2 lbs of wood pellets/hour. Ms Deborah Hanning (NWHPBA) and Dr. James Houck (Omni Environmental Services)[82] give the burn rate of pellet stoves as between 1.0 lbs/hour and 6 lbs/hour depending on the heating ranges (that is, how hot it burns), with the average rate for a normal home being about 2.5 lbs/hour. HS Tarm,[83] a manufacturer of wood-burning equipment, estimates that a 40-lb pellet bag lasts about 24 hours. This is about 1.7 lbs of pellets per hour. The HS Tarm website also gives the heating value of wood pellets as approximately 8,200 Btu/lb. The actual value depends on the type of wood used to make the pellets and the moisture content. Based on the Omni-estimated 2.5 lbs/hour rate and the HS Tarm-published 1.7 lbs/hour rate, the Agency assumed an average wood pellet home will burn 2 lbs of pellets/hour; and therefore in an 8-hour session will burn 16 lbs of pellets (2 lbs/hour × 8 hours = 16 lbs of pellets).

The Agency has partnered with NWHPBA to conduct a study of wood-burning characteristics to determine wood-burning rates and duration of burn sessions in the Puget Sound area. Households with pellet stoves probably use their devices longer than homes with woodstoves and inserts. Households with pellet stoves use their pellet stoves like furnaces and can leave them burning for long hours unattended. However for lack of data, the Agency assumed pellet stove households also burn for 8 hours a burn session, the same duration assumed for woodstoves and fireplace inserts.

Stoves and inserts burn cord wood at 5 lbs/hour, fireplaces burn cord wood at 6 lbs/hour. Based on the efficiency of the heat-burning devices, heat content of cord wood, heat content of manufactured wood, and the burn rates of manufactured wood, the Agency estimated that inserts and stoves burn cord wood at 5 lbs/hour and assumed fireplaces burn at 6 lbs/hour.

Table 4-20 presents the heat content of wood and the wood consumption rate. Table 4-21 presents the combustion efficiency and heat transfer efficiency of stoves and fireplaces. The Agency used the data presented in these tables to estimate the burn rate of cord wood.

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[82] Deborah Hanning, NWHPBA, fireplacegirl32@aol.com, e-mail August 8, 2007; and Dr. James Houck, Omni Environmental Services, houck@omni-test.com, e-mail August 20, 2007.

[83] HS Tarm USA Inc., www.woodboilers.com, e-mail: info@woodboilers.com, (800) 782-9927.

Table 4-20: Heat Content and Burn Rates of Wood Burned in Appliances[84]

Type of Wood	Btu/lb	lbs burned/hour
Firelog	14,167	1.5
Pellet	8,200	1.7
Cord wood	5,200	see below

Table 4-21: Combustion Efficiencies & Cord Wood Burn Rates for Stoves & Fireplaces[85]

Type of Device	Combustion Efficiency (%)	Heat Transfer Efficiency (%)
Uncertified stove	82%	69%
Certified stove	94%	63%
Fireplace	84%	<10%

The Agency estimated the burn rates for uncertified stoves using: $A = [(B \div C) \times D] \div E$

where
- A = pounds of cord wood burned per hour in an uncertified stove
- B = net heat content (Btu/hr) for a typical firelog (14,167 Btu/hr)
- C = net heat content of cord wood (5,200 Btu/hr)
- D = pounds of firelog burned per hour (1.5 lbs/hr)
- E = combustion efficiency of a typical uncertified stove (0.82)

The burn rate for uncertified stoves thus comes to about 5 lbs/hour. The Agency assumed the same 5 lbs/hour rate for other stoves and inserts. Fireplaces have poorer heat transfer efficiency than stoves; therefore the Agency assumed 6 lbs of cord wood/hour for fireplaces.

4.2.3 Summary of Key Assumptions

Table 4-22 summarizes the key assumptions discussed earlier.

Table 4-22: Duration of Burn Sessions and Burn Rates in the Puget Sound Area

Appliance Type	Material Burned	Hours/Burn Session	Lbs Burned/ Session	Lbs/Hour Burn Rate
Fireplace	cord wood	4	24	6
Fireplace insert	cord wood	8	40	5
Stove	cord wood	8	40	5
Fireplace	firelogs	4	6	1.5
Fireplace insert	firelogs	8	12	two 6-lb logs in 8 hrs
Stove	firelogs	8	12	two 6-lb logs in 8 hrs
Pellet-fired stove	pellets	8	16	2 lbs/hour

4.2.4 Estimating Equations

A Pacific Rim Research (PRR)[86] phone survey forms part of the basis for the estimates. The purpose of the survey was to assist the Agency in developing a marketing plan that will motivate individuals to change behavior and attitudes in ways that protect air quality. The survey had a

[84] Firelog: Duraflame, Inc. www.duraflame.com; pellet: HS Tarm USA Inc., www.woodboilers.com; cord wood: AP-42, App. A, selected fuels.

[85] Table 6, Efficiencies of Wood-Burning Devices, Emissions and Energy Efficiencies of Residential Wood Combustion Devices, Omni Environmental Services, August 1993 by Roger Bighouse and Dr. James Houck.

[86] Pacific Rim Research (PRR) survey performed in March 2005; www.prrbiz.com, (206) 623-073; 1109 1st Ave., #300, Seattle, WA 98101.

21% response rate, covered 1,200 households (300 in each county), and had a 6% margin of error. The survey asked for the frequency of burning and type of burning equipment used. The questions relevant to wood burning are:

- Do you have a wood-burning fireplace, wood stove, pellet stove, or fireplace insert?
- What do you most often burn in your wood-burning appliance (fire wood or firelogs)?
- Is your insert or woodstove EPA certified?
- About how many times do your use your wood-burning device in a winter week?

Appendices A43 through A47 summarize portions of the PRR survey relevant to the wood-burning estimates. The survey did not ask for duration of a burn and the burn rate. The Agency assumed the duration of a burn session and the burn rate as presented in Table 4-22. People could misinterpret the stove certification by assuming that once a stove passed a home inspection it must be certified. The option of answers available for the frequency of use made further assumptions necessary. For example two compilers could interpret "usage frequency less than once a week" and "usage frequency more than four times a week" differently.

The PRR survey was used to determine the number of appliances used per winter week and the frequency of use during the winter week. With the assumed burn rates and duration, the Agency estimated the tons of wood burned during the year as follows:

$\underline{A = B \times C}$

where
A = number of appliance types
B = percent of households with appliance type
C = number of households

and

$\underline{D = E \times A}$

where
D = number of appliance types used at specific weekly frequency
E = percent of appliance types used at specified frequency
A = number of appliance types

and

$\underline{F = D \times G \times H \times J}$

where
F = tons of wood burned per winter week
D = number of appliance types used at specific weekly frequency
G = number of times appliance type used per winter week
H = hours used per burn session for appliance type
J = lbs of wood burned per hour by appliance type

and

$\underline{K = (13 \text{ weeks/winter}) \times F}$

where
K = tons burned per winter in appliance type
F = tons burned per winter week in appliance type

and

$\underline{L = K \div M}$

where
L = tons burned per year in appliance type
M = 48%, fraction of annual wood-burning that occurs in winter (see Appendix A48)

The Agency used the following assumptions to interpret the usage frequency from the PRR survey results:

<u>A% of homes used appliances less than once a week</u>
Agency assumed "once in two weeks"

<u>B% of homes used appliances once or twice a week</u>
Agency assumed "0.5 x B% of homes used an appliance once/week, and
0.5 x B% of homes used it twice/week"

<u>C% of homes used appliances 3 or 4 times a week</u>
Agency assumed "0.5 x C% of homes used an appliance 3 times/week, and
0.5 x C% of homes used it 4 times/week"

<u>D% of homes used appliances more than 4 times a week</u>
Agency assumed "0.33 x D% of homes used an appliance 5 times/week, and
0.33 x D% of homes used it 6 times/week, and
0.33 x D% of homes used it 7 times/week"

The Agency used the monthly natural gas distribution of home heating as a surrogate to determine the fraction of annual home heating that occurs each month. Appendix A48 shows the percentage of distribution of home heating natural gas each month. The month of August has the lowest monthly natural gas consumption. The Agency assumed that households used all of the consumption in August for cooking and water heating. Subtracting the August consumption from each month's consumption leaves home heating natural gas consumed during that month.

The historical average for the fraction of annual home heating natural gas consumed in winter comes to approximately 48%. Winter includes the months of December, January, and February.

Puget Sound Energy (PSE) and Cascade Natural Gas Company (CNGC) provided the monthly natural gas consumption data.[87] Puget Sound Energy distributes natural gas in Pierce County, King County, and most of Snohomish County. CNGC distributes natural gas in Kitsap County and northern Snohomish County. For Snohomish County, the monthly consumption provided by PSE and CNGC were added together to obtain total county consumption for the month. For Pierce County and King County, PSE is the only natural gas distributor. CNGC is the only natural gas distributor in Kitsap County.

Tables 4-23 through 4-33 give steps used to estimate wood burned in woodstoves. Similar steps were used to estimate wood burned in fireplaces, inserts, and pellet stoves (shown in Appendices A49 through A74).

4.2.5 Number of Households

Table 4-23 presents the number of housing units, percent of housing units occupied, and number of households. A household is an occupied housing unit.

[87] Julie Waltari, Puget Sound Energy, (425) 456-2945, julie.waltari@pse.com; Beverly Baker-Brooks, Cascade Natural Gas Company, (206) 381-6755, bbrooks@cngc.com.

Table 4-23: Housing Units, Percent Occupancy, Households[88]

County	# of Housing Units	% Occupied	# of Households
King	794,659	95.8%	761,283
Kitsap	99,298	93.3%	92,645
Pierce	305,957	94.1%	287,906
Snohomish	262,424	95.2%	249,828

4.2.6 PRR Survey – Characteristics of Wood Burning in the Puget Sound Area

Table 4-24 presents the number of households that have woodstoves, the percent of woodstoves that burned wood, and the percent of woodstoves that burned firelogs only. If a stove burns wood and logs (interchangeably), it is treated as burning wood.

Table 4-24: Characteristics of Woodstoves (from PRR Survey)[89]

County	% of Households with Woodstoves	% of Stoves that Burn Cord Wood	% of Stoves that Burn Firelogs Only
King	9.3%	72.3%	27.7%
Kitsap	20.75%	75.8%	24.2%
Pierce	13.05%	71.8%	28.2%
Snohomish	12.35%	71.6%	28.4%

Table 4-25 presents the number of wood stoves, the number of woodstoves that burned wood, and the number of woodstoves that burned firelogs only. If a stove burns cord wood and firelogs (interchangeably), it is treated as burning cord wood.

Table 4-25: Number of Woodstoves and Types of Wood Burned

County	# of Woodstoves	# of Stoves that Burn Cord Wood	# of Stoves that Burn Firelogs Only
King	70,799	51,188	19,611
Kitsap	19,178	14,537	4,641
Pierce	37,428	26,873	10,555
Snohomish	30,729	22,002	8,727

The PRR survey asked for the number of times a household used its woodstove in a winter week. Table 4-26 shows the percentage of woodstoves used at the indicated frequency.

Table 4-26: Percent of Woodstoves used at Indicated Frequency

County	1 day in 2 weeks	1 day/ week	2 days/ week	3 days/ week	4 days/ week	5 days/ week	6 days/ week	7 days/ week
King	23.2%	9.8%	9.8%	5.4%	5.4%	9.5%	9.5%	9.5%
Kitsap	23.5%	8.8%	8.8%	5.9%	5.9%	9.8%	9.8%	9.8%
Pierce	45.7%	8.6%	8.6%	5.7%	5.7%	7.6%	7.6%	7.6%
Snohomish	25.0%	11.3%	11.3%	7.5%	7.5%	10.0%	10.0%	10.0%

[88] Housing Units: State of Washington, Office of Financial Management Forecasting Division, *2005 Population Trends*, Table 8: Housing Units by Type of Structure for Cities and Counties, September 2005; percent occupied: U.S. Census Bureau, *United States 2000 Census*. Table DP-1, available at: http://censtats.census.gov/data/wa/05053033.pdf; last 2 digits = county: King (33), Kitsap (35), Pierce (53), and Snohomish (61).

[89] Puget Sound Clean Air Agency 2005 Survey Report, prepared by Pacific Rim Research, Seattle, WA, March 2005.

Table 4-27 presents the number of woodstoves burning cord wood at the indicated weekly frequency.

D = E × A

where

D = number of appliance types used at specific weekly frequency (in Table 4-27)
E = percent of appliance types used at specified frequency (in Table 4-26)
A = number of woodstoves burning cord wood (in Table 4-25)

Table 4-27: Number of Wood Stoves Burning Cord Wood at Indicated Frequency

County	1 day in 2 weeks	1 day/ week	2 days/ week	3 days/ week	4 days/ week	5 days/ week	6 days/ week	7 days/ week
King	11,881	5,027	5,027	2,741	2,741	4,875	4,875	4,875
Kitsap	3,420	1,283	1,283	855	855	1,425	1,425	1,425
Pierce	12,284	2,303	2,303	1,536	1,536	2,048	2,048	2,048
Snohomish	5,500	2,475	2,475	1,650	1,650	2,200	2,200	2,200

Table 4-28 shows the number of woodstoves burning firelogs at the indicated weekly frequency.

D = E × A

where

D = number of appliance types used at specific weekly frequency (in Table 4-27)
E = percent of appliance types used at specified frequency (in Table 4-26)
A = number of woodstoves burning firelogs only (in Table 4-25)

Table 4-28: Number of Woodstoves Burning Firelogs at Indicated Frequency

County	1 day in 2 weeks	1 day/ week	2 days/ week	3 days/ week	4 days/ week	5 days/ week	6 days/ week	7 days/ week
King	4,552	1,926	1,926	1,050	1,050	1,868	1,050	1,050
Kitsap	1,092	410	410	273	273	455	273	273
Pierce	4,825	905	905	603	603	804	603	603
Snohomish	2,182	982	982	655	655	873	655	655

4.2.7 Amount of Wood Burned

Table 4-29 presents the tons of cord wood burned by woodstoves used at the indicated weekly frequency.

F = D × G × H × J

where

F = tons of cord wood burned per winter week (Table 4-29)
D = number of appliance types used at specific weekly frequency (Table 4-27)
G = number of times appliance type used per winter week (Table 4-27
H = hours used per burn session for appliance type (Table 4-22)
J = pounds of wood burned per hour by appliance type (Table 4-22)

Table 4-29: Tons of Cord Wood Burned per Week by Stoves Used at Indicated Frequency

County	1 day in 2 weeks	1 day/ week	2 days/ week	3 days/ week	4 days/ week	5 days/ week	6 days/ week	7 days/ week
King	119	101	201	164	219	487	585	682
Kitsap	34	26	51	51	68	143	171	200
Pierce	123	46	92	92	123	205	246	287
Snohomish	55	50	99	99	132	220	264	308

Table 4-30 presents the tons of firelogs burned by woodstoves used at the indicated frequency.

<u>F = D × G × H × J</u>

where
F = tons of firelogs burned per winter week (Table 4-30)
D = number of appliance types used at specific weekly frequency (Table 4-28)
G = number of times appliance type used per winter week (Table 4-28)
H = hours used per burn session for appliance type (Table 4-22)
J = pounds of wood burned per hour by appliance type (Table 4-22)

Table 4-30: Tons of Firelogs Burned per Week by Stoves Used at Indicated Frequency

County	1 day in 2 weeks	1 day/ week	2 days/ week	3 days/ week	4 days/ week	5 days/ week	6 days/ week	7 days/ week
King	14	12	23	19	25	56	67	78
Kitsap	3	2	5	5	7	14	16	19
Pierce	14	5	11	11	14	24	29	34
Snohomish	7	6	12	12	16	26	31	37

Table 4-31 presents the tons of cord wood and firelogs burned in woodstoves per year.

<u>K = (13 weeks/winter) × F</u>

where
K = tons burned per winter in appliance type
F = tons burned per winter week in appliance type (Tables 4-29 and 4-30)

and

<u>L = K ÷ M</u>

where
L = tons burned per year in appliance type
M = 48% (fraction of annual wood burning that occurs in winter)

Table 4-31: Tons of Wood Burned in Woodstoves per Year

County	Cord Wood	Firelogs
King	69,309	7,966
Kitsap	20,146	1,930
Pierce	32,856	3,872
Snohomish	33,221	3,953

Table 4-32 shows the percentage distribution of woodstoves among certified, uncertified, and catalytic, as estimated from the PRR survey.

Table 4-32: Percent of Woodstoves Uncertified or Certified

County	Uncertified	Certified Catalytic	Certified Non-Catalytic
King	14.8%	55.7%	29.5%
Kitsap	10.0%	70.0%	20.0%
Pierce	23.2%	62.8%	14.0%
Snohomish	13.5%	70.3%	16.2%

Table 4-33 presents the tons of cord wood burned by type of woodstove.

Table 4-33: Tons of Cord Wood Burned by Woodstoves, 2005

County	Uncertified	Certified Catalytic	Certified Non-Catalytic
King	10,258	38,605	20,446
Kitsap	2,015	14,102	4,029
Pierce	7,623	20,635	4,600
Snohomish	4,485	23,354	5,382

Table 4-34 presents the tons of firelogs burned by type of woodstove.

Table 4-34: Tons of Firelogs Burned by Woodstoves, 2005

County	Uncertified	Certified Catalytic	Certified Non-Catalytic
King	1,179	4,437	2,350
Kitsap	193	1,351	386
Pierce	898	2,431	542
Snohomish	534	2,779	640

The steps used to estimate the quantities in Tables 4-24 through 4-34 were repeated for the other wood-burning appliances. Table 4-35 summarizes the tons of wood burned in appliances.

Table 4-35: Tons of Wood Burned, 2005

Wood-Burning Appliance	King Co.	Kitsap Co.	Pierce Co.	Snohomish Co.	Region
Fireplace	56,592	7,896	11,066	12,045	87,599
Uncertified insert	4,412	389	2,756	1,933	9,490
Non-catalytic insert	8,794	779	1,663	2,319	13,555
Catalytic insert	16,604	2,725	7,460	10,063	36,853
Uncertified stove	10,258	2,015	7,623	4,485	24,380
Non-catalytic stove	20,446	4,029	4,600	5,382	34,457
Catalytic stove	38,605	14,102	20,635	23,354	96,696
Pellet-fired stove	11,132	1,695	3,239	7,544	23,610
Firelog (all)	16,813	2,933	6,358	6,850	32,954

4.2.8 Emission Factors

An emission factor for a pollutant is the amount of pollutant per unit quantity of an activity level processed. For wood burning, an emission factor for an appliance is the pounds of a pollutant per ton of wood burned in the appliance. Table 4-36 presents the wood-burning emission factors for criteria pollutants and Table 4-37 shows the wood-burning emission factors for methane and nitrous oxide. Carbon dioxide is excluded from the emissions from biomass. The Agency is currently examining the assumption that biomass burning does not contribute to carbon dioxide emissions.

Table 4-36: Emission Factors for Criteria Pollutants[90]

Wood-Burning Appliance	CO	NOx	PM2.5[91]	SOx	VOC
Fireplace	252.6	2.6	29.8	0.4	229.0
Uncertified insert	230.8	2.8	26.3	0.4	53.0
Non-catalytic insert	140.8	2.0	16.9	0.4	12.0
Catalytic insert	104.4	2.0	17.5	0.4	15.0
Uncertified stove	230.8	2.8	26.3	0.4	53.0
Non-catalytic stove	140.8	2.0	16.9	0.4	12.0
Catalytic stove	104.4	2.0	17.5	0.4	15.0
Pellet-fired stove	39.4	13.8	3.6	0.4	12.0
Firelog	133.0	3.0	24.6	0.4	56.0

Table 4-37: Emission Factors for Greenhouse Gases[92]

Lbs/Ton Burned	N_2O	CH_4	CO_2 Eqv
Fireplace	0.3	30	723
Uncertified insert	0.3	30	723
Non-catalytic insert	0.3	16	429
Catalytic insert	0.3	12	337
Uncertified stove	0.3	30	723
Non-catalytic stove	0.3	16	429
Catalytic stove	0.3	12	337
Pellet-fired stove	0.3	12	337
Firelog	0.3	30	723

CO_2 eqv = (21 × tons CH_4) + (310 × tons N_2O)

EPA guidelines on page 3-63, Section 3.12 in the Inventory of U.S. Greenhouse Emissions and Sinks: 1990-2004, recommend that inventories should not count CO_2 emissions from wood burning because in the long run the replanted trees will grow back and absorb an equivalent amount of carbon dioxide from the atmosphere. Therefore only the nitrous oxide and methane emissions from indoor wood burning are estimated and converted to carbon dioxide equivalents. The GHG entry for indoor wood burning in Table ES-1 (found in the Introduction of this report) represents the contribution from methane and nitrous oxide only. The carbon dioxide from indoor wood burning is not estimated and not included in Table 4-38 (below) or Table ES-1. Regarding carbon dioxide emissions from biomass burning, the Agency followed the IPCC guidelines for the 2005 inventory but may consider other options in future inventories.

[90] U.S. EPA, *AP-42 Compilation of Air Pollutant Emission Factors*, Tables 1.9-1 and 1.10-1; available at: http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s09.pdf & http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s10.pdf; for firelogs: Table 3 of Dioxin/Furan Air Emissions, General Emissions, and Fuel Composition of Duraflame Firelogs and Douglas Fir Cord Wood, prepared for Puget Sound Clean Air Agency by Omni Environmental Services, Beaverton, OR, May 23, 2006.

[91] Residential wood-burning $PM_{2.5}$ emission factor is taken as 86% of PM_{10} emission factor in AP-42. The 86% is the $PM_{2.5}$ fraction of PM_{10} in AP-42, Table 1.6-1 (dry wood burned in boilers).

[92] U.S. EPA, *AP-42 Compilation of Air Pollutant Emission Factors*, Tables 1.9-1 and 1.10-1; available at: http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s09.pdf & http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s10.pdf.

4.2.9 Summary of Emissions

Table 4-38 presents the emissions from indoor wood burning for the Agency's jurisdiction. Appendices A75 through A78 present county-level emissions.

For each pollutant:

Tons emitted = [(tons of wood burned) × (lbs per ton of wood burned)] ÷ 2000

Table 4-38: Tons Emitted in Agency Four-County Region, 2005

Wood-Burning Appliance	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Fireplace	11,064	114	1,305	18	10,030	31,667
Uncertified insert	1,095	13	125	2	252	3,431
Non-catalytic insert	954	14	114	3	81	2,908
Catalytic insert	1,924	37	324	7	276	6,202
Uncertified stove	2,814	34	321	5	646	8,813
Non-catalytic stove	2,426	35	303	7	207	7,391
Catalytic stove	5,048	97	816	19	725	16,274
Pellet-fired stove	465	163	43	5	142	3,974
Firelog (all)	2,191	49	405	7	923	11,912
All indoor wood	27,980	555	3,756	72	13,282	92,572

4.2.10 Improvement of Assumptions for Future Emission Inventories

The burn rate and burn duration assumptions substantially affect the indoor wood-burning emission estimates. To reduce the uncertainty for such an important category, the Agency has partnered with NWHPBA and with Dr. Houck of Omni Environmental Services, and contracted with a survey firm to conduct a comprehensive survey of wood-burning equipment and practices in the Puget Sound area. The Agency will improve wood-burning emission estimates with the results of the survey.

The Agency expects the survey to more accurately determine the:

- duration of a burn session, (how long a household uses a device when used)
- frequency of use
- pounds of wood burned per hour
- cords of wood burned per year
- number of firelogs burned per year
- distribution of usage among the seasons
- number and distribution of types of woodstoves and inserts
- number and distribution of fireplaces

Appendices A43 through A79 present steps used to estimate the amount of wood burned in the various appliance types.

4.3 Outdoor Burning

4.3.1 Land-Clearing Debris

4.3.1.1 Category Description

Land-clearing burning is a method of on-site, land-clearing debris disposal. Developers who burn land-clearing debris must obtain permits, in advance, from the appropriate fire department and local land use authority.

The Agency's Regulation I, Sections 8.09 through 8.12 prohibit outdoor burning in the urban growth areas, the former carbon monoxide non-attainment areas, and other areas in Kitsap County delineated in the Regulation. In the remaining areas where burning is allowed, the Agency's Regulation I, Section 8.04(d) does not relieve burners from obtaining permits from the local fire protection agency and complying with the Uniform Fire Code before burning outdoors.

The estimates in this section cover land-clearing burning for which the developers obtained land-clearing permits and land-clearing burn permits. Shown below is the source classification code (SCC) for land-clearing burning.

SCC	Description
26 10 000 500	Land-clearing burning

4.3.1.2 Key Assumptions

Land-clearing burning is the debris disposal method when a land-clearing permit has been issued by the appropriate county land use authority and burning is permitted. Local fire departments and county fire marshals issue burn permits for land-clearing for a specified duration. Permit holders may burn as necessary, subject to restrictions including burn bans that the fire departments and Puget Sound Clean Air Agency may impose. With the exception of Hat Island Fire Department and Anderson Island Fire Department, the fire departments do not track the acreage, number of piles, and frequency of burning. It is difficult to determine how many times a permit holder burned land-clearing debris or if the permit holder burned at all. Furthermore, no information is available for developers who truck a portion of the debris to landfills and compost facilities, and use some debris for on-site erosion control. For these reasons, the estimates presented here assume that developers burn all the debris cleared in the areas where burning is allowed. The estimates presented here are therefore likely to be overestimates.

The acreages included in land-clearing permits issued by county land use authorities are the basis for estimating the amount of material burned. In each county the number of land-clearing burn permits that the fire departments issued in the areas where the Agency's regulations allow burning exceeds the number of land-clearing permits the county land use authorities issued in those areas. It appears that multiple fire department permits were issued for the same locations due to renewals, etc. For this reason, the Agency has selected the land-clearing permits as its basis for determining the number of acres cleared and burned.

A local estimate of 95 tons/acre reflects the amount of land-clearing debris generated in our 4-county area. Local developers hire companies including Rainier Wood Recyclers to chip debris from land-clearing projects. Bob Sargent, the owner of the company, provided an estimated fuel loading on one cleared acre. Based upon their extensive experience, Mr. Sargent estimates one cleared acre generates about 95 tons of debris.[93] The highest quantity Rainier Wood Recyclers encountered is 180 tons/acre, near Snoqualmie, WA. According to Mr. Sargent this is unusual because the Snoqualmie clearing had very dense and mature second growth forest over very dense, unrotted old growth stump field with large numbers of partially rotted old growth logs. On the low side, they have seen 30 tons/acre on forested acreage (after the merchantable timber had been removed). Mr. Sargent added that from his chipping business experience, more land-clearing burning occurs in Kitsap County, leading to less chipping business there.

Table 16.4-6 of the Emission Inventory Improvement Project, Volume III, recommends 70 tons per acre for unspecified forest residue for the Pacific Northwest. The Agency believes 95 tons per acre is more representative of the Puget Sound area because it is based upon an estimate from a knowledgeable, experienced, local recycling company.

4.3.1.3 Estimating Equations

Tons land-clearing debris burned = (acres of land cleared) x (95 tons/acre)
Emissions = (tons of land-clearing debris burned) × (lbs/ton burned)

4.3.1.4 Activity Levels

The generic equations used to estimate tons of emissions from land-clearing debris burning are:

Acres burned = (number of land-clearing permits issued) x (average acres per permit)
Tons burned = (acres burned) × (95 tons/acre burned)

Table 4-39 presents land-clearing burn permits issued by fire departments in 2005.

Table 4-39: Number of 2005 Land-Clearing Burn Permits Issued by Fire Departments

County	Number of Permits Issued
King	263
Kitsap	865
Pierce	263
Snohomish	140

The fire departments that issue the permits do not track the quantity of land-clearing debris burned under the permits. County land use departments issue land-clearing permits. The county-issued land-clearing permits were researched and the average acreage of the permits determined. However the number of land-clearing debris burning permits issued by fire departments exceeded the number of land-clearing permits issued by the county development departments. Kitsap County fire departments issued substantially more land-clearing burning permits than the other counties. All the fire departments confirmed that the number of land-clearing burning permits they issued do not include residential burn permits. Because the fire department permits do not provide acreage and the county development land-clearing permits do, the Agency used the county development permits as the basis to estimate the number of acres burned.

Table 4.39 is presented for information purposes only. It appears the fire departments counted some permits more than once, that is, if an applicant does not use a burn permit in the specified

[93]E-mail from Bob Sargent, rwrdsl@nwlink.com, owner of Rainier Wood Recyclers, to Amy Fowler, PSCAA, February 26, 2004.

period and applies for renewal, the fire department may count it as a new permit. See Appendices A80 through A84 for details of the land-clearing permits.

Table 4-40 identifies the county departments that issue land-clearing permits.

Table 4-40: Departments Issuing Land-Clearing Permits[94]

County	Issuing Authority in County
King	Department of Development & Environmental Services (DDES)
Kitsap	Kitsap County Community Development (KCCD)
Pierce	Pierce County Planning and Land Services (PALS)
Snohomish	Snohomish County Planning and Development Services (PDS)

Kitsap County issued two types of land-clearing permits: commercial development and single-family development. Pierce County issued permits for residential site development, grading, clearing, forest practice, and commercial development. King and Snohomish counties called permits that were likely to involve vegetative removal, "land-clearing and site development" permits.

Table 4-41 presents the number of permits and acreage cleared.

Table 4-41: 2005 Land-Clearing Permits Issued in Burn Zones

Description of No-Burn Area Permits	# of Permits	Total Acreage	Average Acres/ Permit	
King Co. land-clearing	197	205		1.04
Kitsap Co. commercial development	42	227		5.42
Kitsap Co. single-family development	451	1,025		2.27
All Kitsap Co. development	493	1,252	(weighted)	2.54
Pierce Co. commercial development	23	(not available)	(Kitsap Co. assumed)	5.42
Pierce Co. residential development	241	(not available)	(Kitsap Co. assumed)	2.27
All Pierce Co. development	264	(not available)	(weighted)	2.54
Snohomish Co. site development	57	684		12.0

Pierce County land-clearing permits did not provide acreage cleared. The Agency assumed Kitsap County average acres per permit for Pierce County because Pierce County fire departments near south Kitsap County issued 248 burn permits out of the 263 land-clearing burn permits issued in Pierce County.

For King, Kitsap, and Snohomish counties, land-clearing permits provided the acreages cleared. The average acreage for Snohomish County land-clearing permits is substantially higher than the other counties. Snohomish County issued only 57 permits in the burn areas averaging 12 acres each, King County issued 197 permits averaging 1 acre each, Kitsap County issued 493 permits averaging 2.5 acres each, and Pierce County issued 264 permits. Snohomish County probably classifies its permits differently from the other counties, leading to substantially fewer permits issued, but an average Snohomish County permit has much larger acreage than the other counties' land-clearing permits. Pierce County land-clearing acreage was estimated from:

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[94]DDES: http://www6.metrokc.gov/ddes/scripts/permsearch, accessed April 6, 2006.
KCCD: http://www.kitsapgov.com/dcd/miscstats/statistics.htm, accessed April 11, 2006.
PALS: http://www.co.pierce.wa.us/cfapps/dcis/permitlistreport.cfm, accessed March 28, 2006.
PDS: http://www/co.snohomish.wa.us/pdsapp/activityreports/archive_2005.asp, accessed March 31, 2006.

A = B x C

where:

A = total acres burned in Pierce County
B = number of Pierce County land-clearing permits
C = 2.54 (weighted average number of acres/Kitsap County land-clearing permit)

Table 4-42 presents a succinct summary of the permit data presented in Table 4-41.

Table 4-42: Summary of Land-Clearing Permits and Tons of Debris Burned in Burn Areas

County	# of Permits Issued	Average # of Acres/permit	# of Acres Burned	Tons Burned at 95 tons/acre
King	197	1.04	205	19,464
Kitsap	493	2.54	1,252	118,961
Pierce	264	2.54	672	63,800
Snohomish	57	12.00	684	64,980

The Agency's Regulation I, Sections 8.09 through 8.12 describe the no-burn area. In a verbal communication with Bob Sargent, owner of Rainier Wood Recyclers, he said there is a lot less wood chipping business in Kitsap County than in the other three counties. Burning restrictions in Kitsap County may be looser or non-burning disposal opportunities may be fewer. This explains why developers in Kitsap County burned a lot more than the developers in the other counties.

Pierce County Fire Department #23 Ashford (PCFD #23) provided its burn permit data in cubic yards. Table 4-43 presents the tons of debris burned in the permits issued by PCFD #23.

Table 4-43: Tons of Debris Pile Burned with Permits Issued by Ashford FD (PCFD #23)

Description of Parameter	Quantity	Source of Data
Cubic yards burned	218,717	Ashford FD
Cubic feet burned	5,905,359	27 cubic feet per cubic yard
Packing ratio (or porosity of pile)	20%	Mark Gray, WA DNR, msrk.gray@dnr.wa.gov
Density of wood (normally burned in piles)	28.1 lbs/ft^3	Mark Gray, WA DNR, msrk.gray@dnr.wa.gov
Tons burned (piles permitted by PCFD #23	16,594	(cubic feet)(packing ratio)(density)/ 2000

Totaling the tons estimated in Tables 4-42 and 4-43 gives the estimates shown in Table 4-44.

Table 4-44: Total Tons of Land-Clearing Debris Burned with Permits, 2005

County	Tons of Land-Clearing Debris Burned
King	19,464
Kitsap	118,691
Pierce	80,394
Snohomish	64,980

4.3.1.5 Emission Factors

Table 4-45 presents the emission factors for land-clearing burning.

Table 4-45: Emission Factors for Land-Clearing Burning (lbs/ton burned)[95]

Pollutant	Pounds/Ton	Short Reference
CO	185.4	EIIP, Vol III, Table 16.4-2 (Ward, 1989, Pile)
NOx	4	AP-42, Table 2.5-5, Forest Residue, footnote n
$PM_{2.5}$	23.4	EIIP, Vol III, Table 16.4-2 (Ward, 1989, Pile)
SOx	0.625	Table 3-34, 2005 WA State County Inventories (trash burning)
VOC	15.2	EIIP, Vol III, Table 16.4-2 (Ward, 1989, Pile)
CO_2	3,143.4	EIIP, Vol III, Table 16.4-2 (Ward, 1989, Pile)
CH_4	21.72	EIIP, Vol III, Table 16.4-2 (Ward, 1989, Pile)
N_2O	0.46	Forest Wildfires, AP-42, Table 13.1-5

4.3.1.6 Summary of Emissions

Unlike the burning of other biomass, the land-clearing inventory includes the carbon dioxide emissions from land-clearing. The land cleared and developed will not regrow the vegetative matter. Regrowth would have taken an equivalent amount of carbon dioxide from the air through photosynthesis. Over time, carbon dioxide emitted from biomass burning is not considered by IPCC to increase atmospheric carbon dioxide concentrations because the biomass grows back and takes an equivalent amount of carbon dioxide from the air.[96]

Table 4-46 presents the emissions from land-clearing debris burning.

Table 4-46: Tons of Pollutants Emitted from Land-Clearing Debris Burning

County	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
King	1,804	39	228	6	148	36,418
Kitsap	11,028	238	1,392	37	904	222,583
Pierce	7,454	161	941	25	611	150,449
Snohomish	6,024	130	760	20	494	121,581
Region	26,309	568	3,321	89	2,157	531,031

4.3.2 Yard-Waste Burning

4.3.2.1 Category Description

Yard-waste burning is the disposal method some rural households use to dispose of their yard-waste. Even in the areas where the Agency allows burning, yard-waste burners must still obtain permits from the local fire protection district and burn only when there is no burn ban in effect.

County waste management departments have extensive programs to collect yard waste at the curbside for buildings not exceeding four households. They provide supplementary services such as drop bins, self-hauls, and occasional free drop-offs. These programs, good neighborliness, and the consequences when caught burning, make emissions from yard-waste burning in the incorporated areas negligible. Yard-waste burning does occur in the rural areas where yard-waste collection programs are limited and the nearest drop bin may be miles away.

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[95] EIIP at http://www.epa.gov/ttn/chief/eiip/techreport/volume03/iii16_apr2001.pdf. and AP-42 at http:www.epa.gov/ttn/chief/ap42ch01/index.html. SOx data from WA State Base Year 2005 County Inventories, prepared by the WA State Dept. of Ecology - Air Quality Program, (contact Sally Otterson, sott461@ecy.wa.gov).

[96] Page 3-63, Section 3.12, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004; revised 1996 IPCC Guidelines for National Greenhouse Inventories: Reference Manual, pages 1.3 and 1.10.

Shown below is the source classification code (SCC) for yard-waste burning.

SCC	Description
26 10 000 100	Open burning of yard waste (unspecified)

4.3.2.2 Key Assumptions

Rural households dispose of yard waste not collected at the curb by burning, self-hauling to transfer stations or drop boxes, composting, or dumping. Waste management companies provide curbside pick-up in some rural areas. The counties also provide drop box services and transfer stations where households can self-haul their yard waste. Some households compost in their backyards; others pile up yard waste to rot in their backyards and leave grass clippings on the lawns. A few others dump the waste in ravines and remote areas. The remainder, who have no curbside pick-up, will self-haul, compost, dump, or burn yard waste with or without a permit.

The Agency assumes households that do not subscribe to curbside services generate waste at the same rate as subscribers. The Agency does not have data regarding the households that do not subscribe to curbside pick-up and assumes subscriber and non-subscriber households have similar waste generation characteristics.

Only households in single family units, mobile homes, duplexes, triplexes, and fourplexes are eligible for curbside pick-up. Households in apartment complexes and condominiums do not burn yard waste because property managers or commercial landscapers take care of the yard and properly dispose of the yard waste. Waste management companies and county waste management departments classify housing components containing less than five units as eligible for curbside pick-up. Many rural single-family homes, motor homes, trailer homes, and 2- to 4-unit homes subscribe to curbside pick-up. The maximum possible number of subscribers is the number of households not exceeding 4 units.

The Bellwether Survey is applicable to rural areas. The Bellwether Survey asked rural households about their waste disposal methods. The Agency assumes the responses relevant to yard-waste disposal are applicable to the households that burn.

4.3.2.3 The Bellwether Survey

The estimates are based on information provided by county waste management departments plus responses to yard-waste disposal questions in a December 2006 survey by The Bellwether Group that covered 22 small towns and unincorporated areas.[97] The purpose of the survey was to provide benchmarks for the Agency in advance of a public education campaign about household waste disposal practices, alternatives to burning household wastes, awareness about burning restrictions, and general air quality issues.

The Bellwether survey covered rural areas and small cities. The surveyed areas were:

<u>King Co.</u> E Kent, Maple Valley, Enumclaw, Covington, E Woodinville, Black Diamond, Skykomish
<u>Kitsap Co.</u> Kingston, Poulsbo
<u>Pierce Co.</u> Carbonado, Roy, Eatonville, Orting, Buckley, Wilkeson, South Prairie
<u>Snohomish Co.</u> Granite Falls, Lake Stevens, Gold Bar, Sultan, Stanwood, Darrington

The Bellwether survey asked several questions on waste disposal. Question 4 asked, "When you have yard debris, how do you dispose of it?" Table 4-47 presents percent of rural households that burned yard waste (as estimated from the Bellwether survey, Banner 1, Table 12-1).

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[97]Four-County Outdoor Burning Behavioral and Attitudinal Phone Survey, developed and completed for the Puget Sound Clean Air Agency by The Bellwether Group, 506 2nd Ave, #3000, Seattle, WA 98104, (206) 583-0333, www.thebellwethergroup.net. The methodology quotes the survey frequently as "Bellwether".

Table 4-47 Characteristics of Rural Household (hh) Yard-Waste Disposal

County	# of hh that responded	% of hh that burned openly a	%of hh that burned in barrels b	% of hh that burned a + b
King	213	16.4%	0.9%	17.3%
Kitsap	73	12.3%	1.4%	13.7%
Pierce	105	16.2%	2.9%	19.1%
Snohomish	182	19.8%	2.2%	22.0%

4.3.2.4 Demographic Data

Table 4-48 shows the number of housing units and households eligible to subscribe to curbside pick-up. See Appendices A87-A88 for detailed demographic data used to produce Table 4-48.

Table 4-48: Housing Units & Households Eligible for Curbside Pick-Up in Unincorporated Areas

Description	King Co.	Kitsap Co.	Pierce Co.	Snohomish Co.
1-unit	109,396	49,390	96,150	90,537
2-unit	1,094	1,235	1,762	1,877
3-, or 4-unit	2,188	1,351	2,491	2,537
Mobile home	7,523	9,524	21,503	13,922
All eligible units	120,201	61,500	121,906	108,909
Eligible households	115,153	57,380	114,713	103,681

4.3.2.5 Activity Levels

Each county compiles its waste management data differently, therefore each county's estimates are presented separately. The methodology divides each county into sub-areas compatible with the format the county uses to collect the data. The generic equation used to estimate amount burned in a sub-county area is as follows:

Tons burned = (number of hh that potentially burned) × (tons burned/household)
Tons emitted= [(tons burned) × (pounds/ton burned)] ÷ 2000

Table 4-49 presents the number of households eligible for curbside pick-up, the percent of those households that burned yard waste, the number of rural households that burned, the pounds of yard waste generated per household, and the tons of yard waste burned.

Table 4-49: Yard-Waste Burning Characteristics in Rural Puget Sound Households (hh), 2005[98]

County	Eligible hh	% of hh burning	# of hh burning	Lbs burned/ hh	Tons Burned
King	115,153	17.3%	19,921	1,560	15,539
Kitsap	57,380	13.7%	7,861	1,560	6,132
Pierce	114,713	19.1%	21,910	875	9,756
Snohomish	103,681	22.0%	22,810	1,242	14,168

[98] 2005 Solid Waste Division, Annual Report, King Co. Dept. of Natural Resources, Table A-3. Pierce Co. Single-Cart Curbside Recycling, Seven Months Evaluation, February 2006. 2004 Snohomish Co. Solid Waste Management Data, received from Jon Yeckley by mail, March 29, 2005.

This is an overestimate because the estimates assume burners do burn all their yard wastes. The Bellwether survey asked about composting, self-haul, and dumping but did not ask about households that use other disposal methods and then burn. Appendices A90-A93 show a material balance of yard-waste disposal, which shows that the "tons burned" estimates presented in Table 4-49 are reasonable.

4.3.2.6 Emission Factors

Table 4-50 presents the pounds of pollutants burned per ton of yard waste burned.

Table 4-50: Emission Factors (lbs/ton)[99]

Description	CO	NOx	$PM_{2.5}$	SOx	VOC	CH_4	N_2O	CO_2 Eqv
Lbs/ton	112	4	38	0.625	28	12	0.46	395

4.3.2.7 Summary of Emissions

Applying the emission factors to the tons burned gives the emissions for each county shown in Table 4-51.

Table 4-51: Tons of Emissions from Yard-Waste Burning

Tons	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
King	870	31	295	5	218	3,066
Kitsap	343	12	117	2	86	1,210
Pierce	546	20	185	3	137	1,925
Snohomish	793	28	269	4	198	2,795
Region	2,553	91	866	14	638	8,996

4.3.3 Agricultural Burning

4.3.3.1 Category Description

Agricultural burning covers farm-generated debris burned on farms with permits issued by the Agency. Farmers sometimes burn fields to prepare the land or clear waste from the last harvest. The Agency issues agricultural permits under Agency Regulation I, Section 8.05. Agricultural permits are available only to farmers who can demonstrate that they run a commercial agricultural operation by providing a copy of their most recent IRS Schedule F (Profit or Loss from Farming). Farmers must also demonstrate that the natural vegetation being burned is from the property of the commercial agricultural operation; that it is necessary for crop propagation or rotation, disease or pest control; and that it meets criteria for best-management practices. Agricultural fires are always prohibited during air quality burn bans and fire-safety burn bans.

Shown below is the source classification code (SCC) for agricultural field burning.

SCC	Description
28 01 500 000	Agricultural Field Burning

[99] SOx emission factor: Table 3-34, WA State Base Year 2005 County Inventories (trash burning) taken from the Documentation for the Final 2002 Nonpoint Sector (February 2006), NEI for Criteria and HAPs, prepared by E. H. Pechan & Associates for EPA's OAQPS, RTP, NC 27711. NOx emission factor: AP-42, Table 2.5-5, Forest Residue, footnote n; N_2O: AP-42, Table 13.1-5. N_2O: AP-42, Table 13.1-5. Others: Emission Inventory Improvement Project, Vol III, Table 16.4-7, www.epa.gov/ttn/chief/techreport/volume03. CO_2 eqv = (21 * CH_4 emission factor) + (310 * N_2O emission factor). CO_2 emissions are excluded because the yard vegetation will regrow and take out an equivalent amount of CO_2 from the air. The Agency is re-examining the exclusion of carbon dioxide emissions from biomass burning.

4.3.3.2 Key Assumptions

Farmers obtain permits before they burn. To engage in agricultural field burning, a permit is required in the four counties under Agency jurisdiction. The usual debris for which farmers obtain permits to burn includes pasture land, berries, holiday trees, and decorative plants. This inventory based the burn estimates on the number of agricultural burning permits issued during calendar year 2005.

No agricultural burning occurred without an Agency permit. Outdoor burning complaints reported to the Agency usually concern residential yard waste burning, so the Agency assumes that the lack of complaints for agricultural burning reflects the absence of un-permitted burning.

4.3.3.3 Estimating Equation

$$\text{Emissions} = \text{tons debris burned} \times \text{pounds per ton burned}$$

4.3.3.4 Activity Levels

Table 4-52 presents the number of acres covered by permits in 2005.

Table 4-52: Number of Acres in Permits Issued by the Agency, 2005

Activity Level	King Co.	Kitsap Co.	Pierce Co.	Snohomish Co.
Research			10	
Pasture			10	
Christmas trees		10	36	
Decorative plants	9	10	159	
Berries			10	4
Other		5		
Total	9	25	225	4

4.3.3.5 Fuel Loading Factors

Table 4-53 presents fuel loading[100] for agricultural burning.

Table 4-53: Fuel Loading Factors for Agricultural Burning (tons per acre)

Description	Orchard Tress	Pastureland	Other
Tons per acre	10.4	2.4	4.0

4.3.3.6 Tons Burned

Applying the fuel-loading factors to the acres given in Table 4-52 gives the tons of agricultural debris burned, shown in Table 4-54.

Table 4-54: Tons of Debris Burned with Agricultural Burn Permits

County	Trees, Berries, Decoratives	Pasture Land	Research, Other
King	94		
Kitsap	208		20
Pierce	2,132	24	40
Snohomish	42		

[100]Fuel loading factors (tons/acre) and emission factors (lbs/ton) taken from WA State Base Year 2005 County Emission Inventories, prepared by Sally Otterson, WA State Dept. of Ecology - Air Quality Program, Olympia, Tables 3-26, 3-27, and 3-29.

4.3.3.7 Emission Factors
Table 4-55 presents emission factors[101] for agricultural burning.

Table 4-55: Emission Factors (lbs/ton)[102]

Type of Debris	CO	NOx	$PM_{2.5}$	SOx	VOC	CH_4	N_2O	CO_2 Eqv
Orchard trees	42	5.2	3.7	0.625	3	5.4	0.46	256
Pasture land	101	4.5	15.0	0.625	15	5.4	0.46	256
Research, other	140	4.0	15.8	0.625	19	5.4	0.46	256

4.3.3.8 Summary of Emissions
Table 4-56 presents agricultural burning emissions.

Table 4-56: Tons Emitted from Agricultural Burning

County and Type of Burn	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
King (trees/berries)	2.0	0.2	0.2	0.0	0.1	12.0
Kitsap (trees/berries)	4.4	0.5	0.4	0.0	0.3	26.6
Pierce (trees/berries)	44.8	5.5	3.9	0.4	3.2	272.9
Snohomish (trees/berries)	0.9	0.1	0.1	0.0	0.1	5.3
Pierce (pasture)	1.2	0.1	0.2	0.0	0.2	3.1
Kitsap (research/other)	1.2	0.1	0.2	0.0	0.2	0.1
Pierce (research/other)	2.3	0.1	0.4	0.0	0.4	5.1
King (all agric burning)	2.0	0.2	0.2	0.0	0.1	12.0
Kitsap (all agric burning)	5.5	0.6	0.5	0.1	0.5	26.7
Pierce (all agric burning)	48.3	5.7	4.4	0.7	3.8	281.1
Snohomish (all agric burning)	0.9	0.1	0.1	0.0	0.1	5.3
Region (all agric burning)	56.7	6.6	5.2	0.8	4.5	325.1

The Intergovernmental Panel of Climate Change (IPCC) does not count CO_2 from agricultural burning as contributing to overall greenhouse gases since the combustion is of renewable material. The greenhouse gas emissions for agricultural burning exclude carbon dioxide. The Agency is re-examining the assumption that biomass burning does not contribute to carbon dioxide.

4.3.4 Forest Management and Wildfires

4.3.4.1 Category Description
This is vegetative burning that occurs in national parks and privately managed forests. The Washington DNR tracks burning in private, state, and federal forests. The numbers and sizes of forest fires vary from year-to-year, and there is no correlation between fires that occur in different years. One of the reasons the Agency is interested in including the number of forest fires in its emission inventory is that forest fires result in particulate matter (particle pollution) that can adversely affect health.

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[101]Fuel loading factors (tons/acre) and emission factors (lbs/ton) taken from WA State Base Year 2005 County Emission Inventories, prepared by Sally Otterson, WA State Dept. of Ecology - Air Quality Program, Olympia, Table 3-26, 3-27, and 3-29.

[102]Sources of the emission factors are: SOx: Table 3-34, 2005 WA State Base Year County Inventories, by Sally Otterson, May 9, 2007. N_2O: AP-42, Table 13.1-5 (wildfires). Others: 2005 WA State Emission Inventory by Sally Otterson (sott461@ecy.wa.gov), Table 3.29 and AP-42 Table 2.5-5.

Forest burning falls into two groups.

- Forest wildfire (accidental fires started by lightning or human activities). These usually occur between June and October.
- Management burn. Forest managers usually schedule these in autumn.
  - broadcast burn (foresters intentionally burn an area for forest management purposes)
  - slash burn (forest managers thin out, pile, and burn dead forest debris)

Shown below are source classification codes (SCC) for forest wildfires and management burns.

SCC	Description
28 10 001 000	Forest wildfire
28 10 015 000	Management burn (broadcast burn, slash burn)

4.3.4.2 Key Assumption

DNR data captures all forest fires. EIIP guidelines recommend inventory compilers obtain forest management burning and emissions from local and state forest managers, county departments of natural resources, the U.S. Forest Service (USFS), the Bureau of Indian Affairs, and the U.S. Department of Agriculture (USDA). In Washington State, land managers must report all fires that occur in private and public forests to the DNR. The DNR uses sophisticated models developed by the USFS and the USDA, which give the coordinates and time that a burn occurred.

4.3.4.3 Estimating Equation

Emissions = (tons burned) × (pounds per ton burned)

4.3.4.4 Activity Levels

Table 4-57 presents the number of tons of forest fuel burned in 2005. DNR provided the number of acres burned in wildfires and the tons of debris burned in forest management. The Agency assumed burns at 95 tons of wood material per acre as recommended by Bob Sargent of Rainier Wood Recyclers. (See key assumptions for land-clearing burning in Section 4.3.1.2 of this report.) Appendices A94 and A95 show details of forest burns.

Table 4-57: 2005 Tons of Debris Burned in Management Burns and Forest Fires[103]

Tons Burned	King Co.	Kitsap Co.	Pierce Co.	Snohomish Co.
Forest wildfires (at 95 tons/acre)	115	33	2,312	280
Management burns	24	0	15,058	14

4.3.4.5 Emission Factors

The emission factors in Table 4-58 are from Chapter 13 of the AP 42 Compilation of Air Pollutant Emission Factors[104] and Emission Inventory Improvement Program (EIIP), Vol. III.[105]

[103] E-mail from David Grant, david.grant@wadnr.gov, (360) 902-1318 and Mark Gray mark.gray@wadnr.gov, Smoke & Fuel Management Specialist, WA DNR, Resource Protection, September 20, 2006. Data also available at http://www/nifc.gov/stats and http://www.dnr.wa.gov/fire/pdf/2005giresummary.pdf.

[104] http://www.epa.gov/ttn/chief/ap42/index.html. Navigate to appropriate table in Chapter 1 or 13.

[105] http://www.epa.gov/ttn/chief/eiip/techreport/volume03/iii16_apr2001.pdf.

Table 4-58: Emission Factors for Forest Management Burns and Wildfires

Pollutant	Lbs/Ton Burned	Best Available Reference
CO	222.2	Forest wildfires, AP-42, Table 13.1-4
NOx	4.0	Open burning, AP-42, 2.5-5, forest residue, footnote n
$PM_{2.5}$	13.5	WA DNR data ($PM_{2.5}$ emissions/tons burned)
SOx	0.625	Table 3-34, 2005 WA County Inventories, by Sally Otterson
VOC	15.2	EIIP, Vol III, Table 16.4-2, Ward, 1989, Pile
CH_4	11.1	Forest wildfires, AP-42, Table 13.1-5 (coniferous forests)
N_2O	0.46	Forest wildfires, AP-42, Table 13.1-5 (coniferous forests)

4.3.4.6 Summary of Emissions

Over time, forest burning does not contribute to carbon dioxide because the forests grow back following fires. Based on IPCC guidelines, the Agency assumed the vegetation that grows back takes an equivalent amount of CO_2 from the air to cancel out what was released into the air when the forest burned. Therefore the emissions of CO_2 eqv in Table 4-59 include only CH_4 and N_2O contributions. The Agency is re-examining the assumption that biomass burning does not contribute net carbon dioxide emissions. Table 4-59 presents emissions from forest burning.

Table 4-59: 2005 Estimated Emissions from All Forest Burning, tons

County	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
King	15	0	1	0	1	26
Kitsap	4	0	0	0	0	6
Pierce	1,930	35	117	5	132	3,263
Snohomish	33	1	2	0	2	593
Region	1,982	36	120	6	136	3,888

4.3.5 Structure Burning

4.3.5.1 Category Description

This category covers emissions that result from building structures that burn down. Structure burning generally refers to the types of fires that local firefighters respond to. These fires can result from careless smoking, kitchen accidents, electrical problems, or arson. This category also includes structures burned by fire departments for training purposes, when asbestos is not present. Shown below is the source classification code (SCC) for structure burns.

SCC	Description
28 10 030 000	Structure burn

4.3.5.2 Key Assumptions

The national structure fire rate (2.3 fires per 1,000 people) is representative of the Puget Sound four-county area. Nationwide, 2.3 fires occur per 1,000 people.[106]

The average building fire debris burned (1.15 tons) is representative of debris burned in fires in the Puget Sound four-county area. The Emission Inventory Improvement Project guidelines recommend 1.15 tons of debris burned per fire.[107]

[106] U.S. EPA, *Emission Inventory Improvement Program Vol. III*, Section 5.2, Chap. 18 Structure Fires. http://www.epa.gov/ttn/chief/eiip/techreport/volume03/iii18_apr2001.pdf.

[107] U.S. EPA, *Emission Inventory Improvement Program Vol. III*, Section 4.1.2 Fuel Loading, Chap. 18 Structure Fires.

4.3.5.3 Estimating Equation

Emissions = (tons burned in fire) × (pounds per ton burned)

4.3.5.4 Activity Levels

Based on county population, Table 4-60 shows the 2005 estimates for the number of fires and the tons of debris burned in each fire.

Table 4-60: Human Population, Number of Fires, and Tons Burned in Structure Fires

County	Population (1,000s)[108]	Number of Fires	Tons Burned
King	1,808	4,159	4,783
Kitsap	240	553	636
Pierce	756	1,739	1,999
Snohomish	656	1,508	1,735

4.3.5.5 Emission Factors

Table 4-61 presents emission factors from the Emission Inventory Improvement Program (EIIP), Vol. III and the U.S. EPA AP- 42 Compilation of Air Pollutant Emission Factors.

Table 4-61: Emission Factors for Structure Burning[109]

Pollutant	Pounds/Ton	Reference
CO	60	Table 18.4-1, structure fires, EIIP, Vol III
NOx	1.4	Table 18.4-1, structure fires, EIIP, Vol III
$PM_{2.5}$	10.8	Table 18.4-1, structure fires, EIIP, Vol III
SOx	0.625	Table 3-34, 2005 Washington State County Inventories
VOC	11	Table 18.4-1, structure fires, EIIP, Vol III
CO_2	3,143	Table 16.4-2, open burning, EIIP, Vol III
CH_4	2.9	Table 18.4-1, difference between TOG and VOC factors
N_2O	not available	

4.3.5.6 Summary of Emissions

The tons burned (from Table 4-60) and emission factors (in Table 4-61) were multiplied to obtain the emissions presented in Table 4-62.

Table 4-62: Tons of Estimated Emissions from Structure Burning by County, 2005

County	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
King	143	3	26	2	26	7,662
Kitsap	19	0	3	0	3	1,019
Pierce	60	1	11	1	11	3,203
Snohomish	52	1	9	1	10	2,779
4-County Region	275	6	49	5	50	14,662

[108]Table 4, WA State Office of Financial Management, *2005 Washington Population Trends*, September 2005.
[109]http://www.epa.gov/ttn/chief/eiip/techreport/volume03/iii18_apr2001.pdf. See Table 4-45 of this report.

5 Stationary Area Evaporative Sources

Stationary sources that emit volatile organic compounds (VOCs) from evaporation and do not report their emissions and activity levels to the Agency are called stationary area evaporative sources. Activities that generate VOCs and fall under stationary area evaporative sources include house painting, industrial surface coating, and metal cleaning at facilities that do not report their emissions to the Agency, as well as household activities that release VOCs from solvent-containing applications. Household activities that release VOCs include window-cleaning solvents, perfume application, baking, insecticide application, and car-care products.

5.1 Surface Coating

5.1.1 Architectural Coating

5.1.1.1 Category Description

This category covers emissions that result from coatings applied to non-industrial buildings and structures related to non-industrial buildings. Several types of products are available to coat architectural structures such as buildings, fences, and bridges. Most coatings, such as paint and primers, are applied by homeowners, developers, individuals, or companies employed as coating contractors. These coatings and primers contain volatile organic compounds (VOCs) that escape into the air. This category also includes the emissions from thinners and solvents used in preparing for, and cleaning up after, applications of architectural coatings. Emissions from this category are a significant contributor of VOCs, precursors to the pollutant "ozone".

Coatings used on products and industrial buildings are found in Section 5.1.2 (Industrial and Special Coatings). Below are the source classification codes (SCC) for architectural coatings.

SCC	Description
24 01 003 000	Water-based architectural coating
24 01 002 000	Solvent-based architectural coating
24 01 001 025	Lacquer (for glossy finishes)

5.1.1.2 Key Assumptions

The amount of coating applied in a county is proportional to the number of households (hh) in the county. Homeowners apply coatings to existing homes and fences to maintain their homes and to improve appearance. Developers also apply coatings to new housing units. The Emissions Inventory Improvement Project guidelines recommend using the number of households to apportion national coating consumption to the inventory area level.

All architectural coatings distributed in the U.S. during 2005 were applied in 2005. The few gallons of coating distributed in a previous year but applied in 2005 would be offset by the gallons distributed (but not applied) in 2005. For a running total, these should even out.

All VOCs in the coatings, stains, thinners, and clean-up solvents eventually escape into the air. Estimates here conservatively assume a "worst case" scenario that all VOCs in products applied will eventually evaporate and escape into the air. It is likely that some may not escape, as some painters/appliers will dispose of rags and coating wastes properly (sealing them in airtight containers).

5.1.1.3 Estimating Equations

Gallons of coating for county = [(# of county hh) ÷ (# of U.S. hh)] × (gallons used in U.S.)

Lbs of VOC emitted = (1,000 gallons coating) × (lbs of VOC/1,000 gallons coating)

5.1.1.4 Activity Levels

The activity level for this category is based on the number of households and gallons of paint distributed in King, Kitsap, Pierce, and Snohomish counties during 2005. Table 5-1 shows the number of housing units, percent of housing units occupied, and number of households. A household is an occupied housing unit.

Table 5-1: Number of Households, 2005[110]

Area	# of Housing Units	% Occupied	# of Households
King	794,659	96%	761,283
Kitsap	99,298	93%	92,645
Pierce	305,957	94%	287,906
Snohomish	262,424	95%	249,828
U.S.			111,090,617

Table 5-2 presents the gallons of paint distributed in the inventory area and the U.S.

Table 5-2: 1,000 Gallons of Paints Distributed, 2005[111]

Area	Solvent Paint	Water Paint	Lacquer
King	952	4,519	61
Kitsap	116	550	7
Pierce	360	1,709	23
Snohomish	313	1,483	20
U.S.	138,988	659,448	8,959

5.1.1.5 Emission Factors

Table 5-3 shows architectural coating emission factors from the WA Dept. of Transportation (DOT) and EIIP. The EIIP VOC content is from an EPA study that estimated VOC content of paint distributed in 1993. The National Association of Clean Air Agencies (NACAA) developed a model rule for state and local air agencies to use as guidance in developing VOC-reduction measures. The average VOC content of architectural coatings as recommended by the model rule[112] is about 2,600 lbs of VOC/1,000 gallons of architectural coatings and 2,900 lbs of VOC/gallon of industrial coating. For solvent paint, the Agency used the 1999 WA DOT solvent paint factor because it is more recent than the EIIP 1993 factor and closer to the NACAA-recommended factor. For water paint, the Agency used the EIIP factor because WA DOT water paint is traffic paint, and EIIP paint is likely to be used on buildings.

Table 5-3: Emission Factors for Architectural Coatings (lbs of VOC/1,000 gallons)[113]

Emission Factor Source	Solvent Paint	Water Paint	Lacquer
EIIP	3,870	740	3,870
WA DOT	(Year 1999) 2,910	(Year 2005) 1,300	
Agency estimate	2,910	740	3,870

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[110] Housing Units for Washington Counties: 2005 Population Trends, Housing Units by Type of Structure for Cities and Counties, September 2005, Washington State Office of Financial Management, Forecasting Division; for U.S.: 2005 American Community Survey, Table S2504, Physical Housing Characteristics for Occupied Housing Units. Percent occupied: Profile of General Demographic Characteristics, 2000, Table DP-1; U.S. Census Bureau, http://censstats.census.gov/data/wa/05053033.pdf for King Co. (33); Kitsap Co. (35), Pierce Co. (53); and Snohomish Co. (61). U.S. households: 2005 American Community Survey, S2504, Physical Housing Characteristics for Occupied Housing Units; http://factfinder.census.gov; August 31, 2007.

[111] For U.S. paints: U.S. Census Bureau, *Current Industrial Reports, Paints and Allied Products: 2005*. Available at: http://www.census.gov/industry/1/ma325f05.pdf, August 31, 2007.

[112] Regulating Air Emissions from Paint: A Model Rule for State & Local Agencies, STAPPA/ALAPCO, Oct. 2000.

[113] EIIP, Vol III, Table 5-2, http://www.epa.gov/ttn/chief/eiip/techreport/volume03/archsfc.pdf; August 31, 2007. WA DOT Traffic Office, telephone conversation & MSDS sheet from Ed Lagergren (360) 705-7284, who said DOT no longer uses solvent paint. Probably local transportation departments also use water paint only. Traffic paint falls under special coating.

5.1.1.6 Summary of Emissions

Table 5-4 presents VOC emissions from architectural coatings.

Table 5-4: Estimated Tons of VOC Emitted from Architectural Coatings, 2005

County	Solvent Paint	Water Paint	Lacquer	Total
King	1,386	1,672	119	3,177
Kitsap	169	203	14	387
Pierce	524	632	45	1,201
Snohomish	455	549	39	1,043
4-county Region	2,533	2,057	217	5,807

5.1.2 Industrial and Special Coatings

5.1.2.1 Category Description

This category covers VOC emissions from paint applied to products and non-residential settings. Original equipment manufacturers (OEMs) coat various products such as appliances, vehicles, tools, and furniture. The coatings used by OEMs contain VOCs that evaporate into the air during the application or during the drying process. Coatings applied on roads, traffic signs, vessels, and industrial buildings require special formulations and are called "special coats". Coatings applied in auto refinishing fall under special coatings but in this report auto refinishing is inventoried in Section 5.1.3 (Auto Refinishing). The list of industrial coatings in this report and their EPA source classification codes (SCC) are shown below.

SCC	Description
24 01 008 000	Traffic marking
24 01 025 000 – 24 01 200 000	Industrial coating

5.1.2.2 Key Assumptions

The amount of coating applied in an industry is proportional to the number of employees. Data on OEM paint applied is available at the national level by industry category. Emission Inventory Improvement Project (EIIP) procedures recommend using employment in industrial categories that apply coating, to apportion national OEM paint distributed to the area level inventory.

Traffic coatings applied are proportional to the number of lane miles. Data on traffic paint applied and lane miles are available at the national level. Lane miles are also available at the county level. WA DOT can also provide traffic paint at the DOT region level. The DOT regions do not match the Agency counties and do not include paint applied on county and city roads. The national traffic paint data and lane miles data are used to distribute the traffic paint among the counties, as recommended by the EIIP.

All coatings distributed in 2005 were applied in 2005. Paint distributed in 2004 and applied in 2005 should compensate for paint distributed in 2005 and applied in 2006.

5.1.2.3 Estimating Equations

The amount of coating used in a county for a particular NAICS code is estimated as follows:

$$\text{Gallons} = [(\text{county employment}) \div (\text{U.S. employment})] \times (\text{U.S. gallons})$$

For traffic coating, the corresponding equation used is:

$$\text{Gallons} = [(\text{county lane miles}) \div (\text{U.S. lane miles})] \times (\text{U.S. traffic coatings})$$

Knowing the gallons applied, emissions are estimated using the equation:

Pounds of VOC emitted = (gallons coating applied) × (pounds/gallon)

5.1.2.4 Activity Levels

The activity level for this category is the gallons of OEM and special coatings applied in King, Kitsap, Pierce, and Snohomish counties during 2005. Employment in industries likely to apply coatings is used as a surrogate to apportion coatings distributed in the U.S. to the county level, as shown in Table 5-5. Lane miles, presented in Table 5-6 are used as a surrogate to apportion U.S. traffic paint consumption to the county level.

Table 5-5: 2005 Employment in Industries Likely to Apply Coating[114]

Industry and NAICS Code	King	Kitsap	Pierce	Snohomish	U.S.
Autos, vans, light-duty trucks 33611	10		10		187,216
Heavy-duty trucks 33612	1,750				29,577
Vehicle body & trailers 3362	175		10	88	143,888
Auto parts finishes 3363	1,750		175	60	689,063
Aircraft & rail equipment 3364, 3365	33,169	10	1,750	18,712	397,734
Appliances 333	5,038	117	592	1,352	1,087,944
Metal building products 332	5,971	163	1,874	3,767	1,514,595
Containers & closures 332	5,971	163	1,874	3,767	1,514,595
Wood furniture & fixtures 337	2,014	214	1,395	1,391	555,368
Factory-finished wood 337	2,014	214	1,395	1,391	555,368
Non-wood furniture 337	2,014	214	1,395	1,391	555,368
Machinery & equipment 333	5,038	117	592	1,352	1,087,944
Paper & foil finishes 3222	1,750		750		314,605
Electrical insulation 334 & 335	12,291	246	414	5,228	1,547,403
Powder coating 332	5,971	163	1,874	3,767	1,514,595
Industrial maintenance 31-33	97,525	1,972	20,300	40,927	13,821,976
Ship & boat building 3366	2,138	162	380	1,413	137,633
Aerosol painting, other 31-33	97,525	1,972	20,300	40,927	13,821,976

Table 5-6: Lane Miles in Counties and U.S.[115]

Area	Lane Miles
King County	17,993
Kitsap County	3,626
Pierce County	10,826
Snohomish County	8,485
U.S.	8,338,813

Table 5-7 presents gallons of paint used in OEM and special coatings.

[114]U.S. Census Bureau, *County Business Patterns*, WA, 2005; http://censtats.census.gov/cbpnaic/cbpnaic.shtml, July 30, 2007.

[115]U.S. lane miles: Highway Statistics, 2005, Table HM-48; http://www.fhwa.dot.gov/policy/ohim/hs05/pdf/hm48.pdf; county lane miles: HPMS Miles & VMT by County, 2005 HPMS Database, June 21, 2006 (hard copy provided by Pat Whittaker).

Table 5-7: OEM Coatings and Special Coatings (in thousands of gallons)[116]

Industry	King Co.	Kitsap Co.	Pierce Co.	Sno Co.	U.S.
Autos, vans, light-duty trucks	3		3		54,521
Heavy-duty trucks & vehicles	84			4	7,554
Auto parts finishes	15			4	5,959
Aircraft & rail equipment	797		42	449	9,552
Appliances	38	1	4	10	8,255
Metal building products	128	3	40	81	32,502
Containers & closures	138	4	43	87	35,043
Wood furniture & fixtures	179	19	124	123	49,231
Factory-finished wood	41	4	28	28	11,304
Non-wood furniture	178	19	124	12	49,174
Machinery & equipment	94	2	11	25	20,229
Paper & foil finishes	82		35		14,752
Electrical insulation	3			1	423
Powder coating	255	7	80	161	64,773
Other industrial products	250	5	52	105	35,398
Traffic marking paints	66	13	40	31	30,799
Interior industrial maintenance	116	2	24	49	16,416
Exterior industrial maintenance	213	4	44	89	30,161
Ship & boat building	196	15	35	129	12,594
Aerosol paint	73	1	15	30	10,298
Other special purpose	9	0	2	4	1,223

5.1.2.5 Emission Factors

Table 5-8 presents emission factors for OEM coatings and special coatings.

Table 5-8: Emission Factors for OEM and Special Coating Application[117]

Industrial Coating Category	Pounds per Gallon
Motor vehicle	6.0
Aircraft & rail equipment	3.5
Appliances	6.0
Wood furniture	3.0
Metal building parts	6.0
Containers	4.2
Machinery & equipment	6.0
Non-wood furniture	6.0
Paper, foil	2.9
Electrical insulation	3.0
Powder coat	3.0
Other industrial coats	3.0
Special Coating Category	**Pounds per Gallon**
Traffic marking paint	1.3
Interior industrial building	5.3
Exterior industrial building	5.3
Marine	5.3
Aerosol	5.3
Other (not elsewhere classified)	5.3

[116] Current Industrial Reports, 2005; http://www.census.gov/industrial/1/ma325f05.pdf.

[117] Sources for VOC content of paint: (a) traffic paint: WA DOT, NW & Olympic region, VOC content provided by Ed Lagergren (360) 705-7284; (b) Agency Regulation II, Sections 3.03-3.09; (c) National Rule for VOC Limits, page 8 of Regulating Air Emissions from Paint, STAPPA/ALAPCO Model Rule for State & Local Agencies, October 2000.

5.1.2.6 Total Emissions (from point sources and area sources)

For a specific category, stationary area source emissions are estimated using:

Area source emissions = total emissions - emissions from applicable point source segments Total emissions = (gallons of OEM coating) × (emission factors in Table 5-8) Emissions from applicable point source segments = as reported by sources (see Table 5-10)

Table 5-9 presents total emissions from coatings applied by small sources, and by larger sources that report their emissions to the Agency.

Table 5-9: Total Tons of VOC Emitted from OEM and Special Coatings

Industry Category	King Co.	Kitsap Co.	Pierce Co.	Snohomish Co.
Vehicle coating	306		11	22
Aircraft & rail equipment	1,394		74	786
Appliances	115	3	14	31
Wood furniture	329	35	228	227
Metal building products	384	11	121	243
Containers & closures	415	11	130	262
Machinery & equipment	281	7	33	75
Non-wood furniture & fixtures	535	57	371	370
Paper, film, & foils	119		51	
Electrical insulation	5			2
Powder coating	383	11	120	242
Miscellaneous industrial	375	8	78	157
Traffic markings	100	20	60	47
Interior building maintenance	306	6	64	129
Exterior building maintenance	564	11	117	237
Marine	483	39	92	208
Aerosols	193	4	40	81
Other special purpose coatings	23	1	5	10

Large sources report their emissions to the Agency annually. Table 5-10 shows VOC emissions from the coating activities of the reporting sources.

Table 5-10: Tons of VOC from Agency Point Source Coating Segments, 2005[118]

Type of Industry	King Co.	Kitsap Co.	Pierce Co.	Snohomish Co.
Vehicle coating	106			
Aircraft & rail equipment	95		40	69
Structural metal				29
Wood furniture	125		206	165
Containers	319			
Machinery & equipment	223			11
Non-wood furniture	99			
Paper & foil			18	
Marine	35			135
Other industrial coatings	82		5	

[118]Data compiled from the Agency compliance database as of August 16, 2006. See Appendix A96.

5.1.2.7 Area Source Emissions

Area source emissions = total emissions - emissions from point source coating segments

Table 5-9 showed total emissions and Table 5-10 showed emissions from point source coatings. Table 5-11 shows VOC emissions from stationary area source OEM coating applications.

Table 5-11: Tons of VOC Emitted from OEM Area Sources

Category of Industry	King Co.	Kitsap Co.	Pierce Co.	Snohomish Co.
Vehicle coating	200		11	22
Aircraft & rail equipment	1,299		33	717
Appliances	115	3	14	31
Wood furniture	205	35	22	62
Metal building products	384	11	121	213
Containers & closures	95	11	130	262
Machinery & equipment	58	7	33	65
Non-wood furniture & fixtures	436	57	371	370
Paper, film, & foils	119		33	
Electrical insulation	5			2
Powder coating	383	11	120	242
Miscellaneous industrial coatings	375	8	78	157
OEM area source totals	3,673	141	965	2,143

Table 5-12 presents VOC emissions from special coating applications.

Table 5-12: Tons of VOC Emitted from Special Coating Applications

Special Coating Application	King Co.	Kitsap Co.	Pierce Co.	Snohomish Co.
Traffic markings	43	9	26	20
Interior building maintenance	306	6	64	129
Exterior building maintenance	564	11	117	237
Marine	483	39	92	208
Aerosols	193	4	40	81
Other special purpose coatings	23	1	5	10
Total special purpose coatings	1,613	70	344	684

5.1.3 Auto Refinishing

5.1.3.1 Category Description

This category covers emissions that occur at auto refinishing shops when vehicles are painted. Vehicles in use frequently need repainting due to accidents, aging, deterioration, aesthetics, etc. Auto refinishing shops clean, prime, and apply at least two coats to the vehicle surface. The coating applied to vehicles falls under the special coating category of industrial coating. The Agency keeps auto refinishing permit data on file, and 1999-2000 permit data was used to estimate emissions for this category. Below is the source classification code (SCC) for auto refinishing.

SCC	Description
24 01 005 000	Auto refinishing coating

5.1.3.2 Key Assumption

Characteristics of permits issued to auto refinishing shops in 1999 and 2000 are still applicable in 2005. The Agency researched permits issued between January 1, 1999 and June 30, 2000 and derived average gallons of paint used per shop from the permit data submitted. The Agency assumed the 1999/2000 average used in the 2002 Agency inventory is applicable to 2005. Continuing to analyze individual permits for quantity of paint used in the 600 auto refinishing shops is unnecessary until there are indications that technical innovations would change the results significantly (e.g., higher transfer efficiency paint guns).

5.1.3.3 Estimating Equations

Gallons of coating applied = (# of shops) × (gallons/shop/year)
Lbs of VOC emitted = (gallons of coating applied) × (lbs of VOC/gallon)

Table 5-13 presents a summary of auto refinishing coating permits issued by the Agency from 1999 to 2000. From the permit data, the Agency derived the average number of gallons a refinishing shop uses per year.

Table 5-13: Characteristics of Permits Issued to Auto Body Shops, 1999 and 2000

County	Number of Permits	Gallons Used	Gallons/Shop
King	28	14937	533
Kitsap (assume Pierce)			220
Pierce	7	1537	220
Snohomish	17	4667	274

Appendix A97 presents details of the permits issued to auto body shops and the derivation of the average number of gallons of paint used by an average shop.

5.1.3.4 Activity Levels, Emission Factors, and Summary of Emissions

EPA issued a national rule in 1999 that limits VOC content in auto refinishing paint to 5.25 lbs/gallon. A refinishing shop cannot buy paint that does not comply with the VOC content requirement. From the average gallons per shop, the number of shops, and the 5.25 lbs of VOC per gallon, the tons of VOC emitted from auto refinishing were estimated and are presented in Table 5-14.

Gallons used = (number of shops) × (gallons per shop)
Tons of VOC = (gallons used) × (5.25 lbs per gallon)

Table 5-14: 2005 Refinishing Activity Levels, Emission Factors, and Emissions

County	# of Shops	Gallons/Shop/Year	Gallons Used/Year	Tons of VOC
King	377	533	200,941	527
Kitsap	37	220	8,140	21
Pierce	133	220	29,260	77
Snohomish	107	274	29,318	77
4-county region	654	409	267,659	703

5.2 Metal Cleaning

5.2.1 Category Description

This category covers VOC emissions from metal cleaning activities. Industries such as aerospace, vehicle manufacturing, metal working, and plastics manufacturing clean metals and tools by immersing them in liquid solvents or exposing them to heated solvent vapors. Cleaning in liquid solvents is called cold cleaning. Cleaning via the use of solvent vapors is called vapor degreasing. Once the metals are cleaned, they are removed and left to drip-dry, with the excess cleaning solvent draining back into the pool of solvent. Solvents need to be replenished as they are used up or evaporate. The amount of solvent replenished in a year represents the emission loss per year, less the amount of solvent disposed of off-site in liquid or waste form. Shown below are the source classification codes (SCC) for metal cleaning.

SCC	Description
24 15 300 000	Cold cleaning of metals
24 15 100 000	Open-top degreasing of metals
24 15 200 000	Conveyorized vapor degreasing of metals

5.2.2 Key Assumption

The emissions from metal cleaning activities are characteristic of the industry and proportional to the number of employees in the industry category. The EIIP guidelines recommend an employee-factor method to inventory emissions from solvent cleaning. Industries likely to clean metals and used for emission estimates are shown in Table 5-15.

5.2.3 Estimating Equations

For a category of industrial or commercial sources, the estimating equations are:

Total Emissions = (number of employees) × (lbs of VOC per employee)
Point Source Emissions = sum of emissions from metal cleaning segments
Emissions for Category = (total emissions) – (point source emissions)

Since point sources report their emissions to the Agency, no equation is used to estimate point source emissions. Rather, the emissions from the segments dedicated to metal cleaning are summarized based on reports provided by the point sources. Table 5-15 presents the number of employees in industries likely to clean metals.

Table 5-15: Number of Employees in Industries Likely to Clean Metals, 2005[119]

NAICS	Description of Industry	King Co.	Kitsap Co.	Pierce Co.	Sno Co.
331	Primary metal	1,150		632	375
332	Fabricated metal products	5,971	163	1,874	3,767
333	Machinery, equipment, and appliances	5,038	117	592	1,352
334	Computer & electronics products	10,541	246	404	4,548
335	Electrical equipment	1,750		10	680
336	Transportation equipment	37,835	175	2,494	20,280
337	Furniture & related products	2,014	214	1,395	1,391
339	Miscellaneous	4,425	543	586	1,398
8111	Automotive repair	5,713	707	2,528	1,776
8112	Electronic & electrical equip. repair	899	23	206	39
8113	Machinery, equip., & appliance repair	1,325	25	369	268
8114	HH equip. & personal goods repair	1,388	59	262	194
4411	Auto dealers	8,415	1,060	3,582	2,849
4412	Other vehicle dealers	1,630	224	619	822

[119]U.S. Census Bureau, *County Business Patterns*, Washington, 2005; accessed July 31, 2007; http://censtats.census.gov/cgi-bin/cbpnaic/cbpsect.pl.

5.2.4 Emission Factors

Table 5-16 identifies emission factors used in calculating emissions in this category.

Table 5-16: Emission Factors for Solvent Cleaning (lbs of VOC/employee)[120]

NAICS Code	Description of Industry	Cold Cleaning	Vapor Cleaning
8111 - 8114	Equipment repair	270	9.8
3310 - 3399	Manufacturing	24	9.8
3340 - 3350	Electronic and electrical	24	29
4411 - 4412	Auto dealer	270	9.8

5.2.5 Summary of Emissions

Table 5-17 presents emissions from metal cleaning activities at point sources as reported to the Agency by the point sources.

Table 5-17: Tons of VOCs Emitted by Agency Point Source Cleaning Segments[121]

Industry and Type of Cleaning	King Co.	Kitsap Co.	Pierce Co.	Sno Co.
Aerospace & vehicle mfg. cold cleaning	83		7	168
Cans, machinery, metals products cold cleaning	60			
Other manufacturing cold cleaning	10		35	
Aerospace & vehicle mfg. vapor cleaning	1			18
Other manufacturing vapor cleaning	32		5	4

For a particular NAICS category for cold cleaning or vapor cleaning:

Total tons of VOC from cleaning = (# of employees) × (lbs of VOC/employee)
Area source emissions = (total tons of VOC from cleaning) - (tons of VOC from point sources)

Table 5-18 presents VOC emissions from area source cold cleaning.

Table 5-18: Area Source Cold Metal Cleaning (tons of VOC emitted by category)

Cold Cleaning by Industry	King Co.	Kitsap Co.	Pierce Co.	Sno Co.
Equipment repair	1,259	110	454	307
General manufacturing	524	15	49	175
Electronic & electrical equip. mfg.	148	3	5	63
Auto dealers (auto repair)	1,356	173	567	496
Total cold cleaning emissions	3,287	301	1,075	1,040

Table 5-19 presents VOC emissions from area source vapor cleaning.

Table 5-19: Area Source Metal Cleaning by Vapor Cleaning (tons of VOC)

Vapor Degreasing by Industry	King Co.	Kitsap Co.	Pierce Co.	Sno Co.
Equipment repair	46	4	17	11
Misc. stationary area source mfg.	244	6	32	118
Electronic & electrical equip. mfg.	178	4	6	76
Auto dealers	49	6	21	18
Total vapor degreasing emissions	517	20	75	223

[120] U.S. EPA, *Emission Inventory Improvement Project, Vol. III*, Chapter 6, Solvent Cleaning, Table 6.5-2. http://www.epa.gov/ttn/chief/eiip/techreport/volume03/iii06fin.pdf.

[121] Agency compliance database, accessed June 2006, summarized into general categories to match cleaning category.

5.3 Petroleum Products Distribution

VOC losses occur through evaporation during distribution of petroleum products at gas stations and seaports. Historical estimates indicate emissions at airports are about 7 tons of VOC/year. The Agency considers this as insignificant because it is a very small portion of the VOC emission inventory. This is because pipelines deliver aircraft fuel to the airports and aircraft fuel is not as volatile as motor gasoline. Sea-Tac Airport estimates that VOC loss from aircraft refueling at the airport is about 6 tons per year. At 50°F, the true vapor pressure of gasoline (RVP 8) is 3.2 psia. The corresponding true vapor pressure for Jet A and JP-8 is 0.0060 psia.[122] For VOC emissions from aircraft refueling, the Agency estimated 7 tons in 1996, 6.5 tons in 1999, 6.9 tons in 2002, and 6.5 tons in 2005. Details of VOC emissions from aircraft refueling are therefore not presented here. See Appendix A98 for details of the 2005 VOC emissions from aircraft refueling.

5.3.1 Gasoline Distribution

5.3.1.1 Category Description

VOC losses occur at various points in the gasoline distribution system. This category covers VOC losses from trucks transporting gasoline from refineries and bulk stations to gasoline stations, filling of gasoline service station underground storage tanks (USTs), breathing losses while the gasoline is in the UST, and vehicle operators filling their gas tanks from the USTs.

Tank trucks transport gasoline to retail gas stations, and losses occur in transit from the bulk station to the retail station and from the retail station back to the bulk station. At the retail gas station, losses occur as the tank truck transfers gasoline into the UST. This is Stage I loss. VOCs are also emitted as the gasoline is stored in the USTs. This is called breathing loss. Filling of a vehicle gas tank with gasoline from a UST is called Stage II. Tank filling loss (Stage II loss) and spillage occur when vehicle owners fill their tanks. Shown below is the source classification code (SCC) for gas stations.

SCC	Description
25 01 060 000	Gasoline service stations

5.3.1.2 Key Assumptions

Transfers from the tank truck into USTs at retail sites are controlled. The Agency database indicates that all stations in the Agency's jurisdiction have Stage I controls. Stage I is the filling of the UST at the gasoline dispensing station.

Gas stations dispense gasoline at the midpoint of their respective dispensing ranges. The Agency registers gas stations in the following categories. Stations dispensing:

less than 200,000 gallons (100,000 gallons/year assumed)
between 200,000 and 840,000 gallons (520,000 gallons/year assumed)
between 840,000 and 1,200,000 gallons (1,020,000 gallons/year assumed)
between 1,200,000 and 3,600,000 gallons (2,400,000 gallons/year assumed)
between 3,600,000 and 6,000,000 gallons (4,800,000 gallons/year assumed)
more than 6,000,000 gallons a year (average 12 million gallons/year assumed)

Gerry Pade, Agency Engineer responsible for permitting gas stations, recommends mid-points.

[122]Vapor Pressure: AP-42, Table 7.1.2. Sea-Tac VOC estimate from aircraft refueling: Table 4, Seattle-Tacoma International Airport Non-Road Mobile and Stationary Source Operational Emission Inventories for 2000, 2007 and 2015, June 7, 2002, prepared by CDM.

A gas station that dispenses more than 6 million gallons/year averages 12 million gallons. The Agency has a long history of issuing permits to gas stations. Gerry Pade, the Agency Engineer who currently issues these permits, says the permitting database indicates that gas stations dispensing more than 6 million gallons/year average about 12 million gallons/year.

5.3.1.3 Activity Levels

Gasoline stations in the Agency's jurisdiction submit annual reports to the Agency. Tables 5-20 through 5-25 present data extracted from the Agency compliance database for gasoline stations. A controlled Stage II gasoline station nozzle captures gasoline fumes and sends the fumes back to the UST. Agency regulations require stations that dispense more than 840,000 gallons of gasoline in Kitsap County to use controlled Stage II nozzles. For all other Agency areas, a station that dispenses more than 600,000 gallons must use controlled Stage II nozzles. Table 5-20 shows the number of gasoline stations without controlled Stage II nozzles.

Table 5-20: Number of Gasoline Dispensing Stations without Stage II Controls

Category (gallons/year)	King Co.	Kitsap Co.	Pierce Co.	Sno Co.
<200,000	60	16	35	22
200,000-840,000	26	12	16	19

Table 5-21 shows the number of gallons dispensed at stations without controlled Stage II nozzles.

Table 5-21: Millions of Gallons Dispensed at Gasoline Dispensing Stations without Stage II

Category (gallons/year)	Avg/Station	King Co.	Kitsap Co.	Pierce Co.	Sno Co.
<200,000	0.1	6	2	4	2
200,000-840,000	0.52	14	6	8	10

Table 5-22 presents the number of gasoline stations with controlled Stage II nozzles.

Table 5-22: Number of Gasoline Dispensing Stations with Stage II Controls

Category (gallons/year)	King Co.	Kitsap Co.	Pierce Co.	Sno Co.
<200,000	130	24	48	42
200,000-840,000	225	32	100	102
840,000-1,200,000	114	20	59	55
1,200,000-3,600,000	217	18	82	69
3,600,000-6,000,000	13	1	3	9
>6,000,000	4	1	2	0

Table 5-23 presents gallons dispensed at stations with controlled Stage II nozzles.

Table 5-23: Millions of Gallons Dispensed at Gasoline Dispensing Stations with Stage II

Category (gallons/year)	Avg/Station	King Co.	Kitsap Co.	Pierce Co.	Sno Co.
<200,000	0.10	13	2	5	4
200,000-840,000	0.52	117	17	52	53
840,000-1,200,000	1.02	116	20	60	56
1,200,000-3,600,000	2.00	521	43	197	166
3,600,00-6,000,000	4.80	62	5	14	43
>6,000,000	12.00	48	12	24	0

Table 5-24 summarizes the gallons dispensed at gas stations.

Table 5-24: Millions of Gallons Dispensed in Agency Jurisdiction, 2005

Station Type	King Co.	Kitsap Co.	Pierce Co.	Sno Co.
Without Stage II nozzle	18	8	11	13
With Stage II nozzle	860	91	342	309
All gas stations	877	99	352	322

Table 5-25 shows the percent of gasoline dispensed through Stage II nozzles.

Table 5-25: Percent of Gasoline Dispensed with Stage II Controls

Description	King Co.	Kitsap Co.	Pierce Co.	Sno Co.
% dispensed with Stage II	98%	92%	97%	96%

5.3.1.4 Estimating Equation

VOC Emissions = (1,000 gallons transferred) × (lbs/1,000 gallons at transfer point)

5.3.1.5 Emission Factors

Table 5-26 shows the various emission factors used to estimate VOC emissions at gasoline stations and their sources. During 2002 inspections, 12% of Stage I and 28% of Stage II stations were found to be non-compliant.

Table 5-26: Emission Factors[123]

Description of Activity	Lbs of VOC/ 1,000 gallons	Comments and References
Truck transit loss – in	0.005	AP-42: Table 5.2-5 (mid-point)
Truck transit loss – out	0.055	AP-42: Table 5.2-5 (mid-point)
Transit loss round trip	0.060	Sum of losses (in and out trips)
Controlled balanced Stage I	0.300	AP-42: Table 5.2-7; 93% control
Non-compliant Stage I	4.286	Controlled / (1 - 0.93)
Weighted Stage I emission factor	0.778	EF = (0.88*0.3) + (0.12*4.286)
UST breathing	1.0	AP-42: Table 5.2-7
Uncontrolled Stage II	11.000	AP-42: Table 5.2-7
Controlled Stage II	1.100	AP-42: Table 5.2-7
Weighted Stage II emission factor	3.872	EF = (0.72*1.1) + (0.28*11)
Spillage	0.7	AP-42: Table 5.2-7

Table 5-27 presents a summary of the factors in Table 5-28.

Table 5-27: Summary of Emission Factors

Description of Activity	Lbs/1,000 gallons	Comments & References
Transit, Stage I, and breathing	1.838	EF = (0.060 + 0.778 + 1.000)
Uncontrolled Stage II and spill	11.7	EF = (11.0 + 0.7)
Controlled Stage II and spill	4.572	EF = (3.872 + 0.700)

[123] AP-42, Tables 5.2-5 and 5.2-7; http://www.epa.gov/ttn/chief/ap42/ch05/finalc05s02.pdf, July 31, 2007 and data gathered during an Agency gas station inspection & education enforcement exercise from January-April 2002.

5.3.1.6 Summary of Emissions

Emissions = (transit + breathing + Stage I + Stage II + spillage) loss

This equation simplifies to:

Emissions = (pre-Stage II loss) + (refueling loss)

Pre-Stage II loss includes loss during transit, UST filling, and breathing. Refueling loss includes loss during vehicle tank filling at the retail stations and spillage loss. Table 5-28 presents VOC emissions that occur during gasoline distribution.

Table 5-28: Tons of VOC Emissions Emitted during Gasoline Distribution, 2005

Stage of Distribution	King Co.	Kitsap Co.	Pierce Co.	Sno Co.	Region
Pre-Stage II	807	91	324	296	1,518
Without Stage II nozzle	103	47	62	75	286
With Stage II nozzle	1,966	209	781	707	3,663
Total	2,875	347	1,166	1,078	5,467

5.3.2 Vessel Loading and Unloading

5.3.2.1 Category Description

This category covers VOCs emitted by loading and unloading petroleum products at the seaports. Customers at the Ports of Everett, Tacoma, and Seattle load and unload petroleum products from tankers and barges. The vessels transfer the petroleum products to designated tanks, pipelines, trains, or vehicle tankers, which then transport the products to refineries and customers. Shown below is the source classification code (SCC) for vessel loading and unloading.

SCC	Description
25 05 020 000	Vessel loading and unloading

5.3.2.2 Key Assumption

The Agency assumes that ports not reporting petroleum products shipping have insignificant emissions from vessel loading and unloading of petroleum products. EIIP guidelines recommend inventory compilers use data reported in the Waterborne Commerce of the U.S. (WBC) as activity levels. Historical and 2005 freight handling data in the WBC shows that only Tacoma, Seattle, and Everett ports in the Agency's jurisdiction handle petroleum products. Port Gamble is the only other port in the Agency's jurisdiction that reports activity in the WBC, and it handles only rough timber products. Morrie Ensey (425) 775-4588 x230 of the Port of Edmonds said the Port does not load or unload petroleum products into vessels. Section 5.3.1 (above) includes the fuel dispensing facilities for recreational boats at the marinas.

5.3.2.3 Estimating Equation

Lbs of VOC emitted = (gallons handled) × (lbs of VOC/gallon)

5.3.2.4 Activity Levels

Table 5-29 shows the classification and density recommendations from the EIIP (Table 12.4-2 of Volume III) for common petroleum products handled at ports.

Table 5-29: Petroleum Commodities Classification and Densities[124]

Commodity	Product Classification	Product Density (lbs/gallon)
Crude petroleum	Crude oil	7.30
Gasoline, liquid natural gas	Gasoline	6.17
Kerosene & distillate oil	Distillate oil	7.05
Lube oil, waxes, greases, jellies	Distillate oil	7.05
Residual oil, petroleum coke	Residual oil	7.88
Asphalt, tar, and pitch	Residual oil	7.88
Naphtha and solvents	Jet naphtha	6.76
Other petroleum products	Jet naphtha	6.76

Table 5-30 shows the tons of petroleum products handled by the major ports in the Agency's jurisdiction as reported in the 2005 WBC.

Table 5-30: 1,000 Tons of Petroleum Products Handled at the Ports

Product	Port of Seattle	Port of Tacoma	Port of Everett
Crude petroleum	37	1,663	
Gasoline	373	516	
Kerosene & distillate oil	326	545	51
Residual oil	1,350	1,373	4
Lube oil & grease	79	43	
Petroleum jelly & wax	1	2	
Naphtha & solvents	2	18	
Asphalt, tar, and pitch	8		
Petroleum coke	18	3	
Other petroleum products	15	1	

Table 5-31 presents gallons of petroleum products handled at the ports. The gallons of fuel is derived from the tons of fuel handled at the ports (presented in Table 5-30).

Gallon of fuel = (tons of fuel) × (2,000 lbs/ton) ÷ (density of fuel, lbs/gallon)

Table 5-31: Million Gallons of Petroleum Products Handled at the Ports

Product	Port of Seattle	Port of Tacoma	Port of Everett
Crude petroleum	10	470	
Gasoline	121	167	
Kerosene & distillate oil	92	155	14
Residual oil	343	348	1
Lube oil & grease	22	12	
Petroleum jelly & wax	0	1	
Naphtha & solvents	1	5	
Asphalt, tar, and pitch	2		
Petroleum coke	5	1	
Other petroleum products	4	0	

[124]Classification: EIIP Vol III, Chapter 12, Table 12.4-2 (Marine Vessel Loading). Lbs/gallon: AP-42, Appendix A: Densities of Selected Substances.

5.3.2.5 Emission Factors

Table 5-32 presents emission factors for vessel loading and unloading activities at the ports.

Table 5-32: Emission Factors[125]

Petroleum Product Transferred	Pounds of VOC/Millions of Gallons
Crude petroleum	610
Gasoline	1,800
Kerosene & distillate oil	5
Residual oil	0.04
Lube oil & grease	5
Petroleum jelly & waxes	5
Naphtha	500
Asphalt, tar, & pitch	0.04
Petroleum coke	0.04
Other petroleum products	500

5.3.2.6 Summary of Emissions

Table 5-33 presents VOC emissions from petroleum products handling at the ports.

Table 5-33: Tons of Emissions from Petroleum Products Handling at the Ports

Product Type	Port of Seattle	Port of Tacoma	Port of Everett
Crude petroleum	3	143	
Gasoline	109	151	
Naphtha & solvents		1	
Distillate oil, residual oil, others	1		
All products	114	296	0.04

5.4 OTHER EVAPORATION

5.4.1 Asphalt Paving

5.4.1.1 Category Description

This category covers VOC emissions emitted during road surfacing. It includes the emissions at the site during the preparation of asphalt, thinners, related binders, and the surface evaporation after the asphalt has been laid. It does not include emissions at asphalt manufacturing plants.

Asphalt surfaces and pavements consist of compacted aggregates and an asphalt binder. Aggregates are natural gravel, soil, or by-products of ore-refining processes. The asphalt binder holds the aggregates together and provides a waterproof cover. Asphalt binders consist of asphalt cement and liquefied asphalt. Asphalt cement is the residue of crude oil distillation. The cement is semi-solid and must be pre-heated prior to mixing with the aggregate. There are two types of liquid asphalt:

Emulsified Asphalt, which comprises asphalt, water, and an emulsifying agent, such as soap. This makes it nonflammable and it contains about 9 lbs of VOC/barrel.

Cutback Asphalt, which is an asphalt cement thinned (or cutback) with solvents such as naphtha, residual oils, gasoline, or kerosene to make it more fluid. Depending on the desired viscosity,

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[125] U.S. EPA, *Emission Inventory Improvement Program Vol. III*, Chapter 12, Table 12.4-5 (ship column). http://www.epa.gov/ttn/chief/eiip/techreport/volume03/iii12apr2001.pdf, accessed July 31, 2007.

the proportion of thinning solvent added ranges from 25-to-45%. The amount and type of thinner used makes it rapid cure, medium cure, or slow cure. Cutback asphalt is more volatile than emulsified asphalt and contains about 88 lbs of VOC/barrel.

The pollutant of highest concern from asphalt application is VOC. Eventually, VOC in the solvents used to dilute the asphalt binder escape into the air. The Agency's Regulation II, Section 3.01 does not allow cutback asphalt application during summer months except as a penetrating prime coat on aggregate bases prior to paving, for maintenance, and when temperature is below 50°F.

Shown below are the EPA SCC codes used for the various asphalt paving processes.

SCC	Description
24 61 020 000	Asphalt application (all processes)
24 61 021 000	Cutback asphalt application
24 61 022 000	Emulsified asphalt application

5.4.1.2 Key Assumptions

The amount of asphalt applied is directly proportional to lane miles. Lane miles should reflect asphalt application better than miles of roadway. Lane miles are more closely tied to use of the roadway, which will dictate the frequency of paving and other repairs. The Emission Inventory Improvement Project (EIIP) alternate methods recommends lane miles as a metric to use when apportioning state consumption to the inventory area level (if collecting asphalt application data from city, county, and state transportation agencies is not feasible).

The Amount of asphalt applied in 2005 is the same as the quantity applied in 2004. Energy Information Agency data on asphalt application for 2005 is not yet available.

99% of asphalt applied in the Agency's jurisdiction is emulsified. Due to restrictions on cutback asphalt application, an overwhelming percentage of asphalt applied is emulsified. Steve Landers, Supervisor at WA DOT Material Lab in Olympia (360) 709-5423, estimates that about 99% of asphalt applied statewide is emulsified.

5.4.1.3 Estimating Equations

The equations used to determine county asphalt application are:

County asphalt = (co. lane miles) ÷ (WA lane miles) × (WA asphalt applied)
Emulsified asphalt applied in county = 0.99 x barrels of asphalt applied in county
Cutback asphalt applied in county = 0.01 x barrels of asphalt applied in county
Lbs of VOC from application = (barrels of asphalt applied) x (lbs of VOC/barrel)

5.4.1.4: Activity Levels

Washington State consumed 3,313 barrels of asphalt in 2004.[126]

Table 5-34 shows the percent distribution of applied asphalt and the emission factors for each type of application.

[126] Quantity of Asphalt Applied: Energy Information Administration, *State Energy Data System*, 2004 draft report, Table F8: Asphalt and Road Oil and Other Petroleum Products Consumption by Sector and by State, 2004; http://www.eia.doe.gov/emeu/states/sep_fuel/html/pdf/fuel_ar_po.pdf. Percent distribution: August 27, 2007, call from Steve Landers, Supervisor at WA DOT Material Lab, Olympia, (360) 709-5423 or landers@ws.dot.wa. Lbs of VOC/barrel: Table 17.5-2, Asphalt Paving Emission Factors, EIIP Vol III, Chapter 17.

Table 5-34: Characteristics of Asphalt Application in Washington State, 2005[127]

Asphalt Type	% of Asphalt Applied	Lbs of VOC Emitted/Barrel
Emulsified	99%	9.2
Cutback	1%	88

Table 5-35 shows lane miles and barrels of asphalt applied to roadways in 2005.

Table 5-35: Lane Miles and Barrels of Asphalt Applied

County/Area	Lane Miles	Barrels of Emulsified	Barrels of Cutback
Washington State	173,965	3,279,870	33,130
King County	17,993	339,228	3,427
Kitsap County	3,626	68,356	690
Pierce County	10,826	204,118	2,062
Snohomish County	8,489	160,042	1,617

5.4.1.5 Summary of Emissions

Table 5-36 presents VOC emissions from asphalt paving.

Table 5-36: Tons of VOC from Asphalt Application

County	Emulsified	Cutback	Total Tons of VOC
King	1,560	151	1,711
Kitsap	314	30	345
Pierce	939	91	1,030
Snohomish	736	71	807
Agency Area	3,549	343	3,893

5.4.2 Printing (graphic arts)

5.4.2.1 Category Description

This category covers evaporation that occurs when printing ink is applied to paper in industries such as newspaper production, printed advertisement, and commercial art. Printing inks fall into four main groups: (1) water-based, (2) soy-based, (3) alcohol-based, and (4) other solvent-based. Soy- and water-based inks have less VOCs than alcohol- and solvent-based inks. Many operations not directly involved in printing have small in-house printing jobs, and households also do some printing. Thus, emissions of VOC from printing are best estimated by per capita methods. The Emission Inventory Improvement Project (EIIP) guidelines recommend inventory compilers use a per capita method if emissions from printing are not a critical piece of the inventory. In 1996 and 1999, ten printing sources reported VOC emissions from printing operations to the Agency. In 2005, only Pliant Corporation (in King County) reported VOC emissions to the Agency. The others have improved operations or use inks with lower VOC content and fall below the reporting thresholds. Shown below is the EPA source classification code (SCC) for printing.

SCC	Description
24 25 000 000	All categories of printing (all solvents)

[127] Percent applied: call from Steve Landers, (360) 709-5423, WA DOT Material Lab, September 28, 2007; pounds of VOC per barrel: EIIP, Vol III, Chapter 17, Section 5 (Alternate Methods), Table 17.5-2, September 28, 2007.

5.4.2.2 Key Assumption

EIIP's per capita 1.3 lbs of VOC/person is representative of the Puget Sound area. Page 7.5-10, Section 5.2, Chapter 5 (Alternate Methods), of Chapter EIIP Vol III recommends 1.3 lbs of VOC per capita from printing operations. Soy- and water-based inks are replacing the alcohol and solvent inks. The 1.3 lbs of VOC/person is a 1991 estimate and likely a conservative high-end 2005 estimate. For lack of better data, the Agency used the latest EIIP per capita value of 1.3 lbs of VOC/person.

5.4.2.3 Estimating Equation

Tons of VOC emitted by stationary area source printing operations are estimated with:

$$\text{Tons of VOC} = [(1.3 \text{ lbs} \times \text{population}) \div 2000] - (\text{tons of point source VOC})$$

Pliant Corporation is the only source reporting VOC emissions from printing operations.

5.4.2.4 Activity Levels and Summary of Emissions

Table 5-37 presents population, total tons of VOC from printing operations, Pliant Corporation's emissions from printing operations, and VOC emissions from stationary area source printing.

Table 5-37: Tons of VOC from Printing Operations

County	Population	Tons of VOC at 1.3 lbs/person	Tons of VOC from Point Sources	Tons of VOC from Area Sources
King	1,808,300	1,175	69	1,116
Kitsap	240,000	156	-	156
Pierce	755,900	491	-	491
Snohomish	655,800	426	-	426

Many point sources have improved their printing ink formulations, thereby reducing VOC emissions from their printing segments, and no longer report their emissions to the Agency. Thus VOCs from printing that used to be attributed to point sources are now counted as area source emissions. This could lead to an increase in emissions from area source printing even as emission from all printing operations decline.

5.4.3 Baking

5.4.3.1 Category Description

This category covers VOC emissions from baking processes and activities at commercial bakeries, retail bakeries, and in homes. Baking involves fermentation processes that release VOCs. VOCs from baking processes are predominantly ethanol.

Commercial bakeries bake bread, pastry, etc. on a large scale and distribute them regionwide for sale. Examples of commercial bakeries include United States Bakery, Pacific Northwest Baking Co., and Sara Lee. Retail bakeries are smaller than commercial bakeries and usually have dedicated customers and produce customized bakes. They may be stand-alone or located in a grocery store, such as Safeway, Albertson's, Costco, or QFC. Four bakeries in King and Pierce counties emit VOCs at levels requiring them to report emissions to the Agency. Since a significant amount of baking occurs in homes, VOC emissions from home baking are also included in this inventory. Below is the EPA source classification code (SCC) for baking.

SCC	Description
23 02 050 000	Baking

5.4.3.2 Key Assumption

The pounds of VOC per employee from the bakeries that report emissions to the Agency apply to all commercial bakeries in the four-county jurisdiction. Three bakeries in King County and one bakery in Pierce County reported emissions to the Agency in 2005. The Agency assumed these as the largest bakeries in the counties and estimated the number of their employees from the 2005 County Business Patterns. From the reported emissions and estimated number of employees, the Agency estimated the pounds of VOC emitted per employee for the baking industry in the Puget Sound area.

5.4.3.3 Estimating Equations

VOCs emitted from home baking are estimated in two steps:

Step 1: Tons of home-baked products = # of persons × lbs of products/person ÷ 2000

Step 2: Tons of VOC from home baking = tons of products × lbs of VOC/ton ÷ 2000

For commercial baking, the equations are:

Total Tons of VOC from baking = # of employees × lbs/employee ÷ 2000
VOC from area sources = total tons of VOC - tons of VOC from bakery point sources

5.4.3.4 Home Baking

The Emission Inventory Improvement Project (EIIP) gives the national per capita of home-baked goods[128] as 70 lbs/person and the home baking emission factor as 16 lbs/ton baked. Combining these factors with population, the Agency estimated VOC emissions from home baking as shown in Table 5-38, which presents the county population, the tons of home-baked products, and the VOCs emitted from home baking.

Table 5-38: Home-Baking Activity Levels and Emissions

County	Population	Tons of Baked Products	Tons of VOC from Home Baking
King	1,808,000	63,291	506
Kitsap	240,000	8,414	67
Pierce	756,000	26,457	212
Snohomish	656,000	22,953	184
4-co. region	3,460,000	121,114	969

5.4.3.5 Commercial Baking

To estimate VOC emissions from commercial baking, EIIP recommends a locally-derived per employee factor and number of baking employees. Table 5-39 presents pounds of VOC emitted from the baking segments of bakeries that report emissions to the Agency, the number of employees at the bakeries that report emissions, and the pounds of baking emissions/employee.

Lbs of VOC/employee = (lbs of VOC emitted) ÷ (# of employees)

[128] EIIP Vol III, Baking Abstract, page 2, http://www.epa.gov/ttn/chief/eiip/techreport/volume03/bakeries.pdf.

Table 5-39: 2005 VOC Emissions and Employees at Bakeries Reporting Emissions

Point Source	Lbs of VOC	# of Employees	Lbs of VOC/Employee
U.S. Bakery – So. Weller St. (King Co.)	172,885	750	231
U.S. Bakery – 6th Ave. So. (King Co.)	111,906	380	294
Pacific Northwest Baking Co. (Pierce Co.)	62,569	500	125
Safeway stores (King Co.)	45,703	180	254
All baking point sources	393,063	1,820	217

Table 5-40 shows 2005 bakery employment for the four counties.

Table 5-40: Employment in the Baking Industry, 2005

County	Commercial Bakery Employment	Retail Bakery Employment	Total Bakery Employment
King	2,153	375	2,528
Kitsap		60	60
Pierce	750	60	810
Snohomish	209	60	269

Table 5-41 presents VOC emissions from commercial baking.

Table 5-41: Tons of VOC Emissions from Commercial Baking (at 217 lbs/employee)

County	Total Tons of VOC Emitted	Tons of VOC from Point Sources	Tons of VOC from Area Sources
King	275	166	109
Kitsap	7		7
Pierce	88	31	57
Snohomish	29		29

5.4.3.6 Summary of Emissions

Table 5-42 shows VOC emissions from home, commercial, and total area source baking.

Table 5-42: Tons of VOC from Home and Commercial Area Source Baking, 2005

County	Home Baking	Commercial Baking	Total
King	506	109	615
Kitsap	67	7	74
Pierce	212	57	269
Snohomish	184	29	213
4-county region	969	202	1,171

5.4.4 Pesticide Application

5.4.4.1 Category Description

This category covers emissions from the application of pesticides on farms, cemetery lawns, golf courses, parks, and along roads. Many of the active and inert ingredients in pesticides are VOCs. The VOCs in pesticides themselves, and the solvent carriers, eventually escape into the air. This category does not include household pesticides used in homes and on household lawns.

Household pesticide application is included in Section 5.4.5 (Consumer Products). Users of pesticides add solvent carriers, usually petroleum distillates, to the pesticides they apply. Shown below is the EPA source classification code (SCC) for pesticide application.

SCC	Description
24 61 800 000	Pesticide application

5.4.4.2 Key Assumptions

All pesticides and solvent carriers eventually evaporate, and each pound of non-agricultural active pesticide requires 1.45 lbs of solvent carrier.[129] Pesticides themselves are organic. To apply pesticides, users need to dissolve them in solvents to make spray application easier. It is difficult to estimate the volatile fraction of the active pesticide. The non-volatile fraction of the active pesticide stays in the ground or on the sprayed plants. This inventory conservatively assumes that all the active pesticides eventually evaporate along with the carrier solvent. Thus the estimates presented here are overestimates.

5.4.4.3 Estimating Equation

For pesticide applications, the equation is:

$A = B \times C \times D$

where

- A = pounds of VOC emitted from pesticide application
- B = number of units receiving applied pesticide
- C = pounds of pesticide per unit receiving the pesticide application
- D = pounds of solvent per pound of pesticide applied, 1.45

5.4.4.4 Activity Levels and Emission Factors

Table 5-43 presents types of facilities that receive pesticide application, the rate of application, and the source for the rate of application data.

Table 5-43: Agricultural Pesticide Application Emission Factors[130]

Application Type	Pesticide Use	Reference
Agricultural	66.6 lbs/planted acre	WA Agric Statistics, 2002
Road	2.11 lbs/road mile	King Co. Public Works Dept.
Park & golf course	5.10 lbs/park or golf course	King Co Parks & Recreation
Carrier solvent	1.45 lbs of solvent/lb of pesticide	EPA 450 / 4-91-016, page 32

Table 5-44 presents the number of facilities, road miles, and acres planted for the four counties in the Agency's jurisdiction.

[129] Source: Procedures for Preparation of Emissions Inventories for CO and Precursors of Ozone, Vol. 1, Stationary Area Sources, EPA 450/4-91-016, Ann Arbor, MI, 1992.

[130] U.S. Dept. of Agriculture, National Agricultural Statistics Service, Washington Field Office. Planted Acres: 2005 WA Agricultural Statistics. The 66.6 lbs/acre is an average application rate derived from several tables in the 2002 WA Agricultural Statistics; available at: http://www.nass.usda.gov/wa. E-mail from Pat Whitaker, WA Dept. of Transportation Data Office, HPMS Classification Manager, GIS Liaison, 2005 Highway Performance Monitoring System (HPMS). The number of cemeteries, golf courses, and parks was derived from The Thomas Guide, Thomas Bros. Maps, Rand McNally, 2006. Puget Sound Clean Air Agency, 1990 Emission Inventory. Application rates provided by King Co. Public Works Dept. and Dept. of Parks & Recreation. Lbs of carrier solvent/lb of active pesticide: Procedures for Emission Inventory, EPA 450/4-91-016, 1991, page 32.

Table 5-44: Facilities Receiving Pesticide Application[131]

County	Acres Planted	Road Center Miles	# of Cemeteries	# of Golf Courses	# of Parks
King	800	7,977	59	54	764
Kitsap		1,721	5	12	110
Pierce	300	5,030	27	30	238
Snohomish	8,200	3,954	31	23	220

5.4.4.5 Summary of Emissions

Table 5-45 presents VOC emissions from pesticide application on farms, along roads, and in cemeteries, parks, and golf courses.

Table 5-45: Estimated Tons of VOC Emissions from Pesticide Application, 2005

County	Farms	Roads	Cemeteries, Parks, Golf Courses	Total
King	65	21	6	91
Kitsap		4	1	5
Pierce	25	13	2	39
Snohomish	669	10	2	681

5.4.5 Consumer Products

5.4.5.1 Category Description

This category covers VOCs emitted into the air when people use consumer items. Product manufacturers use solvents as carriers in cosmetics, household cleaners, consumer products, lawn pesticides, common adhesives, sealants, and auto aftermarket paints, thinners, and varnishes. These kinds of products, listed in Table 5-46, contain VOCs that are released into the ambient air when used.

Table 5-46: Examples of Consumer Products that Emit VOC when Used

Type of Consumer Product	Product Examples
Personal use	Hair care, fragrance, oral care, nail care, powder
Household	Surface cleaner, air freshener, polish, etc.
Auto aftermarket	Detailing, repair, windshield, adhesives, sealants
Insecticides & fungicides	Insecticide, fungicide, herbicide, rodenticide, etc.
Coatings & related products	Aerospray, hand-held coating-related products
Miscellaneous products	Arts & crafts supplies, veterinary & pet products, etc.

Shown below are the EPA source classification codes (SCC) for these products.

SCC	Description
24 60 100 000	Personal care
24 60 200 000	Household products
24 60 400 000	Auto aftermarket
24 60 500 000	Consumer coating products
24 60 600 000	Adhesives and sealants
24 60 800 000	Consumer pesticides
24 60 900 000	Miscellaneous

[131] Acres planted: WA State Agric. Statistics, 2002. Road center miles: 2005 HPMS Miles & VMT by County from Pat Whittaker, WA DOT, whittap@wsdot.wa.gov, September 28, 2007. Cemeteries, golf courses, & parks: The Thomas Guide 2006, King, Pierce, & Snohomish counties; and The Road Runner, Kitsap Co. Street Atlas, 2002.

5.4.5.2 Key Assumption

The quantity of VOCs emitted from consumer products is proportional to human population. EIIP guidelines recommend emission compilers use per capita VOC emission factors to estimate VOC emissions from consumer items. EIIP Vol III, Chapter 5 provides per capita factors for various types of consumer items. EPA estimated these factors with the 1991 VOC content of the products. Current products may now have lower VOC contents. Estimates produced with the 1991 factors (the latest available) are likely to be overestimates.

5.4.5.3 Estimating Equation

lbs of VOC emitted for category = # of persons × lbs of VOC/person

5.4.5.4 Activity Levels, Emission Factors, and Summary of Emissions

Table 5-47 presents human population.

Table 5-47: Human Population[132]

County	Human Population (x 1,000)
King	1,808
Kitsap	240
Pierce	756
Snohomish	656
4-county region	3,460

Table 5-48 presents per capita emission factors for consumer items.

Table 5-48: Pounds of VOC per Person[133, 134]

Consumer Product	Pounds per Person
Personal care	2.3
Household products	0.8
Auto aftermarket	1.4
Adhesives, sealants	0.6
Consumer pesticides	1.8
Consumer coatings	1.0
Miscellaneous	0.1

Table 5-49 presents emissions of VOCs from the various types of consumer items.

Table 5-49: Tons of VOC Emitted per Year from Consumer Product Solvents

Product	King Co.	Kitsap Co.	Pierce Co.	Sno Co.	Region
Personal care	2,098	279	877	761	4,014
Household products	714	95	299	259	1,367
Auto aftermarket	1,230	164	514	446	2,351
Adhesives, sealants	515	69	215	187	986
Consumer pesticides	1,609	214	673	584	3,080
Consumer coatings	859	114	359	312	1,644
Miscellaneous	63	8	27	23	121
Total consumer	7,089	942	2,963	2,571	13,565

[132] Washington State Office of Financial Management, *2005 Washington Population Trends*, Table 4.

[133] U.S. EPA, *Emission Inventory Improvement Program, Vol. III*, Chapter 5, Consumer Solvents, Table 5.4-1. Available at: http://www.epa.gov/ttn/chief/eiip/techreport/volume03/iii05.pdf.

[134] U.S. EPA, *Emission Inventory Improvement Program, Vol. III*, Chapter 7, page 7.5-10. Available at: http://www.epa.gov/ttn/chief/eiip/techreport/volume03/iii07.pdf.

5.4.6 Paint Manufacturing

5.4.6.1 Category Description

This category covers VOCs emitted during paint manufacturing. The surface coatings section (Section 5.1) covers emissions from paint application. Paint manufacturing involves adding, mixing, and retrieving various chemicals in large vats. VOCs escape when operators open vats to add or retrieve chemicals. New regulations have reduced emissions from paint manufacturing facilities. Of the paint manufacturers in its jurisdiction, only Parker Paint Manufacturing Co. Inc. (in Tacoma) reports emissions to the Agency. Employment information published in the 2004 County Business Patterns from the U.S. Census Bureau indicates Kitsap and Snohomish counties do not have paint manufacturing facilities. Shown below is the EPA source classification code (SCC) for paint manufacturing.

SCC	Description
23 02 050 000	Paint manufacturing

5.4.6.2 Key Assumption

Each paint manufacturing facility emits 40 lbs of VOC per employee, per year. Based on emission data supplied by Parker Paint and the number of employees at Parker, the emission factor for paint manufacturing emissions is estimated as 40 lbs of VOC per employee. This was applied to other paint manufacturing facilities in the Agency four-county jurisdiction. The Agency assumed Parker Paint is the largest paint manufacturer in Pierce County. From County Business Patterns, the largest paint manufacturer in Pierce County had 170 employees in 2005. Parker Paint emitted 6,730 lbs of VOC from its paint-mixing segments in 2005. Therefore pounds of VOC per Parker Paint employee comes to about 40 lbs of VOC/employee. The Emission Inventory Improvement Project does not have recommended procedures or emission factors for area source paint manufacturing.

5.4.6.3 Estimating Equation

$$\text{Lbs of VOC emitted} = (\text{number of employees}) \times (40 \text{ lbs of VOC/employee})$$

5.4.6.4 Activity Levels, Emission Factors, and Summary of Emissions

Table 5-50 presents the number of employees involved in paint manufacturing and the number of tons of VOC emitted during paint manufacturing.

Table 5-50: Paint Manufacturing Employees and Emissions

County	Number of Employees	Tons of VOC Emitted
King	233	5
Kitsap	-	-
Pierce	175	4
Snohomish	-	-

5.4.7 Sewage Treatment Facilities

5.4.7.1 Category Description

This category covers emissions from wastewater treatment plants. Pipelines carry wastewater from homes as well as from commercial, institutional, and industrial plants to sewage treatment facilities for treatment and then discharge into open waters. The treatment procedures, and burning of methane produced by the treatment, emit VOCs and greenhouse gases. Due to effective controls, most sewage treatment facilities do not emit VOCs at levels requiring them to report emissions to the Agency. The King County Department of Natural Resources wastewater treatment plants at Metro West Point in Seattle and South Plant in Renton are the only sewage treatment plants that report VOC emissions from sewage treatment to the Agency. Shown below is the EPA source classification code (SCC) for sewage treatment facilities.

SCC	Description
26 30 020 000	Sewage treatment facilities

5.4.7.2 Key Assumptions

Emissions from a wastewater treatment plant are proportional to the air flow rate through the odor control equipment installed at the plant. The wastewater facilities do not emit enough pollutants to report emissions to the Agency but they are required to have a permit to operate. Some plants indicated the quantity of wastewater treated in a day. Most facilities indicated the air flow rate through the odor control equipment they need to process the wastewater and sludge. The air flow rate through the odor control equipment is used as a surrogate to estimate emissions from the non-reporting facilities. A surrogate is a substitute used in place of another quantity that is not available or more difficult to obtain.

The throughput for a wastewater treatment facility that has no data on throughput or air flow rate through the odor control equipment is 5 million gallons/day. Where the permit for a facility does not list the air flow rate through the odor control equipment, the daily throughput rate of wastewater, if given, is used as a surrogate to estimate the emissions for the facility. Claude Williams, the Agency Engineer who permits waste treatment plants, recommends 5 million gallons/day throughput for facilities that have no data.

Metro West Point emissions are an appropriate surrogate to use for non-reporting facilities. The 2003 Inventory of King County Air Emissions report has doubts about the emission levels at the South Plant (Renton) "because the system for injecting digester gas into the pipeline may suffer significant leakage". Metro West Point treats 145 million gallons/day; emitting 7,200 lbs of VOC per year, 3.7 tons of N_2O per year, and producing 115 tons of CH_4 per year.[135] Metro West Point VOC emissions come from the sewage treatment/primary system segment of the facility. The South Plant (Renton) VOC emissions come from the solid waste disposal segment of the facility. A review of the Notices of Construction the Agency has issued for the facilities indicates the odor control equipment was for primary and secondary systems of the sewage treatment. The Metro West Point plant is therefore a better surrogate to use for non-reporting facilities.

The wastewater treatment facilities burn the methane they produce. According to Claude Williams, the Agency Engineer who permits waste treatment plants, the wastewater treatment plants do not emit the methane they produce. They flare the methane they produce or burn it in engines, turbines, or boilers. This inventory assumes wastewater plants burn or flare the methane they produce and estimates the carbon dioxide emissions from the methane burning. Burning one ton of methane stoichiometrically produces 2.75 tons of carbon dioxide.

5.4.7.3 Estimating Equations

Emissions of VOC and nitrous oxide from a facility and the methane produced at a facility are estimated from the equation:

[135] Metro West Point reported 7,200 lbs of VOC to the Agency in its 2004 report. Table 8 of the 2003 Inventory of King County Air Emissions, Revision D, December 28, 2004, compiled by Roel Hammerschlag, reports that Metro West Point emitted 3.7 tons of N_2O and produced 115 tons of CH_4.

A = (B ÷ C) × D

where

A = emissions (or methane production) from a wastewater treatment facility
B = air flow rate through the facility's primary odor control equipment
C = Air flow rate through West Point's primary odor control equipment (75,000 cfm)
D = Metro West Point's emissions of specific pollutant

If the flow rate through the facility's odor control equipment is not available and the daily throughput of wastewater treated is available, the estimating equation becomes:

A = (B ÷ C) × D

where

A = emissions from a wastewater treatment facility
B = gallons of wastewater treated at the facility/day
C = gallons of wastewater treated at West Point/day (145 million)
D = Metro West Point's emissions of specific pollutant

A few facilities have no information on quantity of wastewater treated or the air flow rate through the odor control equipment. The Agency assumes such facilities treat 5 million gallons/day.[136] Appendix A99 presents details of the wastewater facilities, flow rate through the odor control equipment, and daily wastewater throughput from each facility.

5.4.7.4 Summary of Emissions

Table 5-51 presents tons of VOC and N_2O emitted from wastewater treatment and tons of methane produced at the wastewater treatment facilities.

Table 5-51: Wastewater Facilities, VOC Emitted, Methane Produced, and N_2O Emitted, 2005

County	Facilities	Tons of VOC Emitted	Tons of CH_4 Produced	Tons of N_2O Emitted
King	26	14	453	15
Kitsap	5	3	94	3
Pierce	13	4	115	4
Snohomish	13	3	94	3
4-county region	57	24	757	25

Table 5-52 summarizes emissions from wastewater facilities in 2005.

Tons CO_2 eqv = (tons of CO_2 from CH_4 burning) + (310 × [tons N_2O emissions])

Table 5-52: Tons of Emissions from Sewage Treatment, 2005

County	VOC	Tons CO_2 (from CH_4 burn)	CO_2 Eqv from N_2O	Total CO_2 Eqv
King	14	1,245	4,544	5,789
Kitsap	3	259	943	1,203
Pierce	4	317	1,153	1,470
Snohomish	3	260	944	1,204
4-county region	24	2,081	7,584	9,665

[136]Claude Williams, Agency Engineer responsible for permitting waste treatment plants, (206) 689-4066.

5.4.8 Soil and Groundwater Remediation

5.4.8.1 Category Description

This category covers emissions from soil and groundwater clean-up activities. Storage tanks at gas stations, industrial facilities, dry cleaners, and other establishments occasionally leak. The leakage can be due to normal wear, rusting, or industrial accident. When tanks leak, contaminants spill into the surrounding soil and groundwater. To clean up these contaminants, Agency Regulation I, Section 6.03(c) requires the owner of the property to obtain a soil and groundwater remediation (SGR) permit from the Agency. SGR involves injecting air into the contaminated soil or groundwater. The injected air picks up the contaminants from the soil or groundwater. The now-contaminated air is extracted and passed through control equipment that strips out the contaminants before venting the cleaned air into the atmosphere. The products spilled primarily emit VOCs. Below is the EPA source classification code (SCC) for soil and groundwater remediation.

SCC	Description
26 30 020 000	Soil and groundwater remediation

5.4.8.2 Key Assumption

Only projects permitted in the last four years are still active. Clean-up projects of this nature typically last four years or less.

5.4.8.3 Estimating Equation

Lbs of VOC emitted = lbs/year from projects permitted in the last 4 years

5.4.8.4 Activity Levels and Summary of Emissions

To determine activity level, the Agency queried its data base for the number of SGR projects permitted after December 31, 2001. The notice of construction worksheets of the permits contain estimated controlled emissions per year, which were then totaled to arrive at the figures in Table 5-53.

Table 5-53: Activity Levels and VOC Emissions from SGR, 2005

County	# of Projects	Lbs Estimated	Tons of VOC Emitted
King	25	35,485	18
Kitsap	-	-	-
Pierce	1	112	0
Snohomish	3	1,821	1
4-county region	29	37,418	19

6 Other Criteria Pollutant Sources

6.1 Particulate Matter from Dust

6.1.1 Particulate Matter from Roads

6.1.1.1 Category Description

This category covers fugitive dust emissions from road surfaces as vehicles move over them. Vehicle traffic on roads kicks up dust. Some of the factors that affect the quantity of dust re-suspended include the type of road surface (paved, unpaved, or surface silt), how well the road is maintained, vehicle weight, vehicle miles traveled, and precipitation. The smaller the dust particles, the longer they take to fall to the ground. Winds can transport such disturbed dust far from the source.

There is a current debate in the inventory community about how to account for re-suspended dust that is repeatedly kicked up. The estimates presented in this report adopted the 2002 National Emissions Inventory (NEI). The NEI follows the EIIP guidelines and AP-42 factors. These guidelines and factors do not account for the dust that falls to the ground and then is re-suspended. The emissions presented are therefore overestimates.

Shown below are the EPA source classification codes (SCC) for fugitive dust from roads.

SCC	Description
22 94 000 000	Fugitive dust from paved roads
22 96 000 000	Fugitive dust from unpaved roads

6.1.1.2 Key Assumptions

2002 National Emissions Inventory (NEI) estimates for road fugitive dust, construction fugitive dust, and commercial meat cooking particulate matter are projected to 2005 with surrogates. The Agency adopted the 2002 NEI. Emissions for these categories have a high level of uncertainty because of depositions, re-suspension, and poor emission factors. Estimates could be off by an order of magnitude. The 2005 emissions are projected from the 2002 EPA NEI estimates with VMT, heavy construction employment, and restaurant employment.

Average vehicle weight in 2002 and 2005 are the same. The 2005 emissions are projected from the 2002 EPA NEI estimates. The estimating equation NEI used to estimate the 2002 emissions is a function of the average weight of all vehicles using the roads. The projection assumes that average vehicle weight for 2002 and 2005 are the same.

Fugitive dust kicked up by vehicles is mitigated by precipitation. Paving roads is the most effective way to control fugitive road dust. Even for paved roads, when vehicles travel wet roads they kick up less dust. For unpaved roads, watering is the best way to reduce fugitive road dust. In the Puget Sound area, the continual drizzle is a natural control for fugitive dust emissions.

Road dust emissions = (uncontrolled emissions) × (annual precipitation factor)[137]

More rainy days lead to lower precipitation factors and therefore lower fugitive emissions. The amount of precipitation in 2005 relative to 2002, therefore, affects the 2005 estimates.

6.1.1.3 Estimating Equations

Equations from AP-42, Chapter 13, Sections 13.2.1 and 13.2.2 are equations EPA used to estimate road dust emissions for the 2002 NEI. For this inventory, the 2002 NEI for road dust was updated with vehicle miles traveled (VMT) and annual precipitation as the surrogates.

[137] AP-42: fugitive dust emissions from paved roads, page 13.2.1-6, equations 1 and 2; and fugitive dust emissions from unpaved roads, page 13.2.2-7, equations 1a, 1b, and 2.

A = (B ÷ C) × (D ÷ E) × F

where

A = 2005 road fugitive dust emissions
B = 2005 vehicle miles traveled
C = 2002 vehicle miles traveled
D = 2005 annual precipitation factor (PF)
E = 2002 annual precipitation factor (PF)
F = 2002 road fugitive dust emissions

For paved roads:

Annual precipitation factor = 1 - [(number of wet days)/1,460]

For unpaved roads:

Annual precipitation factor = (365 - number of wet days)/365)

A wet day is a day with at least 0.01" (0.254 millimeters) of rain.

6.1.1.4 Activity Levels and Summary of Emissions

Table 6-1 shows VMT used as a surrogate. The 2002 VMT and emissions come from the 2002 NEI. The 2005 VMT is from the 2005 Highway Performance Monitoring System (HPMS) as provided by the WA State Dept. of Transportation Data Office.

Table 6-1: Vehicle Miles Traveled (million VMT)[138]

County	2002	2005
King	16,188	16,500
Kitsap	1,556	1,604
Pierce	6,035	6,060
Snohomish	5,232	5,267

Table 6-2 presents number of wet days and precipitation factors for roads.

Table 6-2: Wet Days[139] and Precipitation Factors (PF)

Year	Number of Wet Days	Paved Road PF (%)	Unpaved Road PF (%)
2002	140	90.4%	61.6%
2005	152	89.6%	58.4%

Table 6-3 presents fugitive dust emissions from roads for 2002 and 2005.

Table 6-3: Fugitive Dust Emissions, tons of $PM_{2.5}$

County	Paved Road Dust 2002	Unpaved Road Dust 2002	Paved Road Dust 2005	Unpaved Road Dust 2005	Total Road Dust 2005
King	609	710	615	685	1,300
Kitsap	272	535	278	522	800
Pierce	328	606	326	576	902
Snohomish	536	774	535	737	1,272

[138] 2002 VMT from the 2002 NEI and presented in the Agency 2002 Emission Inventory; 2005 vehicle miles traveled provided by Pat Whittaker of WA State Department of Transportation, whittap@wsdot.wa.gov.

[139] Sea-Tac Meteorological Data, annual summaries for 2002 and 2005.

Again, it is important to note that the emission estimates provided in Table 6-3 are likely gross overestimates.

6.1.2 Particulate Matter from Construction

6.1.2.1 Category Description

This category covers fugitive dust emissions that result from construction activity. It does not include exhaust emissions from the construction equipment. Activities such as building and road construction produce fugitive dust and also re-suspend dust into the air. Continual watering, hosing down construction trucks and machinery, covering truck loads, and covering sand heaps minimize dust emissions. The smaller the dust particles, the longer they take to fall to the ground. Winds can transport such disturbed dust far from the source.

Shown below are the EPA source classification codes (SCC) for construction dust.

SCC	Description
23 11 010 000	Fugitive dust from residential building construction
23 11 020 000	Fugitive dust from non-residential building construction
23 11 030 000	Fugitive dust from road construction

6.1.2.2 Key Assumption

Emissions from construction dust are directly proportional to heavy construction employment (NAICS 2361, 2362, 2373). Surrogates one can use to estimate construction activity include expenditure on construction projects and number of people working in the industry. Employment data is easy to obtain at county levels but expenditure data is hard to get. The Census Bureau publishes construction expenditure data every five years in the Economic Census. The most recent construction expenditure available is 2002 data, published in 2005. More recent (2005) construction employment data is available, and is used in this report.

6.1.2.3 Estimating Equation

For this inventory, the 2002 National Emissions Inventory (NEI) for construction dust was updated with construction employment as the surrogate.

$A = (B \div C) \times D$

where
- A = 2005 fugitive dust emissions from construction activities
- B = 2005 heavy construction employment
- C = 2002 heavy construction employment
- D = 2002 fugitive dust emissions from construction activities

6.1.2.4 Activity Levels and Summary of Emissions

Table 6-4 shows construction employment used as a surrogate. The 2002 emissions come from the 2002 NEI. The construction employment information is from the County Business Patterns statistics.[140] As with the road fugitive dust emissions, there is a debate in the inventory community about how to account for dust that is repeatedly kicked up. The 2002 NEI estimates did not take account of the re-suspension of the dust that falls down. The dust emissions

[140] U.S. Census Bureau, County Business Patterns. Available at: http://censtats.census.gov/cbpnaic/cbpnaic.shtml.

presented here are therefore overestimates. Tables 6-4 and 6-5 present construction employment for 2002 and 2005.

Table 6-4: Construction Employment, 2002

County	Residential Construction	Non-Residential Construction	Road Construction
King	8,531	8,091	2,202
Kitsap	972	296	170
Pierce	1,914	1,528	463
Snohomish	2,355	1,106	1,000

Table 6-5: Construction Employment, 2005

County	Residential Construction	Non-Residential Construction	Road Construction
King	9,646	6,196	3,488
Kitsap	1,170	139	232
Pierce	2,636	1,862	861
Snohomish	2,831	1,168	1,128

Tables 6-6 and 6-7 show fine dust emissions from construction activities in 2002 and 2005.

Table 6-6: Tons of $PM_{2.5}$ Emitted from Construction Activities, 2002

County	Residential Construction	Non-Residential Construction	Road Construction
King	35	698	245
Kitsap	10	34	106
Pierce	30	193	282
Snohomish	44	241	448

Table 6-7: Tons of $PM_{2.5}$ Emitted from Construction Activities, 2005

County	Residential Construction	Non-Residential Construction	Road Construction
King	40	534	388
Kitsap	12	16	145
Pierce	41	235	525
Snohomish	51	255	505

6.1.3 Particulate Matter from Quarrying Activity

6.1.3.1 Category Description

This category covers particulate matter from quarrying activities. Quarrying is a form of mining and involves breaking up stones and preparing aggregates to construction contractors' specifications. Construction activities require materials from quarries. Activities that generate dust at quarries are similar to those that generate dust at construction sites, and the methods used to suppress dust at construction sites also work at quarry sites. Continual watering, hosing down quarry trucks and machinery, covering truck loads, and covering sand heaps minimize dust emissions. The smaller the dust particles re-suspended into the air, the longer they take to fall to the ground. Winds can transport such disturbed dust far from the source. Shown below is the EPA source classification code (SCC) for quarry dust.

SCC	Description
23 25 000 000	Fugitive dust from quarrying activities

6.1.3.2 Key Assumption

$PM_{2.5}$ Emissions from quarrying activities are directly proportional to quarry employment. Quarry employment is used as a surrogate to project the 2002 quarry emissions to 2005. Employment data is easy to obtain at county levels.

6.1.3.3 Estimating Equation

For this inventory, the 2002 National Emissions Inventory (NEI) for quarry dust was updated with quarry employment as the surrogate.

$A = (B \div C) \times D$

where

A = 2005 fugitive dust emissions from quarrying activities
B = 2005 quarrying employment
C = 2002 quarrying employment
D = 2002 fugitive dust emissions from quarrying activities

6.1.3.4 Activity Levels and Summary of Emissions

Table 6-8 shows employment data used as a surrogate and emission estimates.

Table 6-8: Quarry Employment and Tons of Dust Emitted at Quarries

County	2002 Employment	2005 Employment	2002 $PM_{2.5}$	2005 $PM_{2.5}$
King	195	175	35	31
Kitsap	39	20	35	15
Pierce	176	175	35	35
Snohomish	80	175	35	76

6.2 Particulate Matter from Commercial Cooking

6.2.1 Category Description

This category covers particulate matter and VOC emissions from commercial meat cooking at bars and grills. Restaurant aromas clearly indicate that restaurant activities emit pollutants. The most common ways to cook meat are charbroiling and deep fat frying.

Charbroiling can be conveyorized or under-fired. In conveyorized charbroiling, the meat moves through the heat sources slowly while the meat is rotated for even cooking. In under-fired charbroiling, the meat is just rotated while being heated from below. A collection pan placed under the meat collects dripping fat. Charbroiling usually occurs at upscale restaurants such as Ivar's and Scott's Bar and Grill. In deep fat frying, the meat is wholly immersed in cooking oil. When done, the meat is removed with ladles and placed in a sieved container to allow the oil to drip. Deep fat frying occurs at fast food restaurants such as McDonald's and Burger King.

Emissions from fuel burned at restaurants are inventoried under area source fuels. The Agency downloaded the 2002 NEI estimates and adopted them as the 2002 emissions from restaurant meat cooking. This category excludes emissions from residential cooking and recreational barbecuing. Shown below are the source classification codes (SCC) for commercial cooking.

SCC	Type of Cooking
23 02 002 100	Conveyor charbroiling
23 02 002 200	Under-fired charbroiling
23 02 002 300	Deep fat frying
23 02 002 400	Other commercial cooking

6.2.2 Key Assumptions

Emissions from meat cooking are directly proportional to restaurant employment. The quantity of meat cooked would be the best surrogate to use to project meat cooking emissions, however, this data is not available at the county level. The next best surrogate is the number of employees at restaurants that cook meat by charbroiling, but it is not possible to segregate restaurant employment by type of cooking. Restaurant employment is easily available and is used to project the 2002 NEI estimates to 2005.

The 2002 NEI estimates are representative of emissions from meat cooking in restaurants. The Agency assumes the 2002 NEI estimates are representative of emissions from meat cooking at restaurants.

6.2.3 Estimating Equation

$\underline{A = (B \div C) \times D}$

where

A = 2005 fugitive dust emissions from commercial meat cooking
B = 2005 restaurant employment
C = 2002 restaurant employment
D = 2002 fugitive dust emissions from commercial meat cooking

6.2.4 Activity Levels and Summary of Emissions

Table 6-9 presents employment data used as a surrogate. Employment data was obtained from the U.S. Census Bureau. Table 6-10 applies the employment ratios to estimated 2005 $PM_{2.5}$ and VOC emissions from 2002 NEI emission estimates.

Table 6-9: Restaurant Employment (NAICS 7221 & 7222)[141]

County	2002 Employment	2005 Employment
King	56,103	61,732
Kitsap	5,411	6,030
Pierce	15,935	17,830
Snohomish	14,807	16,213

Table 6-10: Emissions from Commercial Cooking, 2002

County	Tons of $PM_{2.5}$ (2002)	Tons of $PM_{2.5}$ (2005)	Tons of VOC (2002)	Tons of VOC (2005)
King	846	931	122	134
Kitsap	76	85	11	12
Pierce	210	221	31	32
Snohomish	198	203	29	30
Region	1,331	1,439	193	209

[141] U.S. Census Bureau, County Business Patterns; available at: http://censtats.census.gov/cbpnaic/cbpnaic.shtml.

7 Other Greenhouse Gas (GHG) Sources

Greenhouse gases (GHG) are gases in the atmosphere that absorb the terrestrial radiation leaving the earth, thus warming the earth. Table 7-1 presents the list of GHG. The most important of these gases are carbon dioxide, methane, and nitrous oxide. Global Warming Potential (GWP) is a measure of the warming impact of a unit weight of the gas relative to a unit weight of carbon dioxide. The U.S. GHG 2005 defines GWP as the ratio of the time-integrated radiative forcing from instantaneous release of one kilogram of a substance relative to that of one kilogram of carbon dioxide. The greenhouse gas heating effect of one unit mass of methane is 21 times that of one unit of carbon dioxide. Similarly, the greenhouse gas heating effect of one unit mass of nitrous oxide is 310 times that of one unit of carbon dioxide.

Data from Table ES-2, U.S. GHG 2005: 1990-2005[142] indicates that 80% of gross GHG emitted in the U.S. comes from combustion sources. Estimates of the 2005 Agency GHG Inventory suggest 83% of GHG emitted in the Agency's four-county jurisdiction comes from combustion sources. The remaining 17% of the GHG in the Puget Sound region is inventoried in this section. Many categories inventoried in Section 7 reference the U.S. GHG 2004.

Table 7-1 presents the types of GHG, the prevalent sources, and their Global Warming Potential.

Table 7-1: GHG Inventoried in this Report and Associated GWP[143]

Symbol	Common Name	Prevalent Sources	GWP
CO_2	Carbon dioxide	Combustion, cement production, lime production	1
CH_4	Methane	Combustion, anaerobic processes, manure mgmt.	21
N_2O	Nitrous oxide	Combustion, manure mgmt.	310
SF_6	Sulfur hexafluoride	Leakage from electric power transmission equip.	23,900
HFC	Halocarbon	Industrial processes, manufacturing	140-11,700

7.1. Greenhouse Gases from Livestock and Land Use

7.1.1 Enteric Emissions from Livestock

7.1.1.1 Category Description

Livestock emit methane from their digestive systems. During digestion, microbes resident in the animal's digestive system ferment food consumed by the animal. This process is called enteric fermentation. Shown below is the EPA source classification code (SCC) for livestock emissions.

SCC	Description
28 05 000 000	Emissions from livestock & manure management

7.1.1.2 Key Assumption

The 2002 livestock population is representative of the 2005 livestock population. This report uses the population of animals reported in the 2002 agricultural census. The U.S. Census Bureau conducts an agricultural census every five years. The latest available census is for 2002. The Agency assumes the 2002 livestock population is representative of the 2005 population.

[142]Table ES-2, Recent Trends in U.S. Emissions and Sinks; U.S. GHG 2005.

[143]Table ES-1, Global Warming Potentials (100-Year Time Horizon); U.S. GHG 2005.

7.1.1.3 Estimating Equation

A = B × C

where

A = kg of enteric methane emitted by animal group
B = number of animals
C = kg of methane per animal (for animal group)

Tons of CO_2 eqv = 21 × tons of methane

7.1.1.4 Animal Population

Table 7-2 presents the population of cattle by county and Table 7-3 presents the population of other types of non-poultry livestock.

Table 7-2: Livestock Population in Puget Sound Counties, 2002[144]

County	Beef Cattle	Beef Cow	Milk Cow
King	8,730	2,376	11,423
Kitsap	95	1.183	22
Pierce	1,049	8,767	4,274
Snohomish	12,751	3,810	15,604

Table 7-3: Other Livestock Population in Puget Sound Counties, 2002

County	Horse	Sheep	Swine	Goat	Mink
King	5,227	1,780	559	165	2,972
Kitsap	1,837	682	495	309	61
Pierce	4,621	2,013	1,124	542	645
Snohomish	4,907	1,676	651	1,026	1,632

7.1.1.5 Emission Factors

Table 7-4 presents kilograms of methane emitted per animal for each animal group.

Table 7-4: Kilograms of Methane Emitted per year per Animal[145]

Type of Animal	kgs of CH_4 per animal
Beef cattle	100
Beef cow	83
Milk cow	115
Horse	18
Sheep	8
Swine	1.5
Goat	5
Mink	0.4

7.1.1.6 Summary of Emissions

Tons CO_2 eqv = [(kg per animal) × (number of animals) × 2.205 × 21] ÷ 2000

[144] http://www.nass.usda.gov/census/census02/volume1/wa/index2.htm; September 13, 2007.

[145] Cattle: U.S. GHG 2000, Tables K-7 and K-9; other animals: U.S. GHG 2004, Table A-152. The factor for minks estimated from that of goats: EF for mink = (mink weight, 5 kg)/(goat weight, 64 kg) * (goat factor, 5).

Table 7-5 presents 2005 enteric emissions from livestock.

Table 7-5: 2005 Enteric Emissions from Livestock, Tons CO_2 Eqv

Type of Animal	King Co.	Kitsap Co.	Pierce Co.	Snohomish Co.	Region
Beef cattle	20,212	2,739	20,298	8,821	52,070
Beef cow	4,566	2,273	16,847	7,322	31,008
Milk cow	30,414	59	11,380	41,546	83,399
Horse	2,178	766	1,926	2,045	6,915
Sheep	330	126	373	310	1,139
Swine	19	17	39	23	98
Goat	19	36	63	119	236
Mink	28	1	6	15	49
Total	57,766	6,016	50,925	60,186	178,893

7.1.2 Manure Management

7.1.2.1 Category Description

The management of livestock manure produces methane and nitrous oxide. Nitrous oxide is produced by nitrification and de-nitrification of the organic nitrogen in the manure and urine. When manure is managed as a slurry in tanks and ponds, the decomposition is anaerobic and tends to produce more methane. When treated as a solid and applied on pasture lands, it produces less methane. The production of nitrous oxide from manure depends on the composition of the manure and urine, and the treatment process.

Shown below is the EPA source classification code (SCC) for livestock manure management.

SCC	Description
28 05 000 000	Emissions from livestock manure management

7.1.2.2 Key Assumptions

The 2002 livestock population is representative of the 2005 livestock population. This report uses the population of animals reported in the 2002 agricultural census. The U.S. Census Bureau conducts an agricultural census every five years. The latest available census is for 2002. The Agency assumes the 2002 livestock population is representative of the 2005 population.

Manure lagoons are the typical treatment methods for manure management in the Puget Sound area and the methane conversion factor for local manure treatments is 68%. The methane conversion factor (MCF) for manure management systems[146] is the potential of conversion of manure into methane. The MCF differs for different types of manure treatments. According to a study by Washington State University, 41% of manure in western Washington dairies use lagoons to treat their manure and 59% use other methods. However, according to a July 17, 2003 King County Department of Natural Resources news release, in King County, manure is typically stored in lagoons and later sprayed onto fields in the spring and summer. Also, manure enforcement actions that the Washington State Department of Agriculture brings

[146](a) Table A-165, MCF by State for Liquid Systems, U.S. GHG 2004; this reports assumed 67.9% for lagoons. (b) Table 3, WA State Dairy Ammonia Emission Model – Final Report, prepared by Brian Lamb et al., for WA Dept. of Ecology, March 15, 2005. (c) King Co. Dept of Natural Resources, July 17, 2003 news release: King County Explores "Manure Power", indicated that typically manure is stored in lagoons and later sprayed. (d) October 27, 2004 news release: Washington State Department of Agriculture takes Enforcement Action against Ferndale Dairy, indicated that dairy farms treat their manure in lagoons.

against dairy farmers typically involve manure lagoons. This report assumes manure lagoons are the typical treatment method for manure management in the Agency's jurisdiction. The MCF for anaerobic manure lagoons is 68%. The MCF for slurry and pit treatments is 23%. This inventory assumes MCF is 68%.

Wet manure systems are the typical Puget Sound treatment systems, and the IPCC nitrous oxide emission factor for wet manure systems is appropriate. For nitrous oxide emissions to occur, the manure must first be handled aerobically for ammonia or organic nitrogen to convert to nitrates and then treated anaerobically where the nitrates produce nitrous oxide and nitric oxide. These emissions most likely occur in dry manure treatment systems. The default IPCC nitrous oxide emission factors per kg of excreted nitrogen[147] are:

dry manure systems: 0.02 kg N2O-N

wet manure systems: 0.001 kg N2O-N

poultry systems: 0.005 kg N2O-N

From the MCF assumption discussed above the appropriate factor for Puget Sound manure treatment systems is 0.001 kg N2O-N per kg N excreted for wet manure systems.

7.1.2.3 Estimating Equations

Methane emissions are estimated from:

$\underline{A = (B \times C \times D \times E \times F)}$

where

A = methane produced by manure treatment, kg
B = total animal mass of farm animals (in 1,000 kg mass)
C = volatile solids (VS) produced per 1,000 kg mass, kg
D = maximum methane production capacity per kilogram of VS, (m^3 CH_4/kg of VS)
E = methane conversion factor, 67.9% for wet manure treatment in lagoons
F = density of methane, 0.662 kg CH_4/m^3 CH_4

Nitrous oxide emissions are estimated from:

$\underline{A = (B \times C \times D \times E)}$

where

A = nitrous oxide produced by manure treatment, kg
B = total mass of farm animals, (in 1,000 kg mass)
C = excreted organic nitrogen per 1,000 kg mass, kg
D = emission factor, kg N_2O-N produced per kg excreted organic nitrogen
E = conversion factor for N_2O-N to N_2O (44/28 = 1.57)

$$\text{Tons } CO_2 \text{ eqv} = (21 \times \text{tons of } CH_4) + (310 \times \text{tons of } N_2O)$$

7.1.2.4 Animal Population

Tables 7-6 and 7-7 present livestock populations.

[147]Nitrous Oxide Emission Factors, Annex A, page A-182, U.S. GHG 2004.

Table 7-6: Cattle and Horse Population in Puget Sound Counties, 2002[148]

County	Beef Cattle	Beef Cow	Milk Cow	Horse
King	8,730	2,376	11,423	5,227
Kitsap	95	1.183	22	1,837
Pierce	1,049	8,767	4,274	4,621
Snohomish	12,751	3,810	15,604	4,907

Table 7-7: Other Livestock Population in Puget Sound Counties, 2002

County	Sheep	Swine	Goat	Mink	Poultry
King	1,780	559	165	2,972	8,983
Kitsap	682	495	309	61	3,061
Pierce	2,013	1,124	542	645	422,406
Snohomish	1,676	651	1,026	1,632	652,239

7.1.2.5 Characteristics of Wet Manure Systems

Table 7-8 presents characteristics of wet manure treatment systems.

Table 7-8: Characteristics of Emissions from Wet Manure Treatment Systems[149]

Animal Type	Typical Animal Mass, kg	kg of VS/day per 1,000 kg mass	m^3 CH_4/kg of VS	Excreted Nitrogen/1,000 kg Mass, Ne	kg N_2O-N/ kg Ne
Beef Cattle	750	10.4	0.17	0.31	0.001
Beef Cow	533	8.71	0.17	0.33	0.001
Milk Cow	604	10.87	0.24	0.44	0.001
Horse	450	10.0	0.33	0.30	0.001
Sheep	80	9.2	0.19	0.42	0.001
Swine	68	5.4	0.48	0.42	0.001
Goat	64	9.5	0.17	0.45	0.001
Mink	10	9.5	0.17	0.45	0.001
Poultry	0.9	15.0	0.36	1.10	0.005

7.1.2.6 Summary of Emissions

Table 7-9 presents methane emissions from manure management.

Table 7-9: Methane Emissions from Manure Management, in tons of CO_2 Eqv/Year

Animal Type	King Co.	Kitsap Co.	Pierce Co.	Snohomish Co.	Region
Beef Cattle	43,972	239	5,284	64,225	113,720
Beef Cow	7,123	1,773	26,282	11,422	46,600
Milk Cow	68,372	66	25,582	93,397	187,416
Horse	29,485	5,181	26,066	27,680	88,412
Sheep	946	181	1,069	890	3,086
Swine	374	166	753	436	1,728
Goat	65	61	213	403	741
Mink	182	2	40	100	324
Poultry	166	28	7,798	12,041	20,033
Total	150,684	7,697	93,086	210,594	462,061

[148] http://www.nass.usda.gov/census/census02/volume1/wa/index2.htm; September 13, 2007.
[149] Tables A-157 and A-158, U.S. GHG 2004.

Table 7-10 presents nitrous oxide emissions from manure management.

Table 7-10: Nitrous Oxide Emissions from Manure Management, in tons of CO_2 Eqv/Year

Animal Type	King Co.	Kitsap Co.	Pierce Co.	Snohomish Co.	Region
Beef Cattle	1,510	8	181	2,206	3,906
Beef Cow	260	65	961	418	1,704
Milk Cow	2,361	2	883	3,225	6,472
Horse	505	89	446	474	1,514
Sheep	39	8	45	37	129
Swine	6	3	12	7	28
Goat	3	3	11	20	37
Mink	9	0	2	5	16
Poultry	48	8	2,244	3,465	5,765
Total	4,742	186	4,786	9,858	19,572

Table 7-11 is the sum of emissions in Tables 7-9 and 7-10 and presents the summary of GHG emissions from manure management.

Table 7-11: Emissions from Manure Management, in tons of CO_2 Eqv

Animal Type	King Co.	Kitsap Co.	Pierce Co.	Snohomish Co.	Region
Beef Cattle	45,482	247	5,465	66,431	117,626
Beef Cow	7,383	1,838	27,243	11,840	48,304
Milk Cow	70,733	68	26,465	96,622	193,888
Horse	29,990	5,270	26,513	28,154	89,926
Sheep	985	189	1,114	927	3,215
Swine	380	168	765	443	1,757
Goat	68	64	223	423	778
Mink	191	2	42	105	340
Poultry	214	36	10,042	15,506	25,798
Total	155,427	7,883	97,872	220,451	481,633

7.1.3 N_2O Emissions from Agricultural Soil Management

7.1.3.1 Category Description

This category includes emissions of nitrous oxides naturally produced in soils by microbial processes of nitrification and de-nitrification. Agricultural activities increase mineral nitrogen availability in soils thereby increasing nitrification and de-nitrification and ultimately the amount of nitrous oxide emitted. Agricultural soils are responsible for the majority of U.S. nitrous oxide emissions.[150]

Direct increases in mineral nitrogen occur through practices such as fertilizer, manure, and sewage sludge applications, manure deposition on pastures, rangeland, and paddocks by grazing animals whose manure is not managed, production of N-fixing legumes, irrigation, tillage practices, and fallowing of land. Indirect emissions of nitrous oxides occur through volatilization and atmospheric deposition of applied nitrogen, as well as surface runoff and leaching of applied nitrogen in groundwater and surface water. Below is the EPA source classification code (SCC) for soil emissions.

SCC	Description
28 01 700 000	Emissions from soil

[150]U.S. GHG 2004, pages 6-18.

7.1.3.2 Key Assumptions

Emissions from soils are directly proportional to land area under consideration. The U.S. GHG 2004 estimated nitrous oxide emissions from agricultural soils with the Tier 3 DAYCENT model. DAYCENT estimates the emissions by simulating crop growth, soil organic matter decomposition, GHG fluxes, and key biogeochemical processes that affect nitrous oxide emissions. The daily weather record entered into the DAYCENT model drives the simulations. The Agency used the applicable land area to apportion U.S. emissions to the county level.

The Puget Sound region does not have significant areas of grassland. The U.S. GHG 2004 presented the nitrous emissions from soil in two steps: direct and indirect emissions. The direct emissions are proportional to cropland acreage and grassland. The Agency assumed the Puget Sound region does not have significant areas of grassland. Hence emissions from grassland are insignificant. Indirect emissions come from all land uses. The Agency therefore used total county land area to apportion U.S. indirect emissions to the county level.

King County 2003 estimated CO_2 sequestrations are most appropriate for the Northwest region. The U.S. GHG 2004 estimated nitrous oxide emissions and carbon dioxide sequestrations from other land uses. The U.S. GHG 2004 base estimates are based on the pine forests of North Carolina, and are not representative of Northwest forests. The emission factors used therefore do not apply to Northwest forests. The Agency adopted the more Northwest-appropriate sequestered emissions estimated by King County in its 2003 Emissions Inventory (please see Section 8 of this report).

7.1.3.3 Estimating Equations

For direct emissions: $A = (B \div C) \times D$

where

- A = direct emissions from croplands in the county
- B = county farm acreage
- C = U.S. farm acreage
- D = direct emissions of nitrous oxide from U.S. farms

For indirect emissions: $A = (B \div C) \times D$

where

- A = indirect emissions from all lands in the county
- B = county land area
- C = U.S. land acreage
- D = indirect emissions of nitrous oxide from U.S. farms

7.1.3.4 Activity Levels and Summary of Emissions

Table 7-12 shows farm acreage and land area. Information was obtained from the 2002 Census of Agriculture.

Table 7-12: Farm Acreage and Land Area[151]

Area	Farm Acreage	Total Land Area (square miles)
King Co.	17,147	2,126
Kitsap Co.	7,914	396
Pierce Co.	28,058	1,679
Snohomish Co.	45,788	2,089
U.S.	436,054,000	3,537,000

[151] Farm acreage: 2002 Census of Agriculture, http://www.nass.usda.gov/census/census02/volume1/wa/index2.htm, http://www.nass.usda.gov/census/census02/volume1/us/index1.htm, September 17, 2007. Land area: U.S. Census Bureau, State and County Quick Facts; http://quickfacts.census.gov/qfd; September 17, 2007.

Table 7-13 presents emissions of nitrous oxide (in carbon dioxide equivalents) from U.S. soils and counties in the Agency's jurisdiction.

Table 7-13: Emissions from Soils (CO_2 eqv of N_2O emissions)[152]

Area	Cropland	Volatilization	Leaching & Run-off	Total
King Co.	5,796	11,464	48,571	65,831
Kitsap Co.	2,695	2,135	9,047	13,857
Pierce Co.	9,485	9,053	38,357	56,895
Snohomish Co.	15,478	11,264	47,723	74,465
U.S.	147,404,000	19,073,000	80,813,000	247,291,000

7.1.4 Landfills

7.1.4.1 Category Description

Waste management companies truck garbage and other wastes to landfills in the Agency's jurisdiction and outside the region. An active landfill is a landfill that continues to receive wastes. Currently, the only landfills active in the region are the King County Cedar Hill Landfill near Maple Valley (King County) and the Pierce County Recycling Composition and Disposal in Graham (Pierce County). The Graham landfill receives waste from Pierce County communities and the city of Tacoma. Landfills continue to emit methane long after they close. Some capture the methane and either flare it or use it to produce power. The CO_2 from such flaring or combustion does not count toward GHG.[153]

The equations EPA uses to estimate landfill gas emissions account for only the methane component of the emissions. The methane recovered and combusted is subtracted from the GHG emissions. The carbon dioxide resulting from the landfill methane combustion is not added to the GHG emissions.[154] Landfill GHG includes only the methane that escapes from the landfill. The assumption that carbon dioxide from landfills does not count towards GHG emissions reduces the effect of landfill emissions on the overall GHG inventory. Shown below is the EPA source classification code (SCC) for landfills.

SCC	Description
26 20 000 000	Landfills

7.1.4.2 EPA and EIIP Estimating Methods

EPA and EIIP recommend compilers use the Landfill Gas Emissions (LandGEM) model to estimate methane generated at a landfill. The LandGEM is a first order decay model developed by EPA. Unlike the Waste Reduction Model (WARM), which includes upstream and haulage emissions in its estimates, LandGEM estimates emissions where they occur. WARM's life-cycle approach is "not appropriate for use in inventories because of the diffuse nature of the emissions and emission reductions contained in a single emission factor".[155]

The LandGEM estimation equation is:

[152] U.S. GHG 2004, Tables 6-15 and 6-16.
[153] U.S. GHG 2005, Section 8.1, page 8-3, Table 8-4; U.S. GHG 2004, Section 8-1, page 8-3, Table 8-4.
[154] EIIP, Vol III, Chapter 15: Landfills.
[155] WARM: http://yosemite.epa.gov/oar/globalwarming.nsf/webprintview/ActionsWasteWARM.html, January 8, 2008.

$$Q = L \times R \times (\exp[-(k \times c)] - \exp[-(k \times t)])$$

where

- L = methane generation potential (m^3 methane per tonne of refuse)
- R = average annual refuse acceptance rate during active life of landfill (tonnes/year)
- k = methane generation rate constant (per year)
- c = time since landfill closure (c = 0 for active landfills)
- t = time since the initial refuse place (years)

Unfortunately, data and characteristics of a landfill required to run this model are not readily available, and are very difficult to obtain. An EIIP alternative method requires knowledge of the area of the landfill cover, the depth of the landfill, the density of the compacted waste, the opening and closing dates of the landfill, etc. A second EIIP alternate method requires using the known population of the area served by the landfill during its lifetime and applying a national per capita waste generation rate to estimate the waste stored in the landfill. Given the lack of information for suggested EIIP methods, the Agency estimated landfill emissions based on landfill permit data for local landfills. The Agency expects the emissions estimate obtained with the permit data method to be more accurate than estimates produced by a model.

7.1.4.3 Agency Method – Permits Issued to Landfills

The Agency issued permits to landfills to collect landfill gas. The landfills either flare the collected gas or burn it to generate power. The Agency based its estimates on these permits using the following assumptions.

7.1.4.4 Key Assumptions

The King County Department of Natural Resources and City of Seattle 2003 estimates for closed landfills are representative of current emissions.[156] The Agency has no data on some closed landfills such as Interbay, Genessee, Judkins Park, Cedar Falls, Bow Lake, South Park, Corliss, and Duvall. The Agency adopted the estimates that King County and the City of Seattle have developed for these landfills.

15% of the landfill gas generated at landfills with landfill gas collection systems escapes the collection system. According to the 2003 King County Emissions Inventory, a 10% escape rate is typical of the most sophisticated landfill collection systems. However Haq Quinn[157] of the Sacramento County Air Quality Management District indicated that, from permit evaluations, their landfill permit engineers assume 15% of generated landfill gas escapes the collection system. Wally Grant, the landfill gas collection system operator at Cedar Hills, said they repair leakages as soon as possible and they have a vacuum over the landfill. However, he cannot tell what percentage of the generated landfill gas escapes as fugitive.

The EIIP default for landfill gas components is appropriate for the Puget Sound Area.[158] According to EIIP, when generation of landfill gas reaches steady state conditions, the generated gas is about 55% methane, 40% carbon dioxide, 5% nitrogen, plus traces of non-methane organics. Wally Grant, the landfill gas collection system operator at Cedar Hills gave the composition of Cedar Hills landfill gas as 40% carbon dioxide and 52% methane. The Agency chose the EIIP default because the Cedar Hills landfill is active and probably has not reached steady state conditions.

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[156] Table 10 of 2003 Inventory of King County Air Emissions, Revision D, December 28, 2004, compiled by Roel Hammerschlag for the Director's office, King Co. Department of Natural Resources and Parks.

[157] Haq Quinn (hquinn@airquality.org), verbal and e-mail communications, September 18, 2007.

[158] Emission Inventory Improvement Project, Vol. III, Chapter 15 (Landfills), Section 4.3, page 15.4-3.

Landfill collection systems operate at about 60% of their rated capacity. Landfill operators intentionally oversize the collection systems to allow for growth and flexibility. Cedar Hills Landfill regularly reports emissions and activity to the Agency. According to Wally Grant and Cedar Hills permit data, Cedar Hills has five collection systems each rated at 3,000 cfm giving a total capacity of 15,000 cfm. Wally adds that the five systems at Cedar Hills actually collect and burn 9,000 cfm. Thus, Cedar Hills runs at about 60% capacity.

Landfills with gas combustion systems and flares destroy the methane completely and the carbon dioxide generated by the landfill or produced by the methane combustion does not count as GHG. The methane in the collected landfill gas burns completely in the flares or the systems used to combust the gas for power. Every kilogram of methane burned produces 2.75 kilograms of carbon dioxide. The IPCC guidelines recommend carbon dioxide emissions at landfills should not count as GHG because the carbon dioxide ultimately came from decaying vegetative matter. The carbon dioxide in the landfill gas and the carbon dioxide produced from the burning of the collected methane do not contribute to GHG. The fugitive methane (that escapes the collection system) contributes to GHG emissions.

7.1.4.5 Estimating Equations

Carbon dioxide equivalent of methane escaping from landfills is estimated from the equations:

$\underline{A = B - C}$

where

A = million cubic feet of fugitive landfill gas/year (landfill gas not collected)
B = million cubic feet of landfill gas generated/year at a landfill
C = million cubic feet of landfill gas collected by collection systems

and

A = 15% of B
C = 85% of B

This simplifies to: $A = (15 \div 85) \times C$

$\underline{C = 0.6 \times D}$

where

D = rated capacity of landfill collection system or landfill gas collected, as given by landfill

Only 55% of the fugitive landfill gas, A is methane. Therefore, fugitive methane is given by:

$\underline{E = 0.55 \times A \times 1000{,}000}$

where

E = cubic feet of methane not collected

and

$\underline{F = (0.02832\ m^3/ft^3) \times (E\ ft^3\ \text{methane/yr}) \times (0.662\ \text{kg methane}/m^3)}$

where

F = kilograms of fugitive methane

Finally, estimating the carbon dioxide equivalent of the fugitive methane gives:

$\underline{G = [21 \times (2.205\ \text{lbs/kg}) \times F]/2000}$

where

G = tons of carbon dioxide equivalent of fugitive methane from landfills

See Appendices A105 and A106 for details of landfill emissions.

Table 7-14 presents the summary of fugitive methane emissions at landfills.

Table 7-14: GHG due to Fugitive Methane Emitted at Landfills, Tons of CO_2 Eqv

Name of Landfill	MCF of CH_4/Year	1,000 m^3 of CH_4/Year	Tons of CO_2 Eqv/Year
King Co. landfills with permits	774	22	336,133
Other King Co. landfills			24,556
Interbay, Judkins Park, Genessee			109,148
Kitsap Co. landfills	215	6	93,401
Pierce Co. landfills	455	13	197,477
Snohomish Co. landfills	206	6	89,584
Agency 4-county region			850,297

7.1.4.6 Effect of Excluding Carbon Dioxide from Landfill Gas Emissions

From assumptions above, 40% of landfill is carbon dioxide (molecular weight 44), 55% is methane (molecular weight 16, global warming potential 21), and 5% nitrogen. For a unit volume of landfill gas generated, the GHG effect if carbon dioxide were included would be:

$$\text{Weight of GHG from unit volume of gas} = [(0.4 \times 1) \text{ of } CO_2 + (0.55 \times 16/44) \text{ of } CH_4] \text{ units}$$

The above equation gives 0.4 units mass of carbon dioxide and 0.2 units mass of methane for every unit volume of landfill gas emitted. Converting the methane to carbon dioxide equivalent, every unit volume of landfill gas emitted gives 4.6 unit mass of carbon dioxide equivalents. Thus, if carbon dioxide were included in the landfill GHG emissions, carbon dioxide would contribute 9% of the GHG emitted by a landfill (i.e., 0.4 units of CO_2 and 4.6 units of CO_2 eqv).

7.2 Greenhouse Gases from Non-Energy Use (NEU) Fuel

GHG emissions occur when industries transport natural gas or consume fuels in ways other than conventional combustion. The IPCC classifies it as "non-energy use of fuel". Rather than being combusted for energy, fuels consumed for non-energy purposes act as building blocks or reagents in fabricating other materials. Such uses include petrochemical synthesis, reductants for metallurgical processes, and non-fuel products such as asphalt, lubricants, and waxes. These materials derived from fossil fuels are important from an emissions perspective because they provide long-term storage of the fuel's carbon. According to the U.S. GHG 2005, emissions from NEU Fuels have increased by 21% since 1990.

Losses of methane occur from coal mining, abandoned coal mines, and petroleum systems primarily associated with crude oil production, processing, and refining operations. About 97% of GHG methane emissions from petroleum systems occur during the production field operations stage. According to Table 3-35 of the U.S. GHG 2004, refining operations contribute 2% of GHG from petroleum systems. Petroleum systems field operations do not exist in the Puget Sound area. The Agency assumes emissions from petroleum field operations are insignificant. Emissions from natural gas distribution are inventoried in Section 7.2.1 and emissions from other NEU fuels are inventoried in Section 7.2.2.

7.2.1 Natural Gas Systems

7.2.1.1 Category Description

Field production and processing of natural gas do not occur on a significant scale in the Puget Sound region. Losses of natural gas occur during its storage and along its transmission lines. The losses occur at points such as above-ground valves and flanges. Industrial pipeline accidents also release natural gas. This category is not a large source of emissions since the distribution occurs primarily via underground pipelines.

Natural gas losses may occur in one or both of the 2 distinct segments: (1) transmission, and (2) distribution. Transmission comprises the main lines owned by large oil companies such as ExxonMobil, Olympic Pipeline, and Williams Company. Even if there are no transmission pipelines in a county, a section of the U.S. transmission line emissions is apportioned to the county because whatever natural gas was ultimately consumed in the county passed through transmission lines before reaching the distribution lines. Distribution comprises the local lines owned by utility companies such as Puget Sound Energy and Cascade Natural Gas Company. The companies' pipelines transport natural gas from the main transmission lines to the end user.

The EPA source classification codes (SCC) do not have a dedicated code for pipeline transportation of natural gas. The Agency uses the EPA SCC code that most closely fits the description, all pipeline transportation, shown below. Energy companies use pipelines to transport crude oil, residual oil, distillate oil, gasoline, jet naphtha, kerosene, and natural gas.

SCC	Description
25 05 040 000	All pipeline transportation

7.2.1.2 Key Assumption

Natural gas losses that occur in an area during transmission, storage, and distribution are proportional to natural gas consumption for that area. Natural gas transmission involves high pressure, large diameter pipelines that transport natural gas from the production and processing area to distribution systems and large volume customers such as power and chemical plants. Distribution pipelines take the high pressure gas from the transmission system, reduce the pressure, and deliver the gas through underground mains and service lines to end users.

7.2.1.3 Estimating Equation

Losses of natural gas are estimated with the equation:

$\underline{A = (B \div C) \times D}$

where
- A = tonnes of CO_2 eqv of GHG emitted during natural gas transmission in a county
- B = billion cubic feet distributed in the county
- C = billion cubic feet of natural gas distributed in the U.S.
- D = tonnes of CO_2 eqv of GHG emitted in the U.S. during natural gas distribution

7.2.1.4 Activity Levels and Summary of Emissions

Table 7-15 presents the consumption of natural gas by area and purpose.

Table 7-15: 2005 Natural Gas Consumption in billion cubic feet (bcf)[159]

Area	Residential	Commercial	Industrial/Power	Transportation	Total
King Co.	28.5	18.6	10.2	2.7	60.0
Kitsap Co.	1.7	0.7	1.7	0.3	4.4
Pierce Co.	9.1	5.9	4.9	1.0	20.9
Snohomish Co.	7.8	3.8	3.8	0.9	16.3
Region	47.1	29	20.6	4.8	101.4
U.S.	4,855	3,142	13,812	592	22,401

[159]Puget Sound Energy and Cascade Natural Gas Company provided county consumption data. See Tables 3-4, 4-4, 4-5, and 4-6 of this report. U.S. data from EIA website: http://www.eia.doe.gov/emeu/states/_seds.html/html; September 20, 2007.

Table 7-16 presents the estimated losses from natural gas transmission and distribution.

Table 7-16: Natural Gas Transmission and Distribution Losses[160] (tonnes CH_4 emitted)

Area	Transmission	Distribution	Total Losses
King Co.	4,890	3,455	8,345
Kitsap Co.	356	251	607
Pierce Co.	1,702	1,202	2,904
Snohomish Co.	1,326	937	2,262
Region	8,273	5,846	14,118
U.S.	1,827,000	1,291,000	3,118,000

The estimates are converted to tons of CO_2 eqv with:

$$\text{Tons of } CO_2 \text{ eqv} = 21 \times (\text{tonnes } CH_4 \times 1{,}000 \times 2.205) \div 2{,}000$$

Table 7-17 shows carbon dioxide equivalent of natural gas transmissions and distribution losses.

Table 7-17: GHG from Natural Gas Distribution (tons CO_2 eqv)

Area	Transmission	Distribution	Total Losses
King Co.	113,193	79,985	193,178
Kitsap Co.	8,230	5,815	14,045
Pierce Co.	39,388	27,832	67,220
Snohomish Co.	30,687	21,684	52,370
Region	191,497	135,316	326,813

7.2.2 Greenhouse Gases from Other Non-Energy Use Fuel

7.2.2.1 Category Description

Industry consumes some petroleum products that are not burned. Such consumption includes application as solvents, lubricants, waxes, or as raw materials in the manufacture of plastics, rubber, synthetic fibers, waxes, and other materials. Rather than being combusted for energy, fuels consumed for non-energy purposes act as building blocks or reagents in fabricating other materials. A certain percentage of this consumption produces greenhouse gases (GHG). The U.S. GHG 2004 calls these kinds of applications of petroleum products for non-energy purposes "non-energy use (NEU) fuel".

There are no SCCs for this type of fuel consumption. For this inventory, the Agency has assigned the non-combusted fuel to the fuel burning category closest to the activity, shown below (see Section 5.3.2 of this report for EIIP classification of fuel unloaded from vessels).

SCC	Description of Category	EIIP Category
22 30 000 000	Transportation lubrication	Distillate oil
21 02 004 000	Industrial lubrication	Distillate oil
21 02 000 000	Miscellaneous	Naphtha, gasoline

7.2.2.2 Key Assumptions

The 2004 GHG fractions of fuels combusted and not combusted are representative of Puget Sound area fuels. According to Table 3-13 of the U.S. GHG 2004, 91% of lubricants are "combusted". Page 3-20 of Section 3.2 of the U.S. GHG 2004 adds that, across the board, 38% of other NEU fuels are "combusted".

[160] U.S. GHG 2004, Table 3-39; U.S. losses apportioned to counties by the ratio of their consumption to U.S. consumption.

Consumption of transportation lubricants is proportional to vehicle miles traveled. Non-road mobile sources such as ships, aircraft, and locomotive engines use lubricants. VMT is used to apportion Washington's consumption of transportation lubricants among the counties because on-road mobile vehicles use an overwhelming majority of transportation fuels.

Consumption of industrial lubricants is proportional to industrial employment. Industrial machinery needs lubrication to run well. The Energy Information Agency (EIA) calls such consumption "industrial consumption of lubricants". The EIA counts lubricants used by industrial non-road engines as part of industrial lubricants. Also EIA lists industrial lubricant consumption in the industrial energy consumption table (see Table 7-18 of this report). Industrial employment is therefore the best surrogate to apportion consumption of industrial lubricants to the counties.

Consumption of Other NEU Fuels is proportional to industrial employment. EIA lists "other NEU fuels" in the industrial consumption table (see Table 7-18 of this report). The "other NEU fuels" category does not appear in residential, commercial, transportation, or electric power tables published by the EIA. Since the EIA publishes "other NEU fuels" in the industrial consumption table, industrial employment would be the best surrogate to apportion emissions from other NEUs to the county level.

7.2.2.3 Estimating Equations

Washington NEU fuel is apportioned to the counties by the following equations:

For transportation lubricants:

$A = (B \div C) \times D$

where
- A = gallons of lubricants consumed in a county
- B = VMT of county
- C = VMT of Washington State
- D = gallons of lubricants consumed in Washington State

For industrial lubricants and other NEU fuels:

$A = (B \div C) \times D$

where
- A = gallons of industrial lubricants or other NEU fuels consumed in a county
- B = Industrial employment (NAICS 31 & 33) of county
- C = Industrial employment of Washington State
- D = gallons of lubricants or other NEU fuels consumed in Washington State

Table 7-18 presents consumption of NEUs in Washington State.

Table 7-18: Consumption of NEUs in Washington State, 2004[161] (1,000 barrels)

Category of Non-Energy Use Fuel	1,000 Barrels Consumed in Washington State
Transportation lubricants	443
Industrial lubricants	178
Other (assumed as naphtha, EIIP guidelines)	30,031

[161] EIA: http://www.eia.doe.gov/emeu/states/_seds.html, September 20, 2007; Tables 10 and 11 of WA series.

Table 7-19 presents VMT and industrial employment for the Agency's four counties and Washington. These are used as surrogates to apportion Washington's consumption of NEU fuel to the county level.

Table 7-19: VMT and Industrial Employment, 2005

Area	# of Industrial Employees	Million VMT
King Co.	97,525	16,500
Kitsap Co.	1,972	1,604
Pierce Co.	20,300	6,060
Snohomish Co.	40,927	5,267
Washington State	256,563	55,487

7.2.2.4 Activity Levels

Table 7-20 presents the amount of NEUs (petroleum fuel consumed in the Puget Sound region but not used for energy) and Table 7-21 presents the portion of the consumed NEUs considered to be "combusted". 91% of the lubricants are combusted and 38% of the other NEUs are combusted.

Table 7-20: 1,000 Gallons of NEU Fuels Consumed in Puget Sound Area, 2005

County	Transportation Lubricants	Industrial Lubricants	Other NEU Fuels
King	5,533	2,842	479,448
Kitsap	538	58	9,695
Pierce	2,032	592	99,798
Snohomish	1,766	1,193	201,203

Table 7-21: 1,000 Gallons of NEU Fuels Considered to be Combusted in Puget Sound Area, 2005

County	Lubricants	Other NEU Fuels
King	7,621	182,190
Kitsap	542	3,684
Pierce	2,388	37,923
Snohomish	2,692	76,457

7.2.2.5 Emission Factors

Table 7-22 presents emission factors for the "combustion" of lubricants and other NEUs.

Table 7-22: Emission Factors for Consumption of NEUs (lbs/1,000 gallons consumed)[162]

NEU Category	CO_2	CH_4	N_2O	CO_2 Eqv
Lubricant	22,468	1.27	0.56	22,668
Other NEU	20,020	1.11	0.49	20.195

7.2.2.6 Summary of Emissions

Emission factors from Table 7-22 are applied to the combusted NEU fuel in Table 7-21 to produce emissions as presented in Table 7-23.

[162] CO_2 emission factors: AP-42, Table 3.3-1 (Gasoline and Diesel Internal Combustion Engines); CH_4 and N_2O: U.S. GHG 2004, Annex A, Table 3-30.

Table 7-23: 2005 GHG Emissions from Consumption of NEU Fuels (tons of CO_2 eqv)

County	Lubrication	Other NEU Fuels	All NEUs
King	86,377	1,839,683	1,926,060
Kitsap	6,141	37,199	43,340
Pierce	27,060	382,933	409,994
Snohomish	30,516	772,035	802,551
Region	150,094	3,031,850	3,181,944

7.3 Other Processes Releasing Greenhouse Gases

Some processes release greenhouse gases directly. These include:

- cement production (limestone breaks down into lime and carbon dioxide)
- steel production (carbon electrodes burn off and release carbon dioxide)
- beverage production (carbon dioxide is used in bottling; consumers release the CO_2)
- dry cleaning (a dry cleaner on Mercer Island uses liquid CO_2 as cleaning fluid)
- power transmission (transformers and other equipment use sulfur hexafluoride)
- hospital surgery (surgical departments of hospitals use nitrous oxide)

7.3.1 Cement Production

7.3.1.1 Category Description

Cement manufacture is an energy- and raw-material intensive process that generates carbon dioxide from the energy consumed in making the cement and the chemical process itself. The carbon dioxide from the energy consumed by cement plants has been accounted for in Section 3 (Point Sources). This section estimates the carbon dioxide released from the chemical process itself.

Cement production releases large amounts of carbon dioxide when limestone, primarily calcium carbonate, breaks down at approximately 1,500°F into lime (calcium oxide) and carbon dioxide. This process is known as calcination. Silica-containing materials are combined with the lime and as the kiln temperature continues to increase to about 2,700°F, clinker is formed. The clinker is allowed to cool and then is mixed with a small amount of gypsum to produce Portland cement.

The Ash Grove cement kiln uses the dry process method and can produce 92 tons of clinker per hour. The LaFarge cement kiln uses the wet process method and can produce 52 tons of clinker per hour. The wet kiln process compared to the dry process requires additional heat to dry the wet slurry. Wet cement kilns therefore burn an additional amount of coal to produce a ton of clinker. Coal used at cement plants is inventoried in Section 3 (see Table 3-4 of this report).

Shown below are the EPA source classification codes (SCC) for point source cement plants.

SCC	Description
305006 (dry process)	The 2 cement plants are point sources. The SCCs are for point sources, there are no area source SCCs.
305007 (wet process)	

7.3.1.2 Key Assumptions

The two cement plants in Seattle do not lime their cement. There are two cement plants in Seattle: Ash Grove and LaFarge. The two plants produce Portland cement and do not add additional liming required in masonry cement.

Ash Grove releases 1,050 lbs of CO_2 per ton of clinker produced and LaFarge releases 1,084 lbs of CO_2 per ton of clinker produced.[163] The U.S. GHG 2004 gives 1,014 lbs of CO_2 per clinker produced. Ash Grove uses the dry process and LaFarge uses the wet process. The wet process requires additional heat to dry the slurry.

7.3.1.3 Estimating Equation

$$\text{Tons of } CO_2 = (\text{tons of clinker produced}) \times (\text{lbs of } CO_2 \text{ per ton of clinker})$$

7.3.1.4 Activity Levels and Summary of Emissions

Table 7-24 gives estimates of clinker production and carbon dioxide emitted from calcination.

Table 7-24: Tons of Clinker Produced and Tons of CO_2 Emitted by Cement Plants, 2005

Cement Plant	Tons of Clinker	Lbs of CO_2/Ton of Clinker	Tons of CO_2 Emitted
Ash Grove	713,452	1,050	374,562
LaFarge	273,325	1,084	148,142
Both plants	986,777	---	522,704

7.3.2 Steel Production

7.3.2.1 Category Description

There are two steel production facilities in King County: Jorgenson and NUCOR. They use the electric arc furnace (EAF) method to turn raw material into steel. The carbon electrodes in the EAF burn off, thus producing carbon dioxide.

SCC	Description
30301540	The 2 steel plants are point sources and use the EAF method. The EPA code presented here is for point sources, there are no equivalent area source SCCs for steel plants.

7.3.2.2 Key Assumptions

The steel plants reported their annual production to the Agency accurately. The two steel plants reported to the Agency that they produced 774,000 tons[164] of steel using the EAF method.

The CO_2 emission factor provided by the U.S. GHG 2004 is representative of emissions from the two facilities. The U.S. GHG 2004 report estimates that producing one ton of steel by the EAF method releases 9.702 lbs of CO_2.[165]

7.3.2.3 Estimating Equation

$$\text{Tons of } CO_2 = (\text{tons of steel produced}) \times (\text{lbs of } CO_2 \text{ per ton of steel})$$

[163] Ash Grove emission factor: Gerald Brown, Ash Grove Safety/Environmental Mgr.; gerald.brown@ashgrove.com, (206) 694-6221; 3801 E. Marginal Way South, Seattle. LaFarge emission factor: Michael Depew, LaFarge Technical Manager; mike.depew@lafarge-na.com, (206) 937-8025, x313; 5400 W. Marginal Way SW, Seattle.

[164] Agency database: 2005 activity reported by Nucor and Jorgenson as of October 25, 2006.

[165] U.S. GHG 2004, pages 4-5 give 4.4 kg of CO_2/ton of steel produced by electric arc furnace.

7.3.2.4 Activity Levels and Summary of Emissions

Table 7-25 presents tons of steel produced at Nucor and Jorgensen by the EAF method and tons of carbon dioxide emitted during steel production.

Table 7-25: Steel Production and Carbon Dioxide Emissions, 2005

Steel Production Facility	Tons of Steel Produced by EAF	Tons of CO_2 Emitted
Nucor	765,990	3,716
Jorgensen	8,144	40
Both facilities	774,134	3,755

7.3.3. CO_2 Consumption at Corry's Fine Dry Cleaning, Mercer Island, WA

7.3.3.1 Category Description

Corry's Fine Dry Cleaning, Mercer Island, WA (Corry's) uses liquid carbon dioxide as cleaning fluid. It is the first dry cleaner in Washington and the only dry cleaning facility in the Agency's jurisdiction to provide carbon dioxide cleaning. It switched from perc to carbon dioxide cleaning in June 2000. It received a 2004 Governor's Award for Pollution Prevention and Sustainable Practices. The Mercer Island Corry's dry cleaning facility buys about 12 tons of liquid carbon dioxide a year. EPA has not established an SCC code for dry cleaners using CO_2.

7.3.3.2 Key Assumption

Corry's reported its carbon dioxide purchases accurately and emitted all 12 tons it purchased in 2005. An Agency inspector, Nina Birnbaum, inspected Corry's in 2004 and found a similar carbon dioxide consumption rate.

7.3.3.3 Activity Levels and Summary of Emissions

Corry's bought 12 tons of carbon dioxide in 2005. Nina Birnbaum, an Agency inspector visited the facility in two consecutive years and found similar purchase patterns. Corry's purchased, consumed, and released 12 tons of CO_2 in 2005.

7.3.4 Sulfur Hexafluoride (SF_6) from Power Distribution

7.3.4.1 Category Description

Transformers and other high voltage power transmission equipment use sulfur hexafluoride as insulators and dielectrics. The equipment eventually loses some of the sulfur hexafluoride through leakage. The SF_6 may also get dirty or contaminated and need replacement. Equipment owners need to replenish the fluid from time-to-time. The annual SF_6 emissions come from the replenished SF_6. There is not an SCC code for this category.

7.3.4.2 Key Assumptions

SF_6 emissions from electric power equipment are proportional to power transmitted. Data on SF_6 purchases is not publicly available. The U.S. emissions reported in the U.S. GHG 2004 are apportioned to Washington by electric power transmission reported by the U.S. Energy Information Agency (EIA). Power transmitted consists of 2 parts: (1) the kW-hrs eventually consumed and (2) the kW-hrs lost while being transmitted to the consumer. EIA reports energy data at the state level.

Power consumed in Washington counties is proportional to population. Power transmission is a better surrogate to use to distribute SF_6 emissions among Washington counties. However, utilities report electric power consumption at the utility coverage level. It is difficult to obtain electric power transmission losses at the county level. Population is used to apportion SF_6 emissions in Washington to the county level, since SF_6 emissions are not a significant part of the inventory.

The methodology used to estimate national sulfur hexafluoride emissions in the U.S. GHG 2004 is representative of Washington State and the Agency's jurisdiction. National estimates of SF_6 losses from power transmissions were based on: (1) reporting from utilities participating in EPA's SF_6 emissions reduction partnership for electric power systems, and (2) utilities transmission lines as reported in the 2004 Directory of Electric Power Producers and Distributors. Transmission lines are defined as miles of lines carrying more than 34,500 volts.

7.3.4.3 Estimating Equations

SF_6 emissions in Washington are estimated from:

$A = (B \div C) \times D$

where

- A = SF_6 emissions in Washington State
- B = electric power consumption and losses in Washington State
- C = electric power consumption and losses in the U.S.
- D = SF_6 emissions as reported by the U.S. GHG 2004

SF_6 emissions in a county are estimated from:

$E = (F \div G) \times A$

where

- E = SF_6 emissions in county
- F = population of county
- G = population of Washington State
- A = SF_6 emissions in Washington State as estimated above

7.3.4.4 Activity Levels and Summary of Emissions

Table 7-26 gives power consumption and transmission losses in Washington State and the U.S.

Table 7-26: kW-hrs of Power Transmitted, 2004[166]

Category of Power	Washington State	U.S.
Residential sales	32,455	1,294,000
Residential losses	72,239	2,879,000
Commercial sales	28,226	1,229,000
Commercial losses	62,820	2,736,000
Industrial sales	19,269	1,019,000
Industrial losses	42,868	2,267,000
Transportation sales	42	7,000
Transportation losses	93	16,000
Total sales	79,982	3,549,000
Total losses	178,020	7,898,000
Total transmitted	258,002	11,447,000

[166] Energy Information Agency, Consumption Estimates, http://www.eia.doe.gov/emeu/states/_seds.html; September 2007.

Table 7-27 presents power consumption in Washington and the U.S., human population in Washington and in the Agency's jurisdiction, and tons of carbon dioxide equivalent of sulfur hexafluoride losses from power transmission equipment.

Table 7-27: Million kW-hrs, Population, and Emissions of SF_6 from Power Equipment (CO_2 eqv)

Area	Billion kW-hrs	Population	Tons of CO_2 Eqv of SF_6
U.S.	11,447		15,211,640
Washington State	258	6,256,400	342,853
King Co.		1,808,300	99,095
Kitsap Co.		240,400	13,174
Pierce Co.		755,900	41,424
Snohomish Co.		655,800	35,938
4-county region		3,460,400	189,631

7.3.5 Nitrous Oxide Emissions from Surgical Wards

7.3.5.1 Category Description

This category covers nitrous oxide emissions from product applications. Nitrous oxide is used in several applications: as an oxidizing agent and etchant in semiconductor manufacturing, as an oxidizing agent in atomic spectrometry, in production of sodium azide (used to inflate airbags), as a fuel oxidant in auto racing, and as an oxidizing agent in jewelers' blowtorches. The overwhelming majority of direct use of nitrous oxide is in hospitals. Below is the EPA SCC code for hospital operations.

SCC	Description
28 50 000 000	Hospitals: all operations

7.3.5.2 Key Assumption

Nitrous oxide emissions from surgical wards are proportional to employment in general medical and surgical hospitals (NAICS 6221). According to the U.S. GHG 2004, Section 5.3, page 5-2, approximately 86% of the nitrous oxide emitted came from applications such as anesthesia during surgeries and other medical procedures.

7.3.5.3 Estimating Equation

N_2O emissions in a county are estimated from:

$E = (F \div G) \times A$

where

- E = N_2O emissions in county
- F = hospital employment in county (NAICS 6221)
- G = hospital employment in U.S.
- A = N_2O emissions from N_2O product applications in U.S.

7.3.5.4 Activity Levels and Summary of Emissions

Table 7-28 presents 2004 hospital employment and carbon dioxide equivalent of nitrous oxide emitted from direct use of the gas.

Table 7-28: Hospital Employment and Emissions of Nitrous Oxide, 2004[167]

Area	Hospital Employment (NAICS 6221)	Tons of CO_2 Eqv of N_2O
U.S.	4,904,344	5,291,005
King Co.	29,461	31,784
Kitsap Co.	1,750	1,888
Pierce Co.	13,204	14,245
Snohomish Co.	3,762	4,059
4-county region	48,177	51,975

7.3.6 Miscellaneous Industrial Processes

7.3.6.1 Category Description

Several other industrial processes emit greenhouse gases (GHG). Relative to the sections discussed earlier, emissions from the individual processes are not large enough to warrant detailed estimation calculations in this report. Employment is therefore used to apportion the emissions as reported in the U.S. GHG 2004 for those industries the Agency believes exist in the Puget Sound area. These include:

- ammonia manufacturing and urea application
- lime manufacturing
- limestone and dolomite application
- Ferroalloy production
- carbon dioxide used to bottle beverages
- nitric acid production
- semiconductor manufacturing
- fluorocarbons emitted during the production of freon
- production of substitutes for ozone depletors (ODCs)
- production of abrasives, inorganics, and other materials

Emissions of carbon dioxide occur during the production of synthetic ammonia, primarily through the use of natural gas as a feedstock. In some plants, the carbon is captured and used to produce urea. Lime is produced when limestone (calcium carbonate) is heated in a kiln to produced lime (CaO) and CO_2. Some of the CO_2 is recaptured for other industrial processes, and some is emitted to the atmosphere.

Limestone and dolomite are extracted for industrial applications such as: a sorbent in flue gas de-sulfurization systems, a purifier in metallurgical furnaces, a raw material for glass manufacturing, and magnesium manufacturing. In some of these applications, the limestone is sufficiently heated to release CO_2 as a byproduct.

CO_2 is emitted from the alloying of iron with other elements to achieve desired properties when metallurgical coke oxidizes to CO_2 during a high temperature reaction with iron and the alloying element.

Carbon dioxide is used and ultimately released in a variety of commercial applications. These include food processing, chemical production, carbonated beverage production, and commercial refrigeration.

[167] Employment data: 2004 County Business Patterns. http://censtats.census.gov/cbpnaic/cbpnaic.shtml. U.S. N_2O Emissions: Tables 5.3 and ES-2 (Executive Summary) of U.S. GHG 2004.

Nitric acid is produced by catalytic oxidation of ammonia. This process releases nitrous oxide as a by-product and vents it to the atmosphere. Semiconductor manufacturing releases fluorinated GHGs, principally PFC, HFC, and SF_6, to the atmosphere.

Some industrial processes, such as those involved in the production of adipic acid and aluminum, do not exist in the Puget Sound area. For the categories that exist in the area as indicated by the Agency registration database or County Business Patterns, the Agency used employment data at the 4-digit NAICS level to apportion GHG reported in the U.S. GHG 2004 to counties.

7.3.6.2 Key Assumption

Emissions as reported in the U.S. GHG 2004 are directly proportional to the number of employees in the various industries in this category. National emissions presented in the U.S. GHG 2004 are apportioned to Puget Sound counties by employment in the specific industry. This assumes that industrial practices of the sources covered, and the methodologies used to estimate emissions from miscellaneous GHG emissions sources at the national level, are representative of the Puget Sound area.

7.3.6.3 Estimating Equation

For a specific category:

$$\text{County emissions} = (\text{county employment}) \div (\text{U.S. employment}) \times (\text{U.S. emissions})$$

7.3.6.4 Activity Levels and Summary of Emissions

Table 7-29 presents the number of U.S. employees and U.S. GHG emissions from industrial processes not discussed in earlier sections, which the Agency database registrations and County Business Patterns (CBP) indicate exist in the Puget Sound area.

Table 7-29: U.S. Employees and Tons of CO_2 Eqv Emitted by Industry, 2005[168]

Industry	NAICS Code	U.S. Employment	1,000 Tons of CO_2 Eqv
Lime manufacturing	3274	18,034	15,102
Ammonia & urea mfg.	3253	31,284	18,626
Limestone use	3274	18,034	7,389
Soda ash manufacturing	3251	162,787	4,636
Phosphoric acid mfg.	3251	162,787	1,538
Ferroalloy manufacturing	3311	109,857	1,419
Carbon dioxide use	3121	132,858	1,304
Silicon carbide production	3297	76,699	147
Nitric acid production	3253	31,184	18,456
ODC substitutes mfg.	3251	162,787	113,888
Freon production	3251	162,787	17,199
Semiconductor mfg.	3344	362,184	5,182

Table 7-30 presents the number of Puget Sound establishments in the categories in Table 7-29 as reported in the 2005 CBP. Table 7-31 presents the number of sources in the categories represented in Table 7-29 that are registered with the Agency. Not all sources are registered with the Agency. Tables 7-30 and 7-31 are presented to confirm that the industries exist in the area.

[168] Tons of carbon dioxide equivalent: Inventory of U.S. GHG 2004, Chapter 4. Employment: 2004 County Business Patterns. See http://censtats.census.gov/cbpnaic/cbpnaic.shtml.

Table 7-30: Number of Establishments by Industry (as reported in the 2005 CBP)[169]

Industry	King Co.	Kitsap Co.	Pierce Co.	Snohomish Co.
Lime manufacturing	5	1	3	1
Ammonia & urea mfg.	7		2	2
Limestone use	5		3	1
Soda ash manufacturing	6		4	
Phosphoric acid mfg.	6		4	
Ferroalloy manufacturing	6	4	4	
Carbon dioxide use	33		3	6
Silicon carbide production	19	1	3	7
Nitric acid production	7		2	2
ODC substitutes mfg.	3		4	
Freon production	3		4	7
Semiconductor mfg.	37	1	4	13

Table 7-31: Number of Establishments by Industry (registered with the Agency in 2005)[170]

Industry	King Co.	Kitsap Co.	Pierce Co.	Snohomish Co.
Lime manufacturing	2			
Ammonia & urea mfg.	3	1	3	1
Limestone use	2		3	9
Soda ash manufacturing	9		3	
Phosphoric acid mfg.	9			
Ferroalloy manufacturing	1		7	
Carbon dioxide use	7			
Silicon carbide production	8	1	5	3
Nitric acid production	3		3	9
ODC substitutes mfg.	9		7	
Freon production	9		7	
Semiconductor mfg.	13		2	3

Table 7-32 presents the number of employees in the Agency's jurisdiction working in industries that emit GHGs, that were not inventoried in earlier sections.

Table 7-32: Employees by Industry and County, 2005[171]

Industry	King Co.	Kitsap Co.	Pierce Co.	Snohomish Co.
Lime manufacturing	205		175	10
Ammonia & urea mfg.	113	9	19	11
Limestone use	205		175	10
Soda ash manufacturing	123		60	
Phosphoric acid mfg.	123		78	
Ferroalloy manufacturing	123		34	
Carbon dioxide use	1,377	16	60	66
Silicon carbide production	213		90	137
Nitric acid production	113	9	19	11
ODC substitutes mfg.	123		60	
Freon production	123		60	
Semiconductor mfg.	2,175		199	393

[169]U.S. Census Bureau, *2004 County Business Patterns*. See http://censtats.census.gov/cbpnaic/cbpnaic.shtml.
[170]Puget Sound Clean Air Agency registration database.
[171]U.S. Census Bureau, *2004 County Business Patterns*. See http://censtats.census.gov/cbpnaic/cbpnaic.shtml.

Table 7-33 presents the tons of carbon dioxide equivalents emitted in miscellaneous industries based on the number of employees.

Table 7-33: Tons of CO_2 Eqv Emitted by Miscellaneous Manufacturing Processes, 2005

Industry	King Co.	Kitsap Co.	Pierce Co.	Snohomish Co.
Lime manufacturing	171,671		146,548	8,374
Ammonia & urea mfg.	67,278	5,358	11,312	6,549
Limestone use	83,994		71,702	4,097
Soda ash manufacturing	3,503		1,709	
Phosphoric acid mfg.	1,162		737	
Ferroalloy manufacturing	1,587		439	
Carbon dioxide use	13,515	157	589	648
Silicon carbide production	408		172	263
Nitric acid production	66,878	5,327	11,245	6,510
ODC substitutes mfg.	86,052		41,977	
Freon production	12,995		6,339	
Semiconductor mfg.	31,119		2,847	5,623
Total	540,164	10,842	295,617	32,064

8 Greenhouse Gas (GHG) Sinks

8.1 Category Description (forest sinks)

After they are emitted, greenhouse gases can be removed from the atmosphere by several processes, most often referred to as "sinks". The Puget Sound area has a great deal of vegetative cover and these plants extract carbon dioxide from the air for use in photosynthesis; this is known as carbon sequestration. EPA does not have an SCC code for carbon sequestration.

8.2 Key Assumptions

The 2003 King County Emission Inventory accurately estimates King County CO_2 sequestration, and its methodology is applicable to other local counties.[172] The 2003 King County Emissions Inventory estimated the quantity of carbon dioxide equivalents sequestered in King County as 830,000 tonnes of CO_2 eqv. King County based its estimate on forested land. (One tonne is equal to 2,205 lbs, or 1.1 U.S. tons.) The Agency adopted this estimate and based estimates for the other three counties on the King County estimate.

The Amount of CO_2 sequestered is proportional to forested area. While all vegetative cover uses up carbon dioxide, forests are the best surrogate to estimate quantity of carbon dioxide sequestered by vegetation. The total land area of the counties is published by the U.S. Bureau of Census and the Washington State Office of Financial Management (OFM). The OFM also publishes the land area of incorporated areas. Incorporated areas of the counties are built up and have no forests. Even the built-up sections of unincorporated areas have more vegetative cover than built-up sections of incorporated areas. In the Puget Sound region, the difference between county square mile area and incorporated square mile area is a good approximation to forested square mile area.

8.3 Estimating Equation (for sequestrated CO_2)

$\underline{A = (B \div C) \times D}$

where

A = tons of carbon dioxide equivalent sequestered by forests in the county
B = square miles of forest land in the county
C = square miles of forest land in King County
D = tons of carbon dioxide equivalent sequestered by King County forests

Table 8-1 presents land area (square miles) of Puget Sound counties, the number of square miles of incorporated areas and forested land, and the quantity of GHG sequestered by forests. Forested land is defined as the area of the county minus the area of the cities.

Table 8-1: Tons of CO_2 Eqv Sequestered and Sequestration Area, 2005[173]

County	Co. Land Area (sq. miles)	Cities Land Area (sq. miles)	Forested Land (sq. miles)	Sequestered GHG (1,000 tons)
King	2,126	379	1,747	915
Kitsap	396	35	361	189
Pierce	1,679	136	1,543	808
Snohomish	2,089	120	1,969	1,031
4-co. region	6,290	669	5,621	2,944

[172] 2003 King Co. Air Emissions, page 63, estimated by Kathy Creahan, King Co. Office of Rural and Resource Programs.

[173] County land area: U.S. Census Bureau, State and County Quick Facts; http://quickfacts.census.gov/qfd., September 17, 2007. Cities land area: Table 9, 2000 Population Trends, WA OFM, Forecasting Division, September 2000.

9 Electricity Production and Consumption

Electric power in the Puget Sound area comes mostly from hydroelectric power. Consequently emissions from power production are very low compared with other parts of the country.

9.1 Emissions from Electric Power Production

Point source emissions previously discussed in Section 3.1 (Ecology Sources) and Section 3.2 (Agency Sources) include emissions from facilities that produce power from burning fossil fuels. This section only includes emissions from activities of plants that relate directly to power production. Facilities in the Agency's jurisdiction that produced electric power in 2005 are:

- Puget Sound Energy....................Greenwater........King Co.
- Puget Sound Energy....................Frederickson......Pierce Co.
- King Co. DNR Wastewater Treatment Division ....Seattle................King Co.
- King Co. DNR Wastewater Treatment Division ....Renton...............King Co.
- Seattle Steam Company (Western Ave.) ....Seattle................King Co.
- Seattle Steam Company (Post Ave.)............................Seattle................King Co.
- University of Washington Power Plant & Hospital......Seattle................King Co.
- Kimberly-Clark ....Everett ....Snohomish Co.
- Simpson Tacoma Kraft Company................................Tacoma.............Pierce Co.

Of the listed facilities, only the Puget Sound Energy and Seattle Steam plants are true utilities. Kimberly-Clark and Simpson Tacoma Kraft Company (Simpson Tacoma) are wood-products processing facilities that burn wood waste to generate electricity. The DNR Wastewater Treatment plants burn methane collected from wastewater treatment to generate electricity. The University Power Plant & Hospital generates electricity but is classified under NAICS 611310 (colleges, universities, professional schools). Table 9-1 shows the quantity of fuel burned at facilities to produce electric power. The facilities reported fuel combustion to the Agency.

Table 9-1: Fuel Burned by Facilities in Agency Jurisdiction to Produce Power, 2005

Facility	City	County	Fuel Type Burned	Quantity Burned	Quantity Unit
Puget Sound Energy	Greenwater	King	distillate oil	5,224	gallons
DNR Wastewater Treatment	Seattle	King	digester gas	499	mcf
DNR Wastewater Treatment	Seattle	King	propane	1000	gallons
DNR Wastewater Treatment	Renton	King	digester gas	20	mcf
Seattle Steam (Western Ave.)	Seattle	King	natural gas	1,460	mcf
Seattle Steam (Western Ave.)	Seattle	King	residual oil	131,425	gallons
Seattle Steam (Post Ave.)	Seattle	King	residual oil	5,410	gallons
Univ. Power Plant & Hosp.	Seattle	King	natural gas	1,410	mcf
Kimberly-Clark	Everett	Sno	natural gas	180	mcf
Kimberly-Clark	Everett	Sno	distillate oil	15,000	gallons
Kimberly-Clark	Everett	Sno	wood	573,813	tons
Simpson Tacoma	Tacoma	Pierce	natural gas	129	mcf
Simpson Tacoma	Tacoma	Pierce	distillate oil	9,186	1,000 gallons
Simpson Tacoma	Tacoma	Pierce	wood	145,436	tons
Puget Sound Energy	Frederickson	Pierce	natural gas	4,665	mcf

Table 9-2 presents the GHG emission factors for fuel combustion. These factors are applied to the fuel consumption in Table 9-1 to estimate GHG emissions from the power generation activities of point sources.

$$CO_2 \text{ eqv factor} = (21 \times CH_4 \text{ factor}) + (310 \times N_2O \text{ factor})$$

The CO_2 eqv factor for wood burning excludes carbon dioxide, as recommended by the IPCC guidelines.

Table 9-2: GHG Emission Factors for Fuel Burned[174]

Fuel Type	Units of Factor	CO_2	CH_4	N_2O	CO_2 Eqv
Natural gas	lbs/mcf	120,000	2.3	2.2	120,730
Distillate oil	lbs/1,000 gallons	22,300	0.052	0.11	22,335
Residual oil	lbs/1,000 gallons	25,000	0.052	0.11	25,035
Propane	lbs/1,000 gallons	12,500	0.2	0.9	12,783
Wood	lbs/million Btu	n/a	0.022	0.013	4.5
Wood	lbs/ton	n/a	0.23	0.14	46.7

Below are the estimating equations used:

Lbs of CO_2 eqv = (quantity of fuel burned) × (lbs of CO_2 eqv/unit of fuel burned)
Tons CO_2 eqv = (lbs of CO_2 eqv emitted) ÷ (2,000 lbs/ton)

Table 9-3 presents GHG emitted at the facilities that burn fuel to produce power.

Table 9-3: Lbs of GHG Emitted by Facilities in Agency Jurisdiction to Produce Power, 2005

Facility	County	Fuel Burned	Lbs of CO_2 Eqv	Tons of CO_2 Eqv
PS Energy, Greenwater	King	distillate oil	116,679	58
DNR Wastewater Plant, Seattle	King	digester gas	60,244,420	30,100
DNR Wastewater Plant, Seattle	King	propane	12,783	6
DNR Wastewater Plant, Renton	King	digester gas	2,414,606	1,210
Seattle Steam (Western Ave.)	King	natural gas	176,227,207	88,100
Seattle Steam (Western Ave.)	King	residual oil	3,290,250	1,650
Seattle Steam (Post Ave.)	King	residual oil	135,440	68
Univ. Power Plant & Hosp.	King	natural gas	170,285,863	85,100
Kimberly-Clark	Sno	natural gas	21,731,454	10,900
Kimberly-Clark	Sno	distillate oil	335,028	168
Kimberly-Clark	Sno	wood	26,806,707	13,400
Simpson Tacoma	Pierce	natural gas	15,574,209	7,790
Simpson Tacoma	Pierce	distillate oil	205,171	103
Simpson Tacoma	Pierce	wood	6,794,305	3,400
PS Energy, Frederickson	Pierce	natural gas	563,169,231	281,585

Table 9-4 presents the tons of GHGs emitted by activities that relate directly to power production. It summarizes Table 9-3 emissions by county.

Table 9-4: Tons of GHG from Electric Power Production Activity in Agency Jurisdiction, 2005

County	CO_2 Eqv
King County	206,364
Pierce County	292,878
Snohomish County	24,437
Total	523,679

[174] Tables and Appendix from AP-42, Fifth Edition; Natural Gas: Emission Factors for Natural Gas Combustion, Section 1.4, Table 1.4-2; Oil: Emission Factors for Oil Combustion, Section 1.3, Tables 1.3-12, 1.3-8, 1.3-3; Propane: Emission factors for LPG Combustion, Section 1.5, Table 1.5-1; Wood: Emission Factors for Wood Waste Combustion, Section 1.6, Table 1.6-3; Appendix A, Thermal Equivalents of Fuel: heat content for wood with 40% moisture is 5,200 Btu/lb.

Relative to GHG emissions from electricity generation in other parts of the country, emissions from electricity generation in the Puget Sound area are small. According to the 2005 GHG Emissions and Sinks, electricity generation contributed 39% of U.S. GHG emissions.

9.2 Emissions from Electric Power Consumption

9.2.1 Category Description

The Puget Sound area gets most of its electricity from hydroelectric power. Table 9-5 shows local electric power utilities and the areas they cover. Skagit, Island, Thurston, Kittitas, and Whatcom counties are outside the Agency's jurisdiction but are served by Puget Sound Energy (PSE). Snohomish PUD serves all of Snohomish County and PSE serves all of Kitsap County.

Table 9-5: Puget Sound Electric Utilities and Areas of Coverage[175]

Puget Sound Energy (PSE)	Seattle City Light (SCL)	Tacoma Power (TP)
King County (except SCL area)	city of Seattle, King Co.	city of Tacoma
Kitsap County	city of Shoreline, King Co.	city of Fircrest
Pierce County (except TP area)		city of University Place
Skagit County		city of Fife
Island County		city of Steilacoom
Thurston County		city of Lakewood
Kittitas County		Fort Lewis Army Base
Whatcom County		McChord AFB
Pt. Townsend, Jefferson Co.		city of Roy
Pt. Ludlow Census Designation Point		
Pt. Hadlock Census Designation Point		
Brinnon Census Designation Point		

Table 9-6 presents the 2005 gigawatt-hours distributed by electricity suppliers in their areas of coverage for residential, commercial, and industrial (RCI) consumption.

Table 9-6: 2005 GWh Supplied by Electric Power Suppliers in their Coverage Areas[176]

Electricity Supplier	Residential (R)	Commercial (C)	Industrial (I)	Total RCI
Puget Sound Energy (PSE)	10,322	8,647	1,358	20,327
Seattle City Light (SCL)	2,955	6,207	see comm'l	9,161
Tacoma Power (TP)	1,753	2,865	see comm'l	4,618
Snohomish Co. PUD (PUD)	3,188	2,243	851	6,282

PSE data includes consumption by counties outside Agency jurisdiction.

[175] PSE: 2006 Annual Report, http://www.pugetenergy.com (select shareholders, financial reports, 2006 annual report); accessed February 14, 2008. SCL: 2006 Annual Report; http://www.ci.seattle.wa.us/light/aboutus/annualreport; accessed February 14, 2008. Tacoma Power: Tacoma Public Utilities Quick Facts 2006, received by mail from Tacoma Power, 3628 South 35th Street, Tacoma, WA 98409, December 24, 2007. PUD: 2006 Annual Report; http://www.snopud.com, February 14, 2008.

[176] PSE: 2006 Annual Report, http://www.pugetenergy.com (select shareholders, financial reports, 2006 annual report); February 14, 2008. SCL: Annual Report: http://www.ci.seattle.wa.us/light/aboutus/annualreport, February 14, 2008. Tacoma Power: by e-mail from Andrew Evancho, aevanch@ci.tacoma.us.wa, December 21, 2007. PUD: Annual Report: http://www.snopud.com/content/external/documents/finance/annual2006; go to snopud.com and enter "annual report" in the search engine. Also by e-mail from Katie Seling, kmseling@snopud.com, December 21, 2007.

9.2.2 Key Assumptions

The Agency made the following assumptions to estimate electricity consumption and emissions.

Gigawatt-hours provided by the suppliers are accurate. The Agency assumes the 2005 data obtained from the websites, publications, and representatives of the utilities is accurate and representative of areas they cover.

Residential consumption in the PSE area is proportional to the number of households in the area, and households use electricity at the same rate throughout the PSE area. PSE serves most of King and Pierce counties. The PSE website provided data for all of its service area. The number of households in the PSE service area is used as a surrogate to apportion PSE residential consumption among areas it serves. The apportionment assumes households have the same average consumption rate.

Commercial consumption in the PSE area is proportional to the number of commercial employees in the area, and consumption per commercial employee is the same throughout the PSE area. The number of commercial employees in the PSE service area is used as a surrogate to apportion PSE commercial consumption among the areas it serves. Apportionment assumes all PSE areas have the same consumption rate per commercial employee.

Industrial consumption in the PSE area is proportional to the number of industrial employees in the area, and consumption per industrial employee is the same throughout the PSE area. The number of industrial employees in the PSE service area is used as a surrogate to apportion PSE industrial consumption among the areas it serves. Apportionment assumes all PSE areas have the same consumption rate per industrial employee.

Industrial and commercial employment for sub-county areas reflects industrial and commercial employment distribution of the county. Total employment data is available for cities in King, Jefferson, and Pierce counties. Industrial and commercial employment data are not available at the city level. In such cases, total city or area employment is separated into commercial and industrial employment with the equation:

$\underline{A = (B \div C) \times D}$

where

- A = commercial employment for city or sub-county area
- B = commercial employment for county as published by the County Business Patterns
- C = total employment for county as published by the County Business Patterns
- D = total employment for city or sub-county area

A similar equation is used to estimate industrial employment for cities in Pierce and King counties.

The 2006 fuel mix for utilities is similar to the 2005 fuel mix and reflects purchases. The emission factors for electricity consumption depend on the fuel mix used to produce the electricity. The 2006 fuel mix obtained from utility websites and publications is similar to the 2005 fuel mix but is more segregated than the 2005 fuel mix. The Agency selected the 2006 fuel mix because it is more segregated (and therefore easier to use).

9.2.3 Surrogates used to Segregate PSE Consumption Data

PSE supplies electricity to areas outside the Agency jurisdiction. The Agency used the number of households plus commercial and industrial employment to divide PSE electricity among areas PSE serves.

Appendix E shows surrogates used to estimate the portion of PSE electricity data consumed in King, Pierce, and Kitsap counties. It identifies the area, electricity supplier, zip code, household, and employment.

9.2.4 Estimating Equations

The Agency estimated gigawatt-hours (GWh) of electricity consumption for PSE coverage areas with the basic equation:

$A = (B \div C) \times D$

where

- A = GWh consumed in the area for category (residential, commercial, or industrial)
- B = surrogate for the category and for the area (as presented in Appendix E)
- C = corresponding surrogate for all areas covered by PSE
- D = GWh for the category for all areas covered by PSE

For an area, GWh and emissions from electricity consumption are calculated with:

Total GWh consumed = (residential + commercial + industrial) GWh
Emissions = (total GWh consumed) × (emission factor, lbs emitted/GWh)

9.2.5 GWh Consumed

PSE, SCL, TP, and PUD provided GWh for areas they cover. Table 9-7 presents the electricity consumption data obtained from the utilities. The table shows the utilities and the GWh they supplied for each of the RCI categories.

Table 9-7: 2005 GWh Supplied by Utilities[177]

Utility	Residential (R)	Commercial (C)	Industrial (I)	Total RCI
PSE (all PSE areas)	10,322	8,647	1,358	20,327
Seattle City Light	2,955	6,207	(see comm'l)	9,161
Tacoma Power	1,753	2,865	(see comm'l)	4,618
Snohomish PUD	3,188	2,243	851	6,282

Table 9-8 presents the GWh consumption as calculated from Table 9-7 using the estimating equations discussed above and the surrogates in Appendix E.

Table 9-8: GWh consumed in the Puget Sound Area, 2005

Utility	Area/County	Residential (R)	Commercial (C)	Industrial (I)	Total RCI
Puget Sound Energy	part of King Co.	4,899	5,451	893	11,243
Puget Sound Energy	all of Kitsap Co.	983	541	32	1,556
Puget Sound Energy	part of Pierce Co.	1,668	801	122	2,592
Seattle City Light	part of King Co.	2,955	5,333	873	9,161
Tacoma Power	part of Pierce Co.	1,753	2,462	403	4,618
Snohomish PUD	all of Sno Co.	3,188	2,243	851	6,282

9.2.6 Emission Factors

The emission factors for electricity depend on the fuel mix used to produce the electricity. Table 9-9 presents fuel mix for four utilities operating in the Agency's jurisdiction. The utilities buy electricity from outside the region. The fuel mix published by the utilities reflects electricity purchases.

[177] PSE: www.pugetenergy.com, (select shareholders, financial reports, annual report, 2006 report).
City Light: www.ci.seattle.wa.us/light/aboutus/annualreport.
Tacoma Power: e-mail from Andrew Evancho, aevanch@ci.tacoma.wa.us, December 24, 2007.
PUD: www.snopud.com, and also from Katie Seling, kmseling@snopud.com, December 24, 2007.

Table 9-9: Percent of Fuel Mix for Utilities Operating in the Puget Sound Area, 2005-06[178]

Type of Fuel	Puget Sound Energy	Seattle City Light	Tacoma Power	Snohomish PUD
Hydro	45%	90%	89%	82%
Wind	2%	4%		
Nuclear	1%	5%	8%	9%
Natural gas	17%	1%	1%	2%
Coal	34%	<1%	2%	6%
Distillate oil	1%			1%
Total	100%	100%	100%	100%

The International Council of Local Environmental Initiatives (ICLEI) developed software, entitled the Clean Air and Climate Protection Software (CACPS), which estimates emissions and emission factors for various types of activities and categories. Fuel mix for a utility is entered into the software and CACPS provides emission factors in pounds/million Btu for that fuel mix. Table 9-10 presents emission factors for electricity consumption for the four Puget Sound utilities, based on CACPS.

Table 9-10: Emission Factors for Electricity Consumption (lbs of pollutant/million Btu)[179]

Utility	CO	NOx	PM_{10}	SOx	VOC	CO_2	CH_4	N_2O
Puget Sound Energy	0.297	0.080	0.250	4.681	0.0060	323.956	0.0040	0.0020
Seattle City Light	0.010	0.003	0.007	0.126	0.0002	11.802	0.0001	0.0001
Tacoma Power	0.017	0.005	0.015	0.274	0.0003	18.717	0.0002	0.0001
Snohomish PUD	0.050	0.014	0.004	0.848	0.0010	57.599	0.0010	0.0004

The emission factors in Table 9-10 are converted to pounds/GWh and presented in Table 9-11. One kWh is equal to 3,410 Btu.[180] Thus one million Btu is equal to 293.255 kWh. One GWh = one million kWh.

$$\text{Lbs/GWh} = [(\text{lbs/million Btu}) \div (293.3\ \text{kWh})] \times (1{,}000{,}000\ \text{kWh per GWh})$$
$$CO_2\ \text{eqv factor} = (CO_2\ \text{factor}) + (21 \times CH_4\ \text{factor}) + (310 \times N_2O\ \text{factor})$$

For fossil fuel combustion in industrial boilers, the Agency assumed PM_{10} emission factors to be the same as $PM_{2.5}$ emission factors.

Table 9-11: Emission Factors for Electricity Consumption (lbs of pollutant/GWh)[181]

Utility	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Puget Sound Energy	1,012.8	272.8	852.5	15,962.2	20.5	1,107,090.6
Seattle City Light	34.1	10.2	23.9	429.7	0.7	40,332.3
Tacoma Power	58.0	17.1	51.2	934.3	1.2	63,963.7
Snohomish PUD	170.5	47.7	13.6	2,891.7	3.4	196,860.0

[178] PSE: www.pugetenergy.com, (select: shareholders, financial reports, annual report, 2006 report).
City Light: www.ci.seattle.wa.us/light/aboutus/annualreport.
Tacoma Power: e-mail from Andrew Evancho, aevanch@ci.tacoma.wa.us, December 24, 2007.
PUD: Annual Report; www.snopud.com/content/external/documents/finance/annual2006.

[179] Electricity consumption factors for utilities in the Agency's jurisdiction as modeled with CACPS and the fuel mix provided by the utilities.

[180] AP-42, Appendix A, Conversion Factors.

[181] Electricity consumption factors for utilities in the Agency's jurisdiction as modeled with CACPS and the fuel mix provided by the utilities.

9.2.7 Summary of Emissions

The Agency estimated emissions from electricity consumption with the equation:

$$\text{Emissions of pollutant} = (\text{GWh consumed}) \times (\text{lbs of pollutant/GWh})$$

Table 9-12 shows pollutant emissions from electricity consumption in the Agency's jurisdiction.

Table 9-12: Tons of Emissions from Electric Power Consumption, 2005

County	Utility	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Kitsap	PS Energy	788	212	663	12,421	16	861,506
Pierce	PS Energy	1,312	354	1,105	20,686	27	1,434,722
King	PS Energy	5,693	1,534	4,792	89,730	115	6,223,430
King	Seattle City Light	156	47	109	1,968	3	184,751
Pierce	Tacoma Power	134	39	118	2,157	3	147,678
Snohomish	Snohomish PUD	536	150	43	9,082	11	618,312
Total		8,619	2,336	6,830	136,044	175	9,470,399

Table 9-13 summarizes the GHG emissions in Table 9-12 by county.

Table 9-13: Tons of Emissions from Electric Power Consumption, 2005

County	CO_2 Eqv
King	6,408,181
Kitsap	861,506
Pierce	1,582,400
Snohomish	618,312
Total	9,470,399

Emissions in Table 9-13 include GHG emissions from power production presented in Table 9-4. To avoid double-counting, the power production GHG emissions in Table 9-14 must be subtracted from the electricity consumption emissions in Table 9-13 to give "net" electricity consumption emissions. Table 9-15 shows "net" electricity consumption (emissions from total electricity consumed minus emissions from local power production from fossil fuels).

Table 9-14: Tons of Emissions from Power Production in the Puget Sound Area, 2005

County	CO_2 Eqv
King	206,364
Pierce	292,878
Snohomish	24,437
Total	523,679

Table 9-15: Tons of Emissions from Electric Power Consumption, 2005

County	CO_2 Eqv
King	6,201,817
Kitsap	851,506
Pierce	1,289,522
Snohomish	593,875
Total	8,946,720

APPENDIX A:
Detailed Tables

A1: Tons of Pollutants Emitted by On-Road Vehicles in King County, 2005

Diesel Vehicle	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
HDDBS	52	246	15	7	15	32,399
HDDV2B	202	753	25	34	42	157,038
HDDV3	70	244	7	11	14	51,973
HDDV4	65	262	7	10	15	47,587
HDDV5	31	125	3	5	7	22,644
HDDV6	211	852	32	25	52	115,661
HDDV7	382	1,384	53	35	89	160,661
HDDV8a	672	2,241	78	48	108	219,564
HDDV8b	3,198	12,809	298	288	521	1,320,535
LDDT12	35	21	2	1	20	2,792
LDDT34	34	41	4	4	20	18,479
LDDV	67	61	7	3	29	11,955
HDDBT	130	580	11	19	12	85,084
Subtotal	5,150	19,618	542	490	946	2,246,372
Gasoline Vehicle	**CO**	**NOx**	**$PM_{2.5}$**	**SOx**	**VOC**	**CO_2 Eqv**
HDGBS	118	15	0	0	9	2,509
HDGBT	263	33	0	0	19	5,613
HDGV2B	8,556	2,586	42	32	635	620,031
HDGV3	767	114	2	1	50	24,138
HDGV4	513	60	1	1	43	9,920
HDGV5	644	116	1	1	54	24,037
HDGV6	1,525	244	3	3	125	48,447
HDGV7	1,000	133	1	1	79	21,650
LDGT1	32,600	1,747	18	36	2,391	688,431
LDGT2	111,050	7,239	61	120	8,174	2,291,661
LDGT3	39,486	2,661	22	53	3,020	998,046
LDGT4	18,329	1,517	10	25	1,429	458,981
LDGV	149,673	9,473	95	159	12,801	2,994,864
MC	1,481	157	2	1	255	15,880
Subtotal	366,004	26,095	259	434	29,083	8,204,207
All Vehicles	371,154	45,713	801	924	30,028	10,450,579

A2: Tons of Pollutants Emitted by On-Road Vehicles in Kitsap County, 2005

Diesel Vehicle	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
HDDBS	9	41	3	1	2	5,376
HDDV2B	20	73	2	3	4	15,267
HDDV3	7	24	1	1	1	5,053
HDDV4	6	25	1	1	1	4,626
HDDV5	3	12	0	0	1	2,201
HDDV6	21	83	3	2	5	11,245
HDDV7	37	135	5	3	9	15,620
HDDV8a	65	218	8	5	11	21,346
HDDV8b	311	1,245	29	28	51	128,384
LDDT12	3	2	0	0	2	271
LDDT34	3	4	0	0	2	1,797
LDDV	7	6	1	0	3	1,162
HDDBT	8	35	1	1	1	5,084
Subtotal	499	1,902	53	47	93	217,433
Gasoline Vehicle	**CO**	**NOx**	**$PM_{2.5}$**	**SOx**	**VOC**	**CO_2 Eqv**
HDGBS	17	2	0	0	1	365
HDGBT	20	2	0	0	1	424
HDGV2B	832	251	4	3	62	60.280
HDGV3	75	11	0	0	5	2,347
HDGV4	50	6	0	0	4	964
HDGV5	63	11	0	0	5	2,337
HDGV6	148	24	0	0	12	4,710
HDGV7	97	13	0	0	8	2,105
LDGT1	3,169	170	2	4	232	66,930
LDGT2	10,796	704	6	12	795	222,798
LDGT3	3,839	259	2	5	294	97,031
LDGT4	1,782	147	1	2	139	44.623
LDGV	14,551	921	9	15	1,244	291,164
MC	144	15	0	0	25	1,544
Subtotal	35,583	2,537	25	42	2,827	797,622
All Vehicles	36,083	4,439	79	90	2,920	1,015,055

A3: Tons of Pollutants Emitted by On-Road Vehicles in Pierce County, 2005

Diesel Vehicle	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
HDDBS	30	141	9	4	8	18616,
HDDV2B	74	276	9	13	16	57,677
HDDV3	26	90	3	4	5	19,089
HDDV4	24	96	3	4	6	17,478
HDDV5	11	46	1	2	3	8,317
HDDV6	78	313	12	9	19	42,480
HDDV7	140	508	19	13	33	59,007
HDDV8a	247	823	29	18	40	80,641
HDDV8b	1,174	4,704	109	106	192	485,003
LDDT12	13	8	1	0	7	1,026
LDDT34	13	15	1	1	7	6,787
LDDV	25	22	2	1	11	4,391
HDDBT	33	147	3	5	3	21,632
Subtotal	1,887	7,191	201	179	349	822,141
Gasoline Vehicle	**CO**	**NOx**	**$PM_{2.5}$**	**SOx**	**VOC**	**CO_2 Eqv**
HDGBS	59	7	0	0	4	1,254
HDGBT	81	10	0	0	6	1,729
HDGV2B	3,142	950	15	12	233	227,723
HDGV3	282	42	1	0	18	8,865
HDGV4	188	22	0	0	16	3,643
HDGV5	237	43	1	0	20	8,828
HDGV6	560	90	1	1	46	17,794
HDGV7	367	49	1	0	29	7,952
LDGT1	11,973	641	7	13	878	252,845
LDGT2	40,786	2,659	23	44	3,002	841,676
LDGT3	14,502	977	8	20	1,109	366,560
LDGT4	6,732	557	4	9	525	168,573
LDGV	54,971	3,479	35	59	4,701	1,099,946
MC	544	58	1	0	94	5,832
Subtotal	134,425	9,584	95	159	10,681	3,013,221
All Vehicles	136,313	16,775	296	339	11,030	3,835,363

A4: Tons of Pollutants Emitted by On-Road Vehicles in Snohomish County, 2005

Diesel Vehicle	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
HDDBS	25	120	8	3	7	15,849
HDDV2B	64	240	8	11	13	50,126
HDDV3	22	78	2	4	4	16,590
HDDV4	21	84	2	3	5	15,190
HDDV5	10	40	1	2	2	7,228
HDDV6	67	272	10	8	17	36,919
HDDV7	122	442	17	11	29	51,283
HDDV8a	215	715	25	15	35	70,084
HDDV8b	1,021	4,088	95	92	166	421,511
LDDT12	11	7	1	0	6	891
LDDT34	11	13	1	1	6	5,898
LDDV	21	19	2	1	9	3,816
HDDBT	30	131	3	4	3	19,272
Subtotal	1,641	6,250	175	156	303	714,657
Gasoline Vehicle	**CO**	**NOx**	**$PM_{2.5}$**	**SOx**	**VOC**	**CO_2 Eqv**
HDGBS	19	2	0	0	1	397
HDGBT	103	13	0	0	8	2,195
HDGV2B	2,731	826	13	10	203	197,912
HDGV3	245	36	1	0	16	7,705
HDGV4	164	19	0	0	14	3,166
HDGV5	206	37	0	0	17	7,673
HDGV6	487	78	1	1	40	15,464
HDGV7	319	42	0	0	25	6,911
LDGT1	10,406	557	6	12	763	219,745
LDGT2	35,447	2,311	20	38	2,609	731,492
LDGT3	12,604	849	7	17	964	318,574
LDGT4	5,851	484	3	8	456	146,505
LDGV	47,775	3,024	30	51	4,086	955,952
MC	473	50	1	0	81	5,069
Subtotal	116,828	8,329	83	138	9,283	2,618,760
All Vehicles	118,468	14,579	257	294	9,586	3,333,418

A5: Summary of Emissions by On-Road Vehicles in King County (tons emitted, 2005)

Type of Vehicle	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Diesel school bus	52	246	15	7	15	32,399
Other diesel vehicle	5,098	19,372	526	483	931	2,213,973
Gasoline school bus	118	15	0	0	9	2,509
Other gasoline vehicle	365,887	26,080	259	433	29,074	8,201,698
LPG vehicle	1	9	0	1	0	8,302
CNG vehicle	54	126	10	1	7	161,557
Total on-road vehicles	371,209	45,848	811	926	30,036	10,620,438

A6: Summary of Emissions by On-Road Vehicles in Kitsap County (tons emitted, 2005)

Type of Vehicle	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Diesel school bus	9	41	3	1	2	5,376
Other diesel vehicle	491	1,862	51	46	90	212,057
Gasoline school bus	17	2	0	0	1	365
Other gasoline vehicle	35,566	2,535	25	42	2,826	797,257
LPG vehicle	0	1	0	0	0	807
CNG vehicle	5	12	1	0	1	15,707
Total on-road vehicles	36,088	4,452	80	90	2,921	1,031,569

A7: Summary of Emissions by On-Road Vehicles in Pierce County (tons emitted, 2005)

Type of Vehicle	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Diesel school bus	30	141	9	4	8	18,616
Other diesel vehicle	1,858	7,049	192	175	341	803,525
Gasoline school bus	59	7	0	0	4	1,254
Other gasoline vehicle	134,366	9,577	95	159	10,677	3,011,967
LPG vehicle	1	3	0	0	0	3,049
CNG vehicle	20	46	4	0	3	59,336
Total on-road vehicles	136,333	16,825	300	340	11,033	3,897,748

A8: Summary of Emissions by On-Road Vehicles in Snohomish County (tons emitted, 2005)

Type of Vehicle	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Diesel school bus	25	120	8	3	7	15,849
Other diesel vehicle	1,615	6,130	167	152	296	698,808
Gasoline school bus	19	2	0	0	1	397
Other gasoline vehicle	116,809	8,327	83	138	9,282	2,618,363
LPG vehicle	0	3	0	0	0	2,650
CNG vehicle	17	40	3	0	2	51,569
Total on-road vehicles	118,586	14,622	260	295	9,588	3,397,637

A9: Kilograms of Fuel Burned by Aircraft during LTOs at McChord AFB, 2005

Type of Aircraft	Type of Engine	2005 LTOs	Kgs Fuel Burned
A-10A Thunderbird	TF34-GE-100-1	1,852	332,881
F-16	F100-PW-100	377	105,232
L-1011-1	RB211-22B	386	731,040
C-130 Hercules	T56-A-9	1,266	849,661
F-15	F100-PW-100	105	58,617
A310	CF6-80A3	15	15,752
A-6 Intruder	J52-P-8B	157	62,518
B707-100	JT3D-3D	22	32,715
B727-100	JT8D-7B	45	43,866
B747-100	JT9D-7A	28	75,529
757-200	PW2037	11	9,510
Beechjet 400	JT15D-5(A-B)	19	2,341
C-12 A / B / C	PT6A-41	330	27,432
C-135	J57-P-22	228	374,515
C-141	TF33-P-7	3,630	6,452,476
C-17A	F117-PW-100	102	198,369
C-21-A	TFE 731-2-2B	438	56,522
C-5 Galaxy	TF39-GE-1	255	493,178
C-9A	JT8D-9	493	327,190
CL 600	ALF 502L-2	58	12,589
DC 8	JT3D-7	203	309,518
DC 9, 10	JT8D-7B	45	25,933
DHC-6	PT6A-27	30	1,875
EA-6B Prowler	J52-P-408	161	130,950
F-14A Tomcat	TF30-P-412A	45	40,114
Gulfstream I	RDa7	37	8,122
KC-10A	CF6-50A	163	281,301
KC-135R	CFM56-2A	615	915,087
Learjet 24D	CJ610-6	46	10,844
N 22B Nomad	22C2250B17B	15	497
S-3B Viking	TF34-GE-400	29	6,624
Swearing Merlin	TPE 331-2	50	2,681
T-37 Tweet	J69-25A	182	20,494
UC-12J	PT6A-42	58	4,821
H-60 Black Hawk	T700-GE-700	21	3,109
Total for McChord AFB			12,023,903

A10: Kilograms of Fuel Burned by Aircraft during LTOs at Fort Lewis Army Base, 2005

Type of Aircraft	Type of Engine	2005 LTOs	Kgs Fuel Burned
A-10A Thunderbird	TF34-GE-100-1	6	1,205
Beechjet 400	JT15D-5 (A-B)	24	3,220
C-12 A / B / C	PT6A-41	112	66,683
C-130 Hercules	TF6-A-9	55	85,939
C-21-A	739	739	7,589
C-5 Galaxy	TF39-GE-1	69	140,759
EA-6B Prowler	J52-P-408	33	28,046
F-15	F100-PW-100	14	8,535
HH-3E Green	T58-GE-5	2,043	385,839
OV-10 Bronco	T76-G-12A	43	3,829
T-37 Tweett	J69-25A	75	9,031
UV-18A	PT6A-27	684	46,426
Total for Fort Lewis			787,101

A11: Kilograms of Fuel Burned by Aircraft during LTOs at Paine Field, 2005

Type of Aircraft	Type of Engine	2005 LTOs	Kgs Fuel Burned
B737-100	JT8D-15	60	50,865
B747-100	JT9D-7A	119	378,020
B757-200	PW2037	28	28,453
B767-200	CF6-80A2	217	291,684
B777-200	PW4077	540	1,070,236
B727-100	JT8D-9A	37	45,171
B727-100C	TAY 651	68	77,437
B727-100F	JT8D-7	10	12,516
B727-200F	JT8D-15	47	62,287
B727-200RE	JT8D-217C	75	101,355
B727-200RF	JT8D-217C	8	10,812
B737-200	JT8D-15A	124	97,929
B737-300	CFM56-3-B1	229	147,470
B737-400	CFM56-3B-2	15	10,318
B737-500	CFM56-3C-1	23	17,426
B747-400	PW4056	1	3,269
B757-200	PW2037	76	77,229
B767-200	CF6-80A2	4	5,377
B767-300	CF6-80A2	11	14,786
A320-200	V2527-A5	32	25,969
DC9, 10	JT8D-7	4	2,858
MD 80-82	JT8D-209	19	16,272
MD 80-83	JT8D-217	2	1,802
MD 90-10	V2524-A5	3	2,186
AN-72	D-36	100	24,421
C-141	TF33-P-100	100	202,318
C-5 Galaxy	TF39-GE-1	100	221,699
CN-235-200	CT7-5	200	17,937
Beech King	PT6A-28	1700	135,950
P-337P Sky	TSIO-360C	20,012	341,566
Cessna 172	IO-320-D1AD	20,012	126,518
Piper PA-28	IO-320-D1AD	20,012	141,715
Total for Paine Field			3,762,851

A12: Kilograms of Fuel Burned by Aircraft during LTOs at Boeing Field, 2005

Type of Aircraft	Type of Engine	2005 LTOs	Kgs Fuel Burned
Beechjet 400	JT15D-5 (A-B)	17,203	2,124,903
Cessna 150	O-200		27,328
Learjet 35 / 36	TFE 731-2-2B	7,501	848,354
B727-100	JT8D-9A	508	514,727
B737-100	JT8D-7A	805	490,543
B747-100	JT9D-7A	315	851,295
B757-200	PW2037	251	217,473
B767-200	CF680A (A1)	14	16,207
B777-200	PW4077	76	137,227
DC8	JT3D-7	240	366,669
Galaxy (IAI) G	PW306A	86,015	22,144,153
Citation SII	JT15D-4	4,547	680,386
Learjet 25B	CJ610-6	2,369	742,175
Saberliner	CF700-2D	1,772	558,064
Gulfstream IV	TAY MK611-8	1,772	978,930
Gulfstream II	SPEY MK51	2,083	1,498,781
MU-300	JT15D-4	1,772	265,151
Convair Liner	RDA10	232	67,614
DHC-6	PT6A-20	13,015	1,049,569
A300-600	CF6-80C2A5F	481	742,830
A310	CF6-80A3	106	127,393
DC9-50	JT8D-17	140	122,968
B707-E	TF33-P-100	57	115,395
DH6-8-100	PW120A	1,239	254,739
MD-80-83	JT8D-219	89	79,763
B757-200	RB211-535C	730	872,874
Total for Boeing Field			35,895,508

A13: Kilograms of Fuel Burned by Aircraft during LTOs at Sea-Tac Airport, 2005

Type of Aircraft	Type of Engine	2005 LTOs	Kgs Fuel Burned
A300-600	CF6-80C2A5F	502	775,262
A310	CF6-80A3	55	66,105
A318	CFM56-5B1	243	198,291
A319	CFM56-5B6/P	5,207	3,278,566
A320	V2527-A5	4,385	3,431,587
A321	CFM56-5B3/P	983	813,820
A340-200	CFM56-5B1	816	1,611,077
ATR42	PM120	217	44,615
B707-100	JT3D-3B	151	268,273
B727-100	JT8D-9A	496	605,534
B737-100	JT8D-15	57,738	48,947,408
B747-100	JT9D-7A	1,524	4,841,196
B757-200	PW2037	11,328	11,511,277
B757-200F	RB211-535E4	1,403	1,588,697
B767-200	CF6-80A2	2,373	3,189,721
B777-200	PW4077	900	1,783,727
Beech King	PT6A-28	52	4,158
C-141	TF33-P-100	1,069	2,162,767
C-5 Galaxy	TF39-GE-1	18	39,907
C-9A	JT8D-9	27	21,434
CL604	CF34-3B	3,136	876,568
Dash 8-400	PW123	232	56,593
DC10-10	CF6-6K	1,495	2,798,779
DC8	JT3D-7	138	243,387
DHC-8-300	PW123	45,417	11,078,924
EMB-120	PW118	5,164	965,286
F-27 Series	Rda7	123	34,706
L-100-30	501D22A	119	93,977
Learjet 35/36	TFE 731-2-2B	17	2,411
MD 11	PW4460	1,600	3,931,018
MD 80	JT8D-209	15,074	12,910,394
MD 80-82	JT8D-209	60	51,388
MD 80-83	JT8D-219	4,411	3,973,174
MD 80-88	JT8D-219	17	15,236
MD 90-10	V2524-A5	396	288,566
Swearingear	TPE331-2	89	7,082
Fokker 60	PT6A-42	19	1,808
A330	PW4168A	583	1,055,040
Total for Sea-Tac Airport			123,567,759

A14: Kilograms of Fuel Burned by Air Taxi Aircraft during LTOs at small airports, 2005

Type of Aircraft	Type of Engine	2005 LTOs	Kgs Fuel Burned
King County	JT15D-5 (A-B)	17,628	2,177,109
Kitsap County	JT15D-5 (A-B)	538	66,454
Pierce County	JT15D-5 (A-B)	1,969	243,210
Snohomish County	JT15D-5 (A-B)	2,545	314,358

A15: Kilograms of Fuel Burned by General Aviation Aircraft during LTOs at small airports, 2005

Type of Aircraft	Type of Engine	2005 LTOs	Kgs Fuel Burned
King County	O-200	181,614	1,067,001
Kitsap County	O-200	72,532	293,831
Pierce County	O-200	121,450	508,593
Snohomish County	O-200	146,391	720,744

A16: Ground Support Equipment (GSE) Output (1,000 hp-hrs) estimated with EDMS 4.5, 2005

Airport	Diesel GSE	Gasoline GSE
Sea-Tac	26,323	15,842
Boeing Field	5,721	7,756
Fort Lewis	1,892	244
McChord Air Force Base	2,334	79
Paine Field	1,018	291
Other King County Airports	1,120	707
Kitsap County Airports	34	22
Civilian Pierce County Airports	125	79
Other Snohomish County Airports	162	102

A17: Ground Support Equipment (GSE) Energy Output estimated with EDMS converted to million Btu

Airport	Diesel GSE	Gasoline GSE
Sea-Tac	67,044	40,351
Boeing Field	14,571	19,755
Fort Lewis	4,818	621
McChord Air Force Base	5,945	200
Paine Field	2,594	741
Other King County Airports	2,852	1,802
Kitsap County Airports	87	55
Civilian Pierce County Airports	319	201
Other Snohomish County Airports	412	260

**A18: 1,000 Gallons of Fuel (at 100% efficiency)
equivalent to output energy estimated with non-road model (million Btu)**

Airport	Diesel GSE	Gasoline GSE
Sea-Tac	489	310
Boeing Field	106	152
Fort Lewis	35	5
McChord Air Force Base	43	2
Paine Field	19	6
Other King County Airports	21	14
Kitsap County Airports	1	0
Civilian Pierce County Airports	2	2
Other Snohomish County Airports	3	2

**A19: 1,000 Gallons of Fuel Input Burned
by Ground Support Equipment (GSE)**

Airport	Diesel GSE at 34% Efficiency	Gasoline GSE at 16% Efficiency
Sea-Tac	1,439	1,939
Boeing Field	313	945
Fort Lewis	103	30
McChord Air Force Base	128	10
Paine Field	56	36
Other King County Airports	61	87
Kitsap County Airports	2	3
Civilian Pierce County Airports	7	10
Other Snohomish County Airports	9	13

A20: Number of Aircraft Operations at Puget Sound Airports for latest available 12 months

King Co. Airport	Air Carrier	Air Taxi	GA Local	GA Itinerant	Military
Sea-Tac	210,603	140,777	49	3,336	54
King Co Int'l	10,384	58,914	92,254	135,569	1,659
Auburn Municipal		6,100	60,000	98,339	100
Kenmore Air Harbor		20,500	7,500	2,500	
Crest Air Park, Kent			10,000	85,700	
Seattle Seaplanes		1,450	50	50	
Enumclaw			5,250	1,000	
Wax Orchards, Vashon			5,000	2,500	
Vashon Municipal			1,000	5,000	
Lester				300	
Bandera				300	
Renton Municipal	282	1,268	69,779	41,353	94
Will Rogers, Renton			1,737	650	
All King Co. Airports	221,269	229,009	252,619	376,597	1,907
Kitsap Co. Airport	**Air Carrier**	**Air Taxi**	**GA Local**	**GA Itinerant**	**Military**
Bremerton National		100	65,000	42,000	900
Port Orchard			5,500	13,000	214
Silverdale			15,000	4,400	25
All Kitsap Co. Airports		100	85,500	59,400	1,139
Pierce Co. Airport	**Air Carrier**	**Air Taxi**	**GA Local**	**GA Itinerant**	**Military**
McChord AFB	106				13,890
Ft Lewis AB		(turboprop) 4,476	(rotary) 54,998		4,476
Puyallup Thun Field		3,388	30,149	56,463	
Eatonville			594	5,000	15
American Lake, Tacoma			50	650	
Tacoma Narrows		1,352	58,734	50,785	1,241
Spanaway Shady Acres			450	600	
Spanaway			4,000	15,000	
All Pierce Co. Airports	106	4,740	93,977	128,498	19,622
Snohomish Co. Airport	**Air Carrier**	**Air Taxi**	**GA Local**	**GA Itinerant**	**Military**
Paine Field	3,494	3,563	99,825	93,722	1,227
Sultan			900	100	
Monroe Firstar			5,044	13,125	
Darrington Municipal			525	2,500	
Arlington Municipal		2,640	75,860	55,950	550
Snohomish Harvey		1,879	93,200	44,352	1,246
All Sno Co. Airports	3,494	8,082	275,354	209,749	3,023
All Airports in Region	224,763	241,831	621,950	714,844	24,552

A21: Emissions from King County Miscellaneous Non-Road Equipment (tons, 2005)

Category	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Gasoline	139,993	1,416	216	59	7,782	317,460
LPG	8,603	1,847	11	2	503	114,029
CNG	946	169	1	0	3	84,997
Diesel	3,435	6,581	554	190	755	621,544

A22: Emissions from Kitsap County Miscellaneous Non-Road Equipment (tons, 2005)

Category	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Gasoline	11,916	115	23	5	784	27,564
LPG	207	45	0	0	12	2,787
CNG	29	5	0	0	0	2,534
Diesel	404	774	64	22	86	72,701

A23: Emissions from Pierce County Miscellaneous Non-Road Equipment (tons, 2005)

Category	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Gasoline	42,899	422	80	19	2669	99,671
LPG	1,546	332	2	0	90	20,266
CNG	165	30	0	0	0	14,846
Diesel	1,769	3,424	280	99	378	323,127

A24: Emissions from Snohomish County Miscellaneous Non-Road Equipment (tons, 2005)

Snohomish County	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Gasoline	40,251	418	74	17	2,538	94,655
LPG	4,044	855	5	1	236	52,842
CNG	344	67	0	0	1	30,897
Diesel	1,058	2,138	171	60	231	197,251

A25: Quantity of Non-Road Mobile Equipment in Puget Sound Region

Category of Equipment	King	Kitsap	Pierce	Snohomish	4-County
2-stroke terrestrial recreational	4,973	1,105	2,763	3,315	12,157
2-stroke construction	1,689	241	1,051	502	3,482
2-stroke industrial	18	0	3	9	31
2-stroke residential L & G	202,178	25,134	76,161	65,844	369,316
2-stroke commercial L & G	33,687	3,211	11,480	11,179	59,558
2-stroke agricultural	2	1	2	4	9
2-stroke commercial	5,921	252	1,036	1,032	8,241
2-stroke logging	49	0	176	88	314
4-stroke terrestrial recreational	10,999	2,391	6,140	7,219	26,749
4-stroke construction	4,816	686	2,998	1,431	9,931
4-stroke industrial	899	19	157	442	1,517
4-stroke residential L & G	385,422	47,914	145,189	125,522	704,048
4-stroke commercial L & G	48,928	4,664	16,674	16,236	86,503
4-stroke agricultural	35	14	49	88	186
4-stroke commercial	74,380	3,166	13,013	12,963	103,522
4-stroke logging	306	0	1,089	546	1,942
LPG terrestrial recreational	7	2	4	5	17
LPG construction	105	15	66	31	217
LPG industrial	4,098	86	712	2,017	6,913
LPG commercial L & G	61	6	21	20	108
LPG commercial	2,096	89	367	365	2,917
CNG industrial	407	9	71	200	688
CNG commercial	353	15	62	62	491
Diesel terrestrial recreational	59	13	33	40	145
Diesel construction	13,282	1,893	8,267	3,947	27,389
Diesel industrial	3,470	248	973	1,505	6,197
Diesel commercial L & G	3,565	340	1,215	1,183	6,303
Diesel agricultural	71	29	98	176	374
Diesel commercial	12,011	511	2,101	2,093	16,717
Diesel logging	25	0	90	45	160
Diesel railway maintenance	14	0	8	14	36
4-stroke railway maintenance	15	0	9	15	40

A26: Fuel Consumption Per Year by Non-Road Mobile Equipment in Puget Sound Region

Category of Equipment	King	Kitsap	Pierce	Snohomish	4-County
2-stroke terrestrial recreational	300,484	66,774	166,936	200,323	734,517
2-stroke construction	154,437	22,008	96,121	45,887	318,451
2-stroke industrial	1,174	24	204	578	1,980
2-stroke residential L & G	418,848	52,069	157,780	136,408	765,106
2-stroke commercial L & G	1769,289	168,669	602,953	587,125	3,128,036
2-stroke agricultural	22	9	31	55	116
2-stroke commercial	185,350	7,889	32,428	32,303	257,970
2-stroke logging	8,715	12	31,044	15,556	55,327
All 2-stroke gasoline	2,838,319	317,454	1,087,496	1,018,234	5,261,504
4-stroke terrestrial recreational	784,208	145,088	451,673	460,678	1,841,647
4-stroke construction	761,942	108,578	474,228	226,390	1,571,138
4-stroke industrial	839,233	17,850	146,531	412,708	1,416,323
4-stroke residential L & G	5,090,079	632,776	1,917,438	1,657,709	9,298,002
4-stroke commercial L & G	11,533,833	1,099,535	3,930,596	3,827,414	20,391,377
4-stroke agricultural	2,502	1,010	3,455	6,179	13,146
4-stroke commercial	9,573,358	407,468	1,674,909	1,668,475	13,324,210
4-stroke logging	14,184	20	50,524	25,317	90,045
4-stroke railway maintenance	1,447	0	909	1,478	3,834
All 4-stroke gasoline	28,600,785	2,412,325	8,650,263	8,286,348	47,949,720
LPG terrestrial recreational	1,947	433	1,081	1,298	4,759
LPG construction	164,737	23,475	102,531	48,947	339,691
LPG industrial	16,075,243	335,521	2,793,273	7,912,680	27,116,717
LPG commercial L & G	163,528	15,589	55,729	54,266	289,112
LPG agricultural	5	2	7	13	28
LPG commercial	1,434,858	61,071	251,036	250,072	1,997,037
LPG railway maintenance	70	0	44	71	185
All LPG	17,840,388	436,092	3,203,702	8,267,346	29,747,528
CNG industrial (mcf)	834	18	145	410	1,407
CNG commercial(mcf)	570	24	100	99	793
All CNG equipment (mcf)	1,404	42	245	510	2,200
Diesel terrestrial recreational	18,439	4,097	10,244	12,292	45,072
Diesel construction	38,357,091	5,465,954	23,873,217	1,1396,738	79,092,999
Diesel industrial	7,794,768	430,016	1,918,655	3527,402	13,670,842
Diesel commercial L & G	2,094,827	199,703	713,893	695,152	3,703,575
Diesel agricultural	122,143	49,290	168,681	301,698	641,811
Diesel commercial	6,225,162	264,960	1,089,124	1084,941	8,664,187
Diesel logging	202,293	286	720,596	361,085	1,284,260
Diesel railway maintenance	23,524	0	14,776	24,017	62,317
All diesel equipment	54,838,247	6,414,306	28,509,186	1,7403,325	107,165,064

A27: Tons of Pollutants Emitted by Residential Sources in King County

Type of Fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	571	1,341	108	9	78	1,722,024
Distillate oil	69	248	6	99	10	308,071
LPG (Propane)	10	73	2	0	2	66,953

A28: Tons of Pollutants Emitted by Commercial Area Sources in King County

Type of Fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	721	859	65	5	47	1,036,602
Distillate oil	37	132	15	53	2	165,562
LPG (Propane)	6	41	1	0	1	37,632

A29: Tons of Pollutants Emitted by Industrial Area Sources in King County

Type of Fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	236	393	21	2	15	338,685
Distillate oil	98	470	39	141	4	437,636
LPG (propane)	15	86	3	0	1	58,062

A30: Tons of Pollutants Emitted by All Area Sources in King County

Type of Fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	1,527	2,592	195	15	141	3,097,311
Distillate oil	203	850	59	293	16	909,269
LPG (propane)	30	201	6	0	4	162,647

A31: Tons of Pollutants Emitted by Residential Sources in Kitsap County

Type of Fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	34	79	6	1	5	102,100
Distillate oil	10	35	1	14	1	42,906
LPG (propane)	5	34	1	0	1	30,827

A32: Tons of Pollutants Emitted by Commercial Area Sources in Kitsap County

Type of Fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	30	36	3	0	2	43,756
Distillate oil	2	6	1	3	0	8,047
LPG (propane)	0	2	0	0	0	2,222

A33: Tons of Pollutants Emitted by Industrial Area Sources in Kitsap County

Type of Fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	71	118	6	1	5	101,624
Distillate oil	2	10	1	3	0	8,876
LPG (propane)	0	2	0	0	0	1,174

A34: Tons of Pollutants Emitted by All Area Sources in Kitsap County

Type of Fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	135	234	16	1	11	247,481
Distillate oil	13	51	2	19	2	59,830
LPG (propane)	5	38	1	0	1	34,222

A35: Tons of Pollutants Emitted by Residential Sources in Pierce County

Type of fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	182	427	35	3	25	548,059
Distillate oil	13	47	1	19	2	58,338
LPG (propane)	6	42	1	0	1	37,995

A36: Tons of Pollutants Emitted by Commercial Area Sources in Pierce County

Type of fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	191	228	17	1	13	274,684
Distillate oil	5	17	2	7	0	21,379
LPG (propane)	1	9	0	0	0	8,072

A37: Tons of Pollutants Emitted by Industrial Area Sources in Pierce County

Type of Fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	170	283	15	1	11	244,205
Distillate oil	20	98	8	29	1	91,369
LPG (propane)	3	18	1	0	0	12,086

A38: Tons of Pollutants Emitted by All Area Sources in Pierce County

Type of Fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	543	037	67	5	49	1,066,947
Distillate oil	38	162	11	55	3	171,087
LPG (propane)	10	68	2	0	1	0

A39: Tons of Pollutants Emitted by Residential Sources in Snohomish County

Type of Fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	156	366	30	2	21	469.614
Distillate oil	7	25	1	10	1	31,464
LPG (propane)	8	58	2	0	1	53,244

A40: Tons Pollutants Emitted by Commercial Area Sources in Snohomish County

Type of Fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	160	190	14	1	10	229,823
Distillate oil	6	23	3	9	0	28,620
LPG (propane)	1	7	0	0	0	6,585

A41: Tons of Pollutants Emitted by Industrial Area Sources in Snohomish County

Type of Fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	109	182	10	1	7	157,160
Distillate oil	41	198	16	59	2	183,897
LPG (propane)	6	36	1	0	1	24,366

A42: Tons of Pollutants Emitted by All Area Sources in Snohomish County

Type of Fuel	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Natural gas	425	738	54	4	39	856,597
Distillate oil	55	246	20	79	3	243,981
LPG (propane)	15	102	3	0	2	84,195

A43: Percent of Households with Wood-Burning Appliances (from PRR Survey), March 2005

County	Fireplaces	Wood Stoves	Pellet Stoves	Inserts
King	30.0%	9.3%	2.7%	4.0%
Kitsap	1703%	20.7%	3.3%	4.0%
Pierce	18.7%	13.0%	2.3%	4.7%
Snohomish	19.5%	12.3%	5.0%	5.3%

A44: Percent of Wood-Burning Appliances Burning Types of Wood, 2005

County	Cord Wood Only	Firelogs Only	Firelogs and Cord Wood
King	59.4%	27.7%	12.9%
Kitsap	70.6%	24.2%	5.2%
Pierce	59.3%	28.2%	12.5%
Snohomish	70.3%	28.4%	1.3%

A45: Percent of Stoves and Inserts with Catalysts and Percent Uncertified, 2005

County	Certified Catalytic	Certified Non-Catalytic	Uncertified
King	55.7%	29.5%	14.8%
Kitsap	70.0%	20.0%	10.0%
Pierce	62.8%	14.0%	23.2%
Snohomish	70.3%	16.2%	13.5%

A46: Percent of Fireplaces Used at Specified Frequencies, 2005

County	Never	<1 time per week	1 or 2 times per week	3 or 4 times per week	>4 times per week
King	26.8%	39.1%	24.0%	4.4%	5.7%
Kitsap	9.1%	36.4%	27.2%	9.0%	18.3%
Pierce	23.8%	52.4%	16.6%	2.4%	4.8%
Snohomish	31.2%	37.5%	18.8%	6.2%	6.3%

A47: Percent of Stoves and Inserts Used at Specified Frequencies, 2005

County	Never	<1 time per week	1 or 2 times per week	3 or 4 times per week	>4 times per week
King	17.9%	23.2%	19.6%	10.8%	28.5%
Kitsap	17.7%	23.5%	17.6%	11.8%	29.4%
Pierce	2.9%	45.7%	17.2%	11.4%	22.8%
Snohomish	7.4%	25.0%	22.6%	15.0%	30.0%

A48: Percent of Monthly Distribution of Residential Natural Gas Consumption

Month	1999	2000	2001	2002	2003	2004	2005
December	13.8%	13.8%	13.8%	13.8%	17.5%	16.4%	19.4%
January	17.3%	17.3%	17.2%	17.3%	16.5%	21.4%	19.8%
February	16.7%	17.7%	16.7%	16.8%	15.3%	17.3%	15.7%
March	14.9%	14.9%	14.9%	15.0%	15.0%	13.5%	12.5%
April	11.0%	10.9%	10.9%	11.0%	10.4%	8.3%	10.4%
May	7.1%	7.1%	7.1%	7.2%	6.8%	4.0%	4.2%
June	3,6%	3.6%	3.6%	3.5%	2.3%	2.6%	2.5%
July	1.3%	1.3%	1.3%	1.2%	0.7%	0.6%	0.7%
August	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
September	0.8%	0.8%	0.8%	0.8%	0.6%	0.8%	0.6%
October	4.2%	4.2%	4.3%	4.1%	2.8%	3.7%	3.6%
November	9.3%	9.4%	9.4%	9.3%	12.1%	11.4%	10.6%
Winter	47.8%	47.8%	46.7%	47.9%	49.3%	55.1%	54.9%
Spring	33.0%	32.9%	32.9%	33.2%	32.2%	25.8%	27.1%
Summer	4.9%	4.9%	4.9%	4.7%	3.0%	3.2%	3.2%
Autumn	14.3%	14.4%	14.5%	14.2%	15.5%	15.9%	14.8%

The Agency selected the fraction of wood burning occurring in winter as 48%[182] (the median value of the most recent seven years).

A49: Number of Housing Units, Percent Occupied, and Number of Households

County	#of Housing Units	% Occupied	# of Households
King	794,659	95.8%	761,283
Kitsap	99,298	93.3%	92,645
Pierce	305,957	94.1%	287,906
Snohomish	262,424	95.2%	249,828

A50: Characteristics of Wood-Burning Fireplaces (from PRR Survey)

County	% of Households with Wood-Burning Fireplaces	% of Fireplaces that Burn Cord Wood	% of Fireplaces that Burn Firelogs only
King	30.0%	72.3%	27.7%
Kitsap	17.3%	75.8%	24.2%
Pierce	18.7%	71.8%	28.2%
Snohomish	19.5%	71.6%	28.4%

A51: Number of Wood-Burning Fireplaces and Types of Wood Burned

County	# of Fireplaces	# of Fireplaces that Burn Cord Wood	# of Fireplaces that Burn Firelogs only
King	228,385	165,122	63,263
Kitsap	16,028	12,149	3,879
Pierce	53,838	38,656	15,182
Snohomish	48,715	34,881	13,835

[182] The Emission Inventory Improvement Project recommends compilers use heating degree days (HDD) to estimate seasonal heating fractions. Using 2005 Sea-Tac Airport HDD gives the winter heating fraction as 45% (with August included in the total) and 47% (with August HDD subtracted from each monthly HDD).

A52: Percent of Wood-Burning Fireplaces Used and Usage Frequency

County	1 day in 2 weeks	1 day/ week	2 days/ week	3 days/ week	4 days/ week	5 days/ week	6 days/ week	7 days/ week
King	39.1%	12.0%	12.0%	2.2%	2.2%	1.9%	1.9%	1.9%
Kitsap	36.4%	13.6%	13.6%	4.5%	4.5%	6.1%	6.1%	6.1%
Pierce	52.4%	8.3%	8.3%	1.2%	1.2%	1.6%	1.6%	1.6%
Snohomish	37.5%	9.4%	9.4%	3.1%	3.1%	2.1%	2.1%	2.1%

A53: Number of Wood-Burning Fireplaces Burning Cord Wood and Usage Frequency

County	1 day in 2 weeks	1 day/ week	2 days/ week	3 days/ week	4 days/ week	5 days/ week	6 days/ week	7 days/ week
King	64,612	19,740	19,740	3,591	3,591	3,192	3,192	3,192
Kitsap	4,417	1,657	1,657	552	552	736	736	736
Pierce	20,248	3,222	3,222	460	460	613	613	613
Snohomish	13,080	3,270	3,270	1,090	1,090	727	727	727

A54: Number of Wood-Burning Fireplaces Burning Firelogs and Usage Frequency

County	1 day in 2 weeks	1 day/ week	2 days/ week	3 days/ week	4 days/ week	5 days/ week	6 days/ week	7 days/ week
King	24,755	7,563	7,563	1,376	1,376	1,223	1,223	1,223
Kitsap	1,410	529	529	176	176	235	235	235
Pierce	7,953	1,265	1,265	181	181	241	241	241
Snohomish	5,188	1,297	1,297	432	432	288	288	288

A55: Tons of Cord Wood Burned by Fireplaces per Winter Week

County	1 day in 2 weeks	1 day/ week	2 days/ week	3 days/ week	4 days/ week	5 days/ week	6 days/ week	7 days/ week
King	388	237	474	129	172	192	230	268
Kitsap	27	20	40	20	27	44	53	62
Pierce	121	39	77	17	22	37	44	52
Snohomish	78	39	78	39	52	44	52	61

A56: Tons of Firelogs Burned by Fireplaces per Winter Week

County	1 day in 2 weeks	1 day/ week	2 days/ week	3 days/ week	4 days/ week	5 days/ week	6 days/ week	7 days/ week
King	37	23	45	12	17	18	22	26
Kitsap	2	2	3	2	2	4	4	5
Pierce	12	4	8	2	2	4	4	5
Snohomish	8	4	8	4	5	4	5	6

A57: Tons of Wood Burned by Fireplaces per Year, 2005

County	Cord Wood	Firelogs
King	56,592	5,421
Kitsap	7,896	630
Pierce	11,066	1,087
Snohomish	12,045	1,194

A58: Characteristics of Fireplace Inserts (from PRR Survey)

County	% of Households with Fireplace Inserts	% of Inserts that Burn Cord Wood	% of Inserts that Burn Firelogs only
King	4.0%	72.3%	27.7%
Kitsap	4.0%	75.8%	24.2%
Pierce	4.7%	71.8%	28.2%
Snohomish	5.3%	71.6%	28.4%

A59: Number of Fireplace Inserts and Types of Wood Burned

County	# of Fireplace Inserts	# of Inserts that Burn Cord Wood	# of Inserts that Burn Firelogs only
King	30,451	22,016	8,435
Kitsap	3,706	2,809	897
Pierce	13,532	9,716	3,816
Snohomish	13,241	9,480	3,760

A60: Percent of Fireplace Inserts Used and Usage Frequency

County	1 day in 2 weeks	1 day/ week	2 days/ week	3 days/ week	4 days/ week	5 days/ week	6 days/ week	7 days/ week
King	23.2%	9.8%	9.8%	5.4%	5.4%	9.5%	9.5%	9.5%
Kitsap	23.5%	8.8%	8.8%	5.9%	5.9%	9.8%	9.8%	9.8%
Pierce	45.7%	8.6%	8.6%	5.7%	5.7%	7.6%	7.6%	7.6%
Snohomish	25.0%	11.3%	11.3%	7.5%	7.5%	10.0%	10.0%	10.0%

A61: Number of Fireplace Inserts Burning Cord Wood and Usage Frequency

County	1 day in 2 weeks	1 day/ week	2 days/ week	3 days/ week	4 days/ week	5 days/ week	6 days/ week	7 days/ week
King	5,110	2,162	2,162	1,179	1,179	2,097	2,097	2,097
Kitsap	661	248	248	165	165	275	275	275
Pierce	4,441	833	833	555	555	740	740	740
Snohomish	2,370	1,067	1,067	711	711	948	948	948

A62: Number of Fireplace Inserts Burning Firelogs and Usage Frequency

County	1 day in 2 weeks	1 day/ week	2 days/ week	3 days/ week	4 days/ week	5 days/ week	6 days/ week	7 days/ week
King	1,958	828	828	452	452	803	803	803
Kitsap	211	79	79	53	53	88	88	88
Pierce	1,744	327	327	218	218	291	291	291
Snohomish	940	423	423	282	282	376	376	376

A63: Tons of Cord Wood Burned by Fireplace Inserts per Winter Week

County	1 day in 2 weeks	1 day/ week	2 days/ week	3 days/ week	4 days/ week	5 days/ week	6 days/ week	7 days/ week
King	51	43	86	71	94	210	252	294
Kitsap	7	5	10	10	13	28	33	39
Pierce	44	17	33	33	44	74	89	104
Snohomish	24	21	43	43	57	95	114	133

A64: Tons of Firelogs Burned by Fireplace Inserts per Winter Week

County	1 day in 2 weeks	1 day/ week	2 days/ week	3 days/ week	4 days/ week	5 days/ week	6 days/ week	7 days/ week
King	6	5	10	8	11	24	29	34
Kitsap	1	0	1	1	1	3	3	4
Pierce	5	2	4	4	5	9	10	12
Snohomish	3	3	5	5	7	11	14	16

A65: Tons of Wood Burned by Fireplace Inserts per Year

County	Cord Wood	Firelogs
King	29,810	3,426
Kitsap	3,893	373
Pierce	11,879	1,400
Snohomish	14,315	1,703

A66: Percent of Fireplace Inserts Uncertified or Certified

County	Uncertified	Certified Catalytic	Certified Non-Catalytic
King	14.8%	55.7%	29.5%
Kitsap	10.0%	70.0%	20.0%
Pierce	23.2%	62.8%	14.0%
Snohomish	13.5%	70.3%	16.2%

A67: Tons of Cord Wood Burned by Type of Fireplace Insert, 2005

County	Uncertified	Certified Catalytic	Certified Non-Catalytic
King	4,412	16,604	8,794
Kitsap	389	2,725	779
Pierce	2,756	7,460	1,663
Snohomish	1,933	10,063	2,319

A68: Tons of Firelogs Burned by Type of Fireplace Insert, 2005

County	Uncertified	Certified Catalytic	Certified Non-Catalytic
King	507	1,908	1,011
Kitsap	37	261	75
Pierce	325	879	196
Snohomish	230	1,197	276

Appendix 69: Characteristics of Pellet Stoves (from PRR Survey)

County	Percent of Households with Pellet Stoves
King	2.7%
Kitsap	3.3%
Pierce	2.3%
Snohomish	5.0%

A70: Number of Pellet Stoves

County	Number of Pellet Stoves
King	20,555
Kitsap	3,057
Pierce	6,621
Snohomish	12,491

A71: Percent of Pellet Stoves Used and Usage Frequency

County	1 day in 2 weeks	1 day/ week	2 days/ week	3 days/ week	4 days/ week	5 days/ week	6 days/ week	7 days/ week
King	23.2%	9.8%	9.8%	5.4%	5.4%	9.5%	9.5%	9.5%
Kitsap	23.5%	8.8%	8.8%	5.9%	5.9%	9.8%	9.8%	9.8%
Pierce	45.7%	8.6%	8.6%	5.7%	5.7%	7.6%	7.6%	7.6%
Snohomish	25.0%	11.3%	11.3%	7.5%	7.5%	10.0%	10.0%	10.0%

A72: Number of Pellet Stoves Used at Indicated Frequency

County	1 day in 2 weeks	1 day/ week	2 days/ week	3 days/ week	4 days/ week	5 days/ week	6 days/ week	7 days/ week
King	4,771	2,018	2,018	1,101	1,101	1,957	1,957	1,957
Kitsap	719	270	270	180	180	300	300	300
Pierce	3,027	567	567	378	378	505	505	505
Snohomish	3,123	1,405	1,405	937	937	1,249	1,249	1,249

A73: Tons of Pellets Burned per Winter Week

County	1 day in 2 weeks	1 day/ week	2 days/ week	3 days/ week	4 days/ week	5 days/ week	6 days/ week	7 days/ week
King	19	16	32	26	35	78	94	110
Kitsap	3	2	4	4	6	12	14	17
Pierce	12	5	9	9	12	20	24	28
Snohomish	12	11	22	22	30	50	60	70

A74: Tons of Pellets Burned per Winter Week and per Year

County	Total Tons Burned/Week	Total Tons Burned/Year
King	411	11,132
Kitsap	63	1,695
Pierce	120	3,239
Snohomish	279	7,544

A75: Tons of Wood-Burning Emissions per Year in King County, 2005

Wood-Burning Appliance	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Fireplace	7,148	74	843	11	6,480	20,458
Uncertified insert	509	6	58	1	117	1,595
Non-catalytic insert	619	9	74	2	53	1,886
Catalytic insert	867	17	146	3	125	2,795
Uncertified stove	1,184	14	135	2	272	3,708
Non-catalytic stove	1,439	20	180	4	123	4,386
Catalytic stove	2,015	39	326	8	290	6,497
Pellet-fired stove	219	77	20	2	67	1,874
Firelog (all)	1,118	25	207	3	471	6,078
All indoor wood	15,118	281	1,989	37	7,996	49,276

A76: Tons of Wood-Burning Emissions per Year in Kitsap County, 2005

Wood-Burning Appliance	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Fireplace	997	10	118	2	904	2,854
Uncertified insert	45	1	5	0	10	141
Non-catalytic insert	55	1	7	0	5	167
Catalytic insert	142	3	24	1	20	459
Uncertified stove	233	3	27	0	53	728
Non-catalytic stove	284	4	35	1	24	864
Catalytic stove	736	14	119	3	106	2,373
Pellet-fired stove	33	12	3	0	10	285
Firelog (all)	195	4	36	1	82	1,060
All indoor wood	2,720	51	373	7	1,215	8,932

A77: Tons of Wood-Burning Emissions per Year in Pierce County, 2005

Wood-Burning Appliance	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Fireplace	1,398	14	165	2	1,267	4,001
Uncertified insert	318	4	36	1	73	996
Non-catalytic insert	117	2	14	0	10	357
Catalytic insert	389	8	66	2	56	1,257
Uncertified stove	880	11	100	2	202	2,757
Non-catalytic stove	324	5	40	1	28	987
Catalytic stove	1,077	21	174	4	155	3,473
Pellet-fired stove	64	22	6	1	19	545
Firelog (all)	423	10	78	1	178	2,299
All indoor wood	4,990	95	680	13	1,988	16,668

A78: Tons of Wood-Burning Emissions per Year in Snohomish County, 2005

Wood-Burning Appliance	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Fireplace	1,521	16	179	2	1,379	4,354
Uncertified insert	223	3	26	0	51	699
Non-catalytic insert	163	2	20	1	14	497
Catalytic insert	525	10	88	2	76	1,694
Uncertified stove	518	6	59	1	119	1,621
Non-catalytic stove	379	5	47	1	32	1,154
Catalytic stove	1,219	23	197	5	175	3,931
Pellet-fired stove	149	52	14	2	45	1,270
Firelog (all)	456	10	84	1	192	2,476
All indoor wood	5,153	128	714	15	2,083	17,696

A79: Tons of Wood-Burning Emissions per Year in Agency 4-County Region, 2005

Wood-Burning Appliance	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Fireplace	11,064	114	1,305	18	10,030	31,667
Uncertified insert	1,095	13	125	2	252	3,431
Non-catalytic insert	954	14	114	3	81	2,908
Catalytic insert	1,924	37	324	7	276	6,202
Uncertified stove	2,814	34	321	5	646	8,813
Non-catalytic stove	2,426	35	303	7	207	7,391
Catalytic stove	5,048	97	816	19	725	16,274
Pellet-fired stove	465	163	43	5	142	3,974
Firelog (all)	2,191	49	405	7	923	11,912
All indoor wood	27,980	555	3,756	72	13,282	92,572

A80: Kitsap County Land-Clearing Permits Issued for Residences, 2005

SFR Permit #	Street Address	City	Acres
02 02818	2333 NW SHERMAN HILL RD	POULSBO	4.55
02 03480	36955 ASPEN WAY NE	HANSVILLE	0.35
03 11350	5316 NE PONDEROSA BLVD	HANSVILLE	0.46
03 11510	15600 CEDAR PARK RD SE	OLALLA	1.30
03 13243	29571 BEACH DR NE	POULSBO	0.73
04 15597	8684 SEABECK HWY NW	SILVERDALE	2.28
04 17062	2303 GARFIELD AVE SE	PORT ORCHARD	0.96
04 17907	9756 NW HOLLY RD	BREMERTON	2.50
04 17909	9760 NW HOLLY RD	BREMERTON	2.50
04 17981	28099 GAMBLE BAY RD NE	KINGSTON	0.68
04 17983	28097 GAMBLE BAY RD NE	KINGSTON	0.68
04 18466	7619 PHILLIPS RD SE	PORT ORCHARD	1.34
04 18503	1261 WOODS RD SE	PORT ORCHARD	1.21
04 18928	8729 HONEYCOMB CT NW	SEABECK	0.30
04 18958	4667 NW WALGREN DR	SILVERDALE	0.50
04 18996	22246 MILLER BAY RD NE	POULSBO	2.08
04 19518	14110 ANATEVKA LN SE	OLALLA	5.00
04 19643	12979 NW HOLLY RD	BREMERTON	2.30
04 20547	21614 BIG VALLEY RD NE	POULSBO	16.97
04 20559	10415 WYE LAKE BLVD SW	PORT ORCHARD	0.56
04 21261	6711 NE ADMIRALTY LN	HANSVILLE	0.20
04 21299	4903 SW WAVA LN	PORT ORCHARD	2.28
04 21384	22139 RHODODENDRON LN NW	POULSBO	2.18
04 21522	3280 LOST CREEK LN NW	BREMERTON	2.47
04 21747	6355 TROON AVE SW	PORT ORCHARD	0.32
04 21758	7022 NE 288TH ST	KINGSTON	9.79
04 21919	2056 OPDAL RD E	PORT ORCHARD	2.50
04 21935	5160 MCCOOL PL SW	PORT ORCHARD	1.21
04 22078	5287 CRANE AVE E	PORT ORCHARD	0.45
04 22182	3920 FOREST DR NE	BREMERTON	0.42
04 22194	297 LEWIS RD W	BREMERTON	2.71
04 22249	724 NE MT MYSTERY LOOP	POULSBO	0.47
04 22256	7788 SE KING RD	PORT ORCHARD	2.40
04 22274	5402 E BLAISDELL LN	PORT ORCHARD	0.87
04 22357	NULL	NULL	NULL
04 22364	18030 VIKING WAY NW	POULSBO	1.03
04 22367	20960 JACK DAVIS PL NE	INDIANOLA	2.31
04 22383	26456 RITTER LN NE	KINGSTON	2.50
04 22388	1908 SE VALE RD	PORT ORCHARD	0.35
04 22400	7028 BEAUCHAMP LN NW	SEABECK	5.00
04 22424	1934 NE SAWDUST HILL RD	POULSBO	6.85
04 22451	3193 NW 19TH ST	BREMERTON	0.29
04 22578	436 NE OYSTER POINT DR	POULSBO	0.73
04 22610	7616 LARSON LN NW	BREMERTON	4.52
04 22627	41329 FOULWEATHER BLUFF RD NE	HANSVILLE	9.84
04 22634	6454 NE COLUMBIA ST	SUQUAMISH	0.10
04 22690	3701 ALBRIGHT AVE SE	PORT ORCHARD	4.55
04 22730	7373 LARSON LN NW	BREMERTON	3.00
05 22805	1851 COLE LOOP SE	PORT ORCHARD	0.61
05 22954	12857 WICKS END LN SW	PORT ORCHARD	5.03
05 22956	2500 OPDAL RD E	PORT ORCHARD	0.51

A80: Continued

SFR Permit #	Street Address	City	Acres
05 23041	28151 ST HWY 104 NE	KINGSTON	10.00
05 23053	687 NW WALKER RD	POULSBO	2.50
05 23073	5856 LARSON LN NW	BREMERTON	5.00
05 23095	26448 ANSELL RD NW	POULSBO	0.33
05 23155	4303 SE MULLENIX RD	PORT ORCHARD	2.03
05 23227	9497 SE GLENDALE ST	PORT ORCHARD	0.81
05 23230	9508 SE GLENDALE ST	PORT ORCHARD	0.86
05 23236	13029 OLD MILITARY RD NE	POULSBO	2.00
05 23248	8750 ROW LN SE	PORT ORCHARD	0.82
05 23258	8110 ORCHARD AVE SE	PORT ORCHARD	2.51
05 23302	3673 VICTORY DR SW	PORT ORCHARD	5.17
05 23311	3243 VICTORY DR SW	PORT ORCHARD	0.35
05 23335	26201 BERGSAGEL RD NE	POULSBO	2.48
05 23336	26200 BERGSAGEL RD NE	POULSBO	2.48
05 23359	2620 NE STRAND RD	BREMERTON	4.67
05 23364	14109 VINTAGE DR SW	PORT ORCHARD	2.32
05 23436	9324 SE OVERAA RD	PORT ORCHARD	2.38
05 23449	639 VIOLA PL W	BREMERTON	2.21
05 23458	636 BREMERTON BLVD W	BREMERTON	0.07
05 23486	22180 APOLLO DR NE	POULSBO	0.18
05 23528	2979 GARFIELD AVE SE	PORT ORCHARD	0.39
05 23535	5140 MCCOOL PL SW	PORT ORCHARD	1.78
05 23545	3193 WOODS RD E	PORT ORCHARD	1.42
05 23562	6184 SE NELSON RD	OLALLA	2.27
05 23608	20930 SEAPORT PL NW	POULSBO	5.96
05 23646	24739 HILLBEND LN NE	KINGSTON	0.69
05 23668	7679 OUTBACK AVE NW	BREMERTON	2.50
05 23715	9112 MISERY POINT RD NW	SEABECK	1.00
05 23729	988 PUGET DR E	PORT ORCHARD	2.32
05 23736	8151 E SEAVIEW DR	PORT ORCHARD	1.16
05 23773	7541 OLD MILITARY RD NE	BREMERTON	0.27
05 23775	7543 OLD MILITARY RD NE	BREMERTON	0.24
05 23783	2775 NE STRAND RD	BREMERTON	1.66
05 23801	34276 BRIDGE VIEW DR NE	KINGSTON	0.44
05 23817	9751 CALUMET DR NW	BREMERTON	2.13
05 23859	15545 CRESCENT VALLEY RD SE	OLALLA	5.31
05 23895	15825 NW HITE CENTER RD	BREMERTON	2.50
05 23898	8816 NE MAPLE AVE	INDIANOLA	0.09
05 23898	8816 NE MAPLE AVE	INDIANOLA	0.14
05 23936	22980 CLEAR CREEK RD NW	POULSBO	6.95
05 24017	10397 SIDNEY RD SW	PORT ORCHARD	1.33
05 24020	9063 NE ST HWY 104	KINGSTON	9.84
05 24038	24475 JEFFERSON PL NE	KINGSTON	0.47
05 24041	16631 DELATE RD NE	POULSBO	0.34
05 24055	829 NW PIONEER HILL RD	POULSBO	0.40
05 24061	1356 MORGAN RD NW	BREMERTON	0.35
05 24069	1360 MORGAN RD NW	BREMERTON	0.35
05 24076	31511 NIGHT OWL AVE NE	KINGSTON	2.50
05 24093	15660 PEACOCK HILL RD SE	OLALLA	1.98
05 24110	7547 CLOVER VALLEY RD SE	PORT ORCHARD	0.28
05 24110	7547 CLOVER VALLEY RD SE	PORT ORCHARD	0.14

A80: Continued

SFR Permit #	Street Address	City	Acres
05 24139	3450 LONG LAKE RD SE	PORT ORCHARD	4.92
05 24170	6495 NE TWIN SPITS RD	HANSVILLE	4.77
05 24176	34330 BRIDGE VIEW DR NE	KINGSTON	0.44
05 24189	17310 MORGANMARSH LN W	BREMERTON	2.36
05 24195	6854 NE ST HWY 104	KINGSTON	0.81
05 24213	577 SW DOGWOOD RD	PORT ORCHARD	2.88
05 24214	34545 BRIDGE VIEW DR NE	KINGSTON	0.55
05 24217	6577 NW NORTHRIDGE LN	BREMERTON	3.74
05 24269	60 CARSON AVE SE	PORT ORCHARD	0.93
05 24272	17088 ST HWY 305 NE	POULSBO	3.94
05 24275	10497 NE WEST KINGSTON RD	KINGSTON	0.55
05 24309	4959 MINARD RD W	BREMERTON	3.79
05 24322	10055 SE COTTONWOOD DR	PORT ORCHARD	1.34
05 24344	2699 ROCKY POINT RD NW	NULL	0.42
05 24344	2699 ROCKY POINT RD NW	NULL	0.76
05 24349	7272 ALPENVIEW PL NW	BREMERTON	1.18
05 24355	7470 TURKO LN NW	BREMERTON	2.50
05 24404	20529 MILLER BAY RD NE	POULSBO	0.56
05 24407	4710 TIGER LAKE RD W	BREMERTON	1.00
05 24500	6424 E MICHIGAN ST	PORT ORCHARD	0.48
05 24521	18746 AUGUSTA AVE NE	SUQUAMISH	0.09
05 24557	8831 NW PEACE AND QUIET WAY	SILVERDALE	4.53
05 24607	3225 RIDGEVIEW DR NE	BREMERTON	0.36
05 24622	1493 YUKON HARBOR RD SE	PORT ORCHARD	0.29
05 24681	5698 NE GAMBLEWOOD RD	KINGSTON	0.24
05 24705	12102 NE APPLE COVE LN	KINGSTON	0.82
05 24714	15584 VINCENT RD NW	POULSBO	3.19
05 24716	24745 HILLBEND LN NE	KINGSTON	1.21
05 24718	24733 HILLBEND LN NE	KINGSTON	1.02
05 24801	9285 W BELFAIR VALLEY RD	BREMERTON	3.13
05 24804	30310 ST HWY 3 NE	POULSBO	2.56
05 24816	8800 NW PEACE AND QUIET WAY	SILVERDALE	4.53
05 24834	5838 SCHOOL ST NE	BREMERTON	0.13
05 24863	22260 WAVECREST AVE NE	POULSBO	0.18
05 24901	3518 HARPER HILL RD SE	PORT ORCHARD	1.75
05 24913	26458 RITTER LN NE	KINGSTON	2.50
05 24931	20564 GERALDCLIFF DR NE	INDIANOLA	0.18
05 24972	15140 NW HITE CENTER RD	BREMERTON	4.80
05 24973	601 RIVERVIEW DR W	BREMERTON	4.77
05 24997	17166 LEMOLO SHORE DR NE	POULSBO	0.44
05 25018	37589 OLYMPIC VIEW RD NE	HANSVILLE	0.28
05 25055	23058 JEFFERSON POINT RD NE	KINGSTON	0.64
05 25068	7835 NW ANDERSON HILL RD	SILVERDALE	1.25
05 25068	7835 NW ANDERSON HILL RD	SILVERDALE	1.25
05 25073	16390 TUKWILLA RD NE	POULSBO	0.85
05 25078	18281 SWALLING PL NW	POULSBO	4.96
05 25085	3470 ANDERSON RD SE	PORT ORCHARD	1.00
05 25118	1788 FRONT AVE W	BREMERTON	0.35
05 25139	4565 OAKHURST LANE SW	PORT ORCHARD	5.18
05 25147	14187 GLENWOOD RD SW	PORT ORCHARD	2.32
05 25240	29140 SCENIC DR NE	POULSBO	2.53

A80: Continued

SFR Permit #	Street Address	City	Acres
05 25269	7503 PHILLIPS RD SE	PORT ORCHARD	1.31
05 25276	2467 ALASKA AVE E	PORT ORCHARD	0.31
05 25277	25761 TYTLER RD NE	POULSBO	3.00
05 25293	1950 LOST CREEK LN NW	BREMERTON	5.00
05 25294	11500 NW DOYLE LN	SILVERDALE	0.41
05 25296	2309 NE WYOMING ST	BREMERTON	0.35
05 25328	24418 SOUTH KINGSTON RD NE	KINGSTON	0.23
05 25337	7065 SE GRANT ST	PORT ORCHARD	0.19
05 25338	6988 E DAKOTA ST	PORT ORCHARD	0.20
05 25348	12556 SEABECK HWY NW	BREMERTON	0.50
05 25375	18280 SWALLING PL NW	POULSBO	6.00
05 25388	12142 WYE LAKE BLVD SW	PORT ORCHARD	0.41
05 25410	14330 CENTRAL VALLEY RD NW	POULSBO	4.88
05 25426	9952 FAIRVIEW LAKE RD SW	PORT ORCHARD	0.53
05 25449	4355 SE BEAR TREE LN	PORT ORCHARD	5.63
05 25500	7325 HAWKSTONE AVE SW	PORT ORCHARD	0.31
05 25517	13225 BOLIN POINT PL NE	POULSBO	0.78
05 25535	1061 FRANCIS AVE NW	BREMERTON	0.69
05 25550	13581 NW NORTHWOODS ST	BREMERTON	1.14
05 25554	14141 ANATEVKA LN SE	OLALLA	5.00
05 25572	8388 SW ASBERRY WAY	PORT ORCHARD	0.39
05 25573	8413 SW ASBERRY WAY	PORT ORCHARD	0.36
05 25617	15355 FAIRVIEW LAKE RD SW	PORT ORCHARD	10.00
05 25631	11000 NW QUIET WATERS WAY	BREMERTON	1.25
05 25648	5663 CENTRAL VALLEY RD NW	BREMERTON	1.04
05 25674	25866 PIONEER WAY NW	POULSBO	6.58
05 25685	1927 NW RAMPART RIDGE CT	BREMERTON	0.17
05 25694	4342 NW KELLY RD	BREMERTON	0.70
05 25709	7987 NE SUNNYWOODS LN	KINGSTON	0.50
05 25713	13959 CARNEY LAKE RD SW	PORT ORCHARD	0.46
05 25715	6489 NE PROSPECT ST	SUQUAMISH	0.10
05 25737	7501 TURKO LN NW	BREMERTON	5.00
05 25740	NULL	BREMERTON	0.54
05 25746	9641 KODIAK PL SW	PORT ORCHARD	4.48
05 25758	1365 SW CHIPMUNK HILL LN	PORT ORCHARD	2.50
05 25783	10500 RISING HILL LN NW	SILVERDALE	26.16
05 25789	10800 WICKS LAKE RD SW	PORT ORCHARD	4.75
05 25803	682 SW BIRCH RD	PORT ORCHARD	4.94
05 25811	4028 NE LUXURY LN	BREMERTON	0.37
05 25870	10331 WILLAMETTE MERIDIAN RD NW	SILVERDALE	4.80
05 25878	3889 REFLECTION LN E	PORT ORCHARD	0.24
05 25879	27389 LINDVOG RD NE	KINGSTON	2.35
05 25896	4857 W SHERMAN HEIGHTS RD	BREMERTON	0.18
05 25903	38372 HOOD CANAL DR NE	HANSVILLE	0.20
05 25920	2432 ALASKA AVE E	PORT ORCHARD	0.20
05 25935	571 RIVERVIEW DR W	BREMERTON	4.64
05 25943	2294 RIDGEWAY DR NW	BREMERTON	0.16
05 25997	4717 JULIAN RD SW	PORT ORCHARD	3.77
05 26011	15782 PEACOCK HILL RD SE	OLALLA	4.62
05 26012	14104 CARNEY LAKE RD SW	PORT ORCHARD	2.94
05 26014	2211 STEAMBOAT LOOP E	PORT ORCHARD	0.46

A80: Continued

SFR Permit #	Street Address	City	Acres
05 26083	21443 VIRGINIA AVE NE	KINGSTON	0.41
05 26119	7945 ILLAHEE RD NE	BREMERTON	0.26
05 26356	27323 GAMBLE BAY RD NE	KINGSTON	0.23
05 26360	3718 W MADRONA ST	BREMERTON	0.19
05 26361	664 RAPTOR LN NW	BREMERTON	2.74
05 26362	177 NW CARTER FARMS CT	BREMERTON	0.45
05 26364	7816 NE ROCKY LN	KINGSTON	2.55
05 26367	6472 WEXFORD AVE SW	PORT ORCHARD	0.29
05 26383	12322 NE PHILIP DR	KINGSTON	0.39
05 26384	12312 NE PHILIP DR	KINGSTON	0.39
05 26387	8517 BANNER RD SE	PORT ORCHARD	2.50
05 26434	3220 NW SHADOW GLEN BLVD	SILVERDALE	0.80
05 26438	2943 GARFIELD AVE SE	PORT ORCHARD	0.24
05 26444	22419 MILLER BAY RD NE	POULSBO	2.63
05 26448	25881 CANYON RD NW	POULSBO	5.00
05 26457	11878 CARTER AVE SW	PORT ORCHARD	0.21
05 26458	11850 CARTER AVE SW	PORT ORCHARD	0.21
05 26492	15854 SANDY HOOK RD NE	POULSBO	2.26
05 26501	13807 SW FALLS CT	PORT ORCHARD	0.72
05 26532	5577 SE BULMAN AVE	PORT ORCHARD	0.93
05 26539	830 COLCHESTER DR E	PORT ORCHARD	0.48
05 26571	6161 E COLLINS RD	PORT ORCHARD	1.00
05 26574	12876 CEDAR AVE NW	POULSBO	0.09
05 26579	13322 NW HOLLY RD	BREMERTON	0.21
05 26585	7615 SW SYLVAN ST	PORT ORCHARD	0.59
05 26594	3838 SE EASY STREET LN	PORT ORCHARD	0.60
05 26601	6870 NW RANGER WAY	SILVERDALE	2.67
05 26648	5120 SEABECK HOLLY RD NW	BREMERTON	4.97
05 26651	5030 SEABECK HOLLY RD NW	BREMERTON	4.97
05 26653	25266 WAGHORN RD NW	POULSBO	5.06
05 26706	22437 MILLER BAY RD NE	POULSBO	2.84
05 26708	4787 FIR DR NE	BREMERTON	0.64
05 26711	13585 FAGERUD RD SE	OLALLA	4.96
05 26733	5681 TROON AVE SW	PORT ORCHARD	0.41
05 26737	10404 NELS NELSON RD NW	POULSBO	2.44
05 26743	4142 NW GUSTAFSON RD	SILVERDALE	2.50
05 26748	19119 HARRIS AVE NE	SUQUAMISH	0.14
05 26754	6423 CEDAR TERRACE LN NW	BREMERTON	0.26
05 26772	463 MEADOWOOD DR NW	BREMERTON	2.05
05 26773	8840 LAWRENCE DR SE	PORT ORCHARD	1.16
05 26777	8729 ROW LN SE	PORT ORCHARD	3.12
05 26781	16765 SEABECK HOLLY RD NW	BREMERTON	2.75
05 26793	27474 GAMBLE BAY RD NE	KINGSTON	0.21
05 26799	8902 LAWRENCE DR SE	PORT ORCHARD	1.36
05 26807	1883 VISTA RAMA DR E	PORT ORCHARD	0.38
05 26810	39175 BEAR BERRY PL NE	HANSVILLE	7.97
05 26832	4520 NE ROVA RD	POULSBO	4.98
05 26833	3630 VICTORY DR SW	PORT ORCHARD	1.50
05 26834	9615 BANNER RD SE	OLALLA	4.77
05 26835	9585 BANNER RD SE	OLALLA	4.45
05 26836	7669 NE MISS HAILEY LOOP	KINGSTON	1.00

A80: Continued

SFR Permit #	Street Address	City	Acres
05 26841	9012 PIKE PL SE	PORT ORCHARD	2.34
05 26848	8185 AUTUMN HILLS PL NE	BREMERTON	0.30
05 26855	34274 HOOD CANAL DR NE	KINGSTON	0.46
05 26887	352 NE WALKER RD	POULSBO	4.50
05 26964	1327 PETER HAGEN RD NW	BREMERTON	2.70
05 26965	14936 JOY LN SW	PORT ORCHARD	4.94
05 27012	11420 JOLETTA AVE SW	PORT ORCHARD	5.00
05 27063	1660 NW SHERWOOD ST	BREMERTON	0.31
05 27076	1636 NW SHERWOOD ST	BREMERTON	0.35
05 27087	36000 HANSVILLE RD NE	KINGSTON	5.00
05 27092	37046 ASPEN WAY NE	HANSVILLE	0.31
05 27097	4111 NE GUNDERSON RD	POULSBO	2.31
05 27106	13885 NW CANVASBACK CT	BREMERTON	1.44
05 27146	TEMP – 12926 BETHEL BURLEY RD SE	PORT ORCHARD	2.50
05 27147	TEMP – 12908 BETHEL BURLEY RD SE	PORT ORCHARD	2.50
05 27151	33580 WIDMARK RD NE	KINGSTON	10.02
05 27153	6191 SW RHODODENDRON DR	PORT ORCHARD	0.21
05 27160	2521 NE JOHN CARLSON RD	BREMERTON	0.34
05 27163	2199 NE SAWDUST HILL RD	POULSBO	2.77
05 27172	3843 BROOK LN NW	BREMERTON	0.23
05 27246	1079 NE MCWILLIAMS RD	BREMERTON	0.64
05 27261	23826 NW OLD HOLLY HILL RD	BREMERTON	3.11
05 27266	11849 DENNY AVE SW	PORT ORCHARD	0.21
05 27271	7388 HAWKSTONE AVE SW	PORT ORCHARD	0.33
05 27300	8454 TOWNS SUMMIT PL NW	SILVERDALE	0.18
05 27301	8460 TOWNS SUMMIT PL NW	SILVERDALE	0.21
05 27306	5143 SE LAKE VALLEY RD	PORT ORCHARD	6.16
05 27308	5310 NE ADMIRALTY WAY	HANSVILLE	0.28
05 27314	2225 NELLITA RD NW	BREMERTON	20.00
05 27314	2225 NELLITA RD NW	BREMERTON	1.09
05 27391	17434 HALLMAN RD NW	POULSBO	3.18
05 27392	22203 SEA SHELL PL NE	KINGSTON	0.33
05 27423	38163 FAWN RD NE	HANSVILLE	0.30
05 27430	7727 NE POINT NO POINT RD	HANSVILLE	0.51
05 27434	26372 EDGEWATER BLVD NW	POULSBO	0.34
05 27436	8461 LONG LAKE RD SE	PORT ORCHARD	5.00
05 27439	6462 PROVOST RD NW	BREMERTON	0.94
05 27452	14014 KEGLEY RD NW	SILVERDALE	9.96
05 27510	14769 SILVERDALE WAY NW	SILVERDALE	5.00
05 27512	1949 BABY DOLL RD E	PORT ORCHARD	2.52
05 27525	27293 BALMORAL PL NE	KINGSTON	0.79
05 27526	20845 FERN ST NE	INDIANOLA	0.34
05 27603	6304 NE CENTER ST	SUQUAMISH	0.25
05 27609	14441 SANDY HOOK RD NE	POULSBO	0.96
05 27639	20974 VIRGINIA AVE NE	KINGSTON	0.40
05 27642	8090 ST HWY 3 SW	BREMERTON	8.56
05 27654	7119 E CRESTWOOD CT	PORT ORCHARD	0.22
05 27657	2499 CEDAR ST E	PORT ORCHARD	0.20
05 27659	6113 E COLLINS RD	PORT ORCHARD	1.00
05 27663	8139 SE MILLIHANNA RD	OLALLA	2.38
05 27724	1618 MORGAN RD NW	BREMERTON	1.18

A80: Continued

SFR Permit #	Street Address	City	Acres
05 27730	7425 SE SEDGWICK RD	PORT ORCHARD	0.85
05 27732	6211 E KRYSTAL WOODS WAY	PORT ORCHARD	3.56
05 27746	7266 E MAPLE ST	PORT ORCHARD	0.38
05 27758	17389 HALLMAN RD NW	POULSBO	5.00
05 27763	26443 BARRETT RD NE	KINGSTON	0.12
05 27805	13958 MINTER LN SW	PORT ORCHARD	2.50
05 27825	1924 HIGGINS RD SE	PORT ORCHARD	0.55
05 27844	10400 WOODCHUCK LN SE	PORT ORCHARD	5.03
05 27850	6385 NW AIRPARK CT	SILVERDALE	0.39
05 27857	4880 LONE BEAR LN SW	PORT ORCHARD	5.17
05 27866	23361 W LUDVICK LAKE DR	SEABECK	19.16
05 27873	11061 SABER LN SE	PORT ORCHARD	2.21
05 27875	9375 PHILLIPS RD SE	PORT ORCHARD	2.48
05 27890	4744 CALAMITY LN NW	BREMERTON	2.50
05 27900	13881 BROWNSVILLE HWY NE	POULSBO	1.49
05 27917	13396 GRAYWOLF PL NE	POULSBO	0.49
05 27921	36701 TAMARACK DR NE	HANSVILLE	0.38
05 27922	1468 WOODS RD E	PORT ORCHARD	1.34
05 27932	631 RIVERVIEW DR W	BREMERTON	4.73
05 27960	8654 SUNGATE PL NE	BREMERTON	0.98
05 27970	9338 NW ANDERSON HILL RD	SILVERDALE	0.55
05 27988	4789 NE TWIN SPITS RD	HANSVILLE	1.06
05 28105	1601 NE MADISON RD	POULSBO	2.50
05 28130	12835 BURCHARD DR SW	PORT ORCHARD	0.44
05 28131	5463 E BLAISDELL LN	PORT ORCHARD	0.52
05 28134	5457 E BLAISDELL LN	PORT ORCHARD	0.53
05 28197	7284 SIDNEY RD SW	PORT ORCHARD	1.03
05 28214	38129 BRANT RD NE	HANSVILLE	0.28
05 28235	36279 HOOD CANAL DR NE	HANSVILLE	0.85
05 28248	7175 NE BUCK LAKE RD	HANSVILLE	0.54
05 28254	25866 PIONEER WAY NW	POULSBO	6.58
05 28265	5898 LARSON LN NW	BREMERTON	5.00
05 28354	3244 ANDERSON RD SE	PORT ORCHARD	1.61
05 28355	5904 HARLOW DR NW	BREMERTON	0.54
05 28361	9193 SE WILLOCK RD	OLALLA	5.00
05 28367	11430 ALPINE DR SW	PORT ORCHARD	0.30
05 28370	4208 FRENDER LN NW	BREMERTON	4.89
05 28381	192 GOLD CREEK RD NW	BREMERTON	0.40
05 28463	11655 JACOBS LN SE	OLALLA	4.77
05 28465	38206 FAWN RD NE	HANSVILLE	0.29
05 28467	8981 WYVERN DR SE	PORT ORCHARD	2.57
05 28493	7018 MUIRKIRK LN SW	PORT ORCHARD	0.51
05 28534	13237 BOLIN POINT PL NE	POULSBO	0.68
05 28569	24763 BIG VALLEY RD NE	POULSBO	2.50
05 28621	15901 WINDY CEDAR LN SE	PORT ORCHARD	6.17
05 28622	29233 BROWNLEE PL NE	POULSBO	0.51
05 28650	16245 NW HITE CENTER RD	BREMERTON	2.41
05 28705	16792 NW ONE MILE RD	BREMERTON	4.59
05 28749	14126 NW BONKLA LN	BREMERTON	0.71
05 28759	1062 NW SHERMAN HILL RD	POULSBO	0.30
05 28773	13504 WOODSIDE LN SW	PORT ORCHARD	2.37

A80: Continued

SFR Permit #	Street Address	City	Acres
05 28774	13321 WALLACE RD SE	OLALLA	4.76
05 28820	13140 CEDAR AVE NW	POULSBO	0.16
05 28846	11733 BANNER RD SE	OLALLA	7.29
05 28875	6284 NE PONDEROSA BLVD	HANSVILLE	0.42
05 28898	7440 LAZY S LN NE	BREMERTON	0.27
05 28913	21119 VIRGINIA AVE NE	KINGSTON	0.39
05 28968	23721 SOUTH KINGSTON RD NE	KINGSTON	6.78
05 28990	18458 DIVISION AVE NE	SUQUAMISH	0.08
05 29012	1600 ROCKY POINT RD NW	BREMERTON	0.38
05 29058	5451 E BLAISDELL LN	PORT ORCHARD	0.55
05 29061	5456 E BLAISDELL LN	PORT ORCHARD	0.52
05 29079	32385 OLD HANSVILLE RD NE	KINGSTON	3.11
05 29143	15931 WINDY CEDAR LN SE	PORT ORCHARD	5.45
05 29163	5381 SW PARADISE LN	PORT ORCHARD	3.32
05 29178	4535 NE LINCOLN RD	POULSBO	5.00
05 29204	13756 MEMORY LN SW	PORT ORCHARD	2.50
05 29220	21304 STOTTLEMEYER RD NE	POULSBO	2.50
05 29285	36953 HOOD CANAL DR NE	HANSVILLE	0.27
05 29293	23600 W LUDVICK LAKE DR	SEABECK	20.29
05 29361	4787 E HILLCREST DR	PORT ORCHARD	0.31
05 29385	25584 NORMAN RD NE	KINGSTON	1.08
05 29387	4013 NE LUXURY LN	BREMERTON	0.49
05 29394	1153 SE SPRUCE RD	PORT ORCHARD	1.00
05 29411	13201 BOLIN POINT PL NE	POULSBO	1.17
05 29424	6240 SW OLD CLIFTON RD	PORT ORCHARD	5.00
05 29436	15165 GLENWOOD RD SW	PORT ORCHARD	2.50
05 29438	6460 ANDY ROGERS PL NW	SEABECK	7.50
05 29439	7630 SE SOUTHWORTH DR	PORT ORCHARD	2.06
05 29477	4868 E COLLINS RD	PORT ORCHARD	1.41
05 29584	30768 HANSVILLE RD NE	NULL	2.63
05 29618	2809 LOST CREEK LN NW	BREMERTON	4.68
05 29644	21398 INDIANOLA RD NE	POULSBO	1.25
05 29645	21416 INDIANOLA RD NE	POULSBO	1.25
05 29669	20839 KASTER RD NW	POULSBO	1.10
05 29735	2433 GREENHAVEN PL NW	BREMERTON	0.33
05 29759	27584 SERENE DR NE	KINGSTON	0.26
05 29779	12101 OLYMPIC VIEW RD NW	SILVERDALE	10.50
05 29792	7479 SE NELSON RD	OLALLA	2.60
05 29816	1650 ROCKY POINT RD NW	BREMERTON	0.38
05 29823	11764 CARTER AVE SW	PORT ORCHARD	0.21
05 29832	25172 WAGHORN RD NW	POULSBO	5.06
05 29844	6201 SE MILE HILL DR	PORT ORCHARD	4.94
05 29852	9242 BETHEL BURLEY RD SE	PORT ORCHARD	2.34
05 29876	6445 CHEYNEY LN NW	BREMERTON	2.48
05 29898	NULL	NULL	5.00
05 29913	5056 SW LAKE HELENA RD	PORT ORCHARD	2.45
05 29928	6388 FOLEY LN NW	BREMERTON	5.05
05 30006	39036 SHERLIND RD NE	HANSVILLE	0.22
05 30015	8008 E BARSAY LN	PORT ORCHARD	0.23
05 30016	8009 E BARSAY LN	PORT ORCHARD	0.23
05 30034	3584 E CALISTOGA CT	PORT ORCHARD	0.16

A80: Continued

SFR Permit #	Street Address	City	Acres
05 30036	3572 E CALISTOGA CT	PORT ORCHARD	0.17
05 30040	3213 ANDERSON RD SE	PORT ORCHARD	0.96
05 30041	3229 ANDERSON RD SE	PORT ORCHARD	0.96
05 30056	13304 NW DANCING DEER WAY	BREMERTON	5.00
05 30090	7987 SE PROMENADE LN	PORT ORCHARD	2.23
05 30093	4101 HARRIS RD SE	PORT ORCHARD	0.40
05 30094	4109 HARRIS RD SE	PORT ORCHARD	0.39
05 30182	7701 SIDNEY RD SW	PORT ORCHARD	1.00
05 30192	10980 BANNER RD SE	OLALLA	2.50
05 30198	8830 NW PEACE AND QUIET WAY	SILVERDALE	4.58
05 30259	1968 NE STILES ST	KEYPORT	0.06
05 30471	12854 BETHEL BURLEY RD SE	PORT ORCHARD	2.51
05 30474	12890 BETHEL BURLEY RD SE	PORT ORCHARD	2.50
05 30516	9611 KODIAK PL SW	PORT ORCHARD	4.33
05 30616	4645 JULIAN RD SW	PORT ORCHARD	10.00
05 30670	490 KITSAP LAKE RD NW	BREMERTON	0.50
05 30832	11990 SEABECK HWY NW	BREMERTON	0.35
05 30855	38027 VISTA KEY DR NE	HANSVILLE	0.25
05 30874	6970 E DAKOTA ST	PORT ORCHARD	0.20
05 30900	13207 BOLIN POINT PL NE	POULSBO	0.86
05 31093	17897 DIVISION AVE NE	SUQUAMISH	0.46
05 31143	13213 BOLIN POINT PL NE	POULSBO	0.85
05 31166	2440 ALASKA AVE E	PORT ORCHARD	0.31
05 31210	21141 JEFFERSON BEACH RD NE	KINGSTON	0.41
05 31230	29820 SCENIC DR NE	POULSBO	1.88
05 31269	6585 NE MAPLE ST	SUQUAMISH	0.05
05 31308	2730 LEGEND LN NW	BREMERTON	6.09
05 31323	6388 EBBERT DR SE	PORT ORCHARD	0.47
05 31324	6376 EBBERT DR SE	PORT ORCHARD	0.47
05 31374	6436 CHEYNEY LN NW	BREMERTON	2.48
05 31412	6532 CHEYNEY LN NW	BREMERTON	5.00
05 31417	9065 NE ST HWY 104	KINGSTON	9.84
05 31505	1915 NW RAMPART RIDGE CT	BREMERTON	NULL
05 31564	7161 NE WILLIAM ROGERS RD	INDIANOLA	0.21
05 31575	13272 BANNER RD SE	OLALLA	2.01
05 31577	NULL	NULL	5.00
05 31635	1391 NE HUDSON AVE	POULSBO	5.19
05 31640	2789 HILLSIDE DR NE	BREMERTON	0.33
05 31728	522 NW WASHINGTON PL	POULSBO	0.05
05 31752	38201 FAWN RD NE	HANSVILLE	0.30
05 31780	2535 CEDAR ST E	PORT ORCHARD	0.25
05 31826	24670 WAGHORN RD NW	POULSBO	5.07
05 31925	6490 ILLAHEE RD NE	BREMERTON	0.51
05 32132	15371 NE PETTERSON RD	KEYPORT	0.15
H-01 00086424	9695 NE KINGSTON FARM RD	NULL	2.59

A81: Kitsap County Land-Clearing Permits Issued for Commercial Development, 2005

Street Address	City	Acres
Null	Null	1.38
Null	Null	8.67
Null	Null	6.82
9450 Willamette Meridian Road NW	Silverdale	4.98
Null	Null	25.00
2647 Garfield Avenue SE	Port Orchard	1.10
11588 Clear Creek Road NW	Silverdale	3.40
Stanford Grading	Null	.45
5321 Sidney Road SW	Port Orchard	8.98
5321 Sidney Road SW	Port Orchard	9.70
22900 Stottlemeyer Road NE	Poulsbo	4.39
22900 Stottlemeyer Road NE	Poulsbo	5.44
22900 Stottlemeyer Road NE	Poulsbo	9.73
22900 Stottlemeyer Road NE	Poulsbo	6.99
22900 Stottlemeyer Road NE	Poulsbo	18.86
22900 Stottlemeyer Road NE	Poulsbo	7.04
Null	Null	6.97
13133 Page Road NW	Silverdale	3.56
1539 Corbett Drive NW	Bremerton	1.34
Null	Null	.96
Lodwig Estates Grading	Null	.68
Null	Null	.68
Null	Null	.24
2057 Woods Road E	Port Orchard	4.66
15668 Viking Way NW	Poulsbo	3.86
Null	Null	4.90
Total		150.78
26 permits (average acreage)		5.80
5626 SW Imperial Way	Landfill (S of Bremerton)	559.92
Additional SDAP acreage obtained by web research and not included in list above.		
1883 SE Bielmeier Road		1.00
1606 NE Midgard Way	Poulsbo	11.00
Thomas Storage		0.12
1809 Cole Loop SE	Port Orchard	0.14
17220 Clear Creek Road	Poulsbo	9.39
Vintage at Silverdale	Silverdale	4.68
Henderson Fill		0.07
3569 Anderson Hill Road SW	Port Orchard	0.46
8868 Sesame Street NW	Silverdale	2.30
8843 Clearwater Lane SE	Port Orchard	5.04
299 National Avenue	Bremerton	0.36
3999 NW Sunde Road	Silverdale	12.45
Winger Grading		0.88
1296 NE Mt Olympus Lane	Bremerton	18.84
Lexington Grading		5.24
Dickey Wood Grading		4.73
Additional web research total		76.70
16 permits (average acreage)		4.80
Average for all acreage		5.42

A82: King County Land-Clearing Permits Issued in Burn Areas, 2005

Description of Permit	Location Address	Area	Acres
Remove 7 hazard trees on 8 lots	19722 NE 169th St	Bear Creek	0.8
Remove trees on 8 lots	21614 NE 165th St	Bear Creek	0.8
Clear vegetation	21416 NE 146th Pl	Bear Creek	0.7
Clear blackberries	21833 NE 79th ST	Bear Creek	0.7
Clear trees from area	26317 NE 54th Pl	Bear Creek	0.7
Clear area, remove trees on 8 lots	15116 210th Ave NE	Bear Creek	0.8
Remove hazard trees from 8 lots	21121 NE 129th Ct	Bear Creek	0.8
Clear trees and brush	26520 NE 70th St	Bear Creek	0.7
Remove trees and stumps	25215 NE 52nd Pl	Bear Creek	0.7
Remove dying trees on 8 lots	4518 228th Ave NE	Bear Creek	0.8
Remove 6 trees on 8 lots	19119 NE 146th Way	Bear Creek	0.6
Remove trees on 8 lots	23337 NE 138th Way	Bear Creek	0.8
Clear 6 acres	NE 80th St / 250th Ave NE	Bear Creek	6.0
Remove 12 trees on 8 lots	5435 219th Ave NE	Bear Creek	0.8
Remove saplings, trees on 0.41 acres	25930 NE 80th St	Bear Creek	0.4
Remove trees on 7 lots	19118 238th Ave NE	Bear Creek	0.7
Thin trees on 6 parcels	NE 146th Way/191st Ave NE	Bear Creek	0.6
Remove 3 trees on 8 lots	19724 NE 127th Pl	Bear Creek	0.3
Remove 4 maples	5811 245th Pl NE	Bear Creek	0.4
Clear blackberries	10042 206th Ave NE	Bear Creek	0.7
Remove trees on 8 lots	20035 NE 192nd St	Bear Creek	0.8
Remove trees on 8 lots	15958 Avondale Rd NE	Bear Creek	0.8
Remove hazard trees on 8 lots	18833 NE 143rd St	Bear Creek	0.8
Clear and remove trees on 8 lots	8813 221st Ave NE	Bear Creek	0.8
Remove 12 trees on 8 lots	5216 240th St SE	Bear Creek	0.8
Remove trees	12409 203rd Ave NE	Bear Creek	0.7
Remove 1 hemlock, 6 firs on 7 lots	33802 NE 45th St	Carnation	0.7
Clear 8 lots	22505 NE 39th Way	E Sammamish	0.8
Clear 0.36 acres for him	SE 8th/Redmond-Fall City Rd	E Sammamish	0.4
Clear, grade, and landscape	117 290th Ave NE	E Sammamish	0.7
Remove 5 trees from 7-lot area	63610 NE Index Rd	East King Co.	0.7
Log trees, clear vegetation	65115 NE Stevens Pass Hwy	East King Co.	0.7
Remove 3 hazard trees	63605 NE Index Creek Rd	East King Co.	0.3
Clear & remove trees	24833 SE 380th St	Enumclaw	0.7
Grade & clear 9 lots	Agricultural activity	Enumclaw	0.9
Clear 2.47 acres brush	29322 SE 374th St	Enumclaw	2.5
Remove alders along rd on 9 lots	34850 336th Ave SE	Enumclaw	0.9
Agriculture; remove trees on 9 lots	41428 292nd Way SE	Enumclaw	0.9
Remove trees to build on 9 lots	32523 342nd Ave SE	Enumclaw	0.9
Remove 1 hazard tree	372210 W Lake Walker Dr SE	Enumclaw	0.1
Agricultural; remove 3 trees	19107 SE 400th St	Enumclaw	0.3
Clear 4 acres for pastures	38912 244th Ave SE	Enumclaw	4.0
Remove blackberries	36543 218th Ave SE	Enumclaw	0.7
Clear 1.5 acres on 9 lots for view & homes	34850 336th Ave SE	Enumclaw	1.5
Clear blackberries	SE 448th St/248th Ave SE	Enumclaw	0.7
Site Prep for homes and agriculture	SE 409th St	Enumclaw	0.7
Clear, 9 single-family homes, no burning	30235 19th Ave SE	Maple Valley	0.9
Remove trees and stumps	23610 SE 196th St	Maple Valley	0.7
Clear blackberries	24409 250th Ave SE	Maple Valley	0.7
Grade 8 lots, no burning	12508 188th Lane SE	Newcastle	0.8
Clear 8 lots	15247 162nd Ave SE	Newcastle	0.8
Clear & grade access road	SE 110th St/176th Ave SE	Newcastle	0.7
Remove trees from 8 lots	19620 SE 150th St	Newcastle	0.8

A82: Continued

Description of Permit	Location Address	Area	Acres
Remove 30 trees from 8 lots	9702 178th Ave SE	Newcastle	0.8
Clear blackberries	SE 127th St/202nd Pl SE	Newcastle	0.7
Clear blackberries	11817 164th Ave SE	Newcastle	0.7
Remove trees and stumps	14741 209th Ave SE	Newcastle	0.7
Clear berries and vegetation on 8 lots	19625 SE 140th St	Newcastle	0.8
Remove trees on 9 lots for homes	16117 SE 114th St	Newcastle	0.9
Remove hazard trees on 8 lots	12930 184th Ave SE	Newcastle	0.8
Clear 0.35 acres	SE May Valley Rd/SE 111th Pl	Newcastle	0.4
Clear 1.3 acres	SE North Bend Way	North Bend	1.3
Clear site for future development	SE North Bend Way	North Bend	0.7
Clear & remove trees	15906 NE 135th	Northshore	0.7
Remove hazard trees, 8 lots	17325 174th Ave NE	Northshore	0.8
Remove 6 hazard trees	14629 NE 166th St	Northshore	0.6
Remove trees on 8 lots	16506 NE 132nd St	Northshore	0.8
Clear blackberries	16003 154th Ave NE	Northshore	0.7
Clear trees, 20 ft radius	15701 161st Ave NE	Northshore	0.1
Remove 15 trees on 1.1 acres	17120 166th Pl NE	Northshore	1.1
Remove trees from 8 lots	17700 NE 143rd Pl	Northshore	0.8
Remove trees on 8 lots	12912 167th Ave NE	Northshore	0.8
Remove trees on 8 lots for buildings		Northshore	0.8
Remove trees on 8 lots	19203 Redmond Rd NE	Redmond	0.8
Remove 6 trees on 8 lots	13656 Woodinville-Rdmd Rd	Redmond	0.8
Grading	SE Mill Rd/Meadowbrook Wy	Snoqualmie	0.7
Grading	SE 25th/364th Ave SE	Snoqualmie	0.7
Clear 7 lots	49903 SE 171st St	Snoqualmie	0.7
Clear 24,000 sq ft for 1 single-family home	SE 163rd St	Snoqualmie	0.6
Clear shrubs on 8 lots	19045 296th Pl NE	Snoqualmie	0.8
Removal trees on 7 lots	12829 276th Way NE	Snoqualmie	0.7
Remove trees on 7 lots	49512 SE 172nd St	Snoqualmie	0.7
Remove 20 trees on site	33409 NE 70th St	Snoqualmie	4.0
Clear 2.3 acres vegetation	5705 358th Way SE	Snoqualmie	2.3
Clear blackberries	36827 NE 24th St	Snoqualmie	0.7
Clear and grade landscape	29261 SE 5th St	Snoqualmie	0.7
Clear blackberries		Snoqualmie	0.7
Clear trees and brush	Tolt Highlands Rd NE	Snoqualmie	0.7
Clear 9 lots for additional parking	7606 Lake Alice Rd SE	Snoqualmie	0.9
Remove invasive berries		Snoqualmie	0.7
Remove 40% of trees to leave 140/acre	NE 91st Way/153rd Ave NE	Snoqualmie	0.9
Agriculture; clear 7 lots	NE Cherry Valley Rd	Snoqualmie	0.7
Clear trees and shrubs	11615 268th Dr NE	Snoqualmie	0.7
Remove Japanese knotweed	14637 438th Ave SE	Snoqualmie	0.7
Log & clear portion of 2 parcels	43833 SE Tanner Rd	Snoqualmie	0.2
Log & clear site for future development	SE N Bend Way/SE 140th St	Snoqualmie	0.7
Clear and grade 2.5 acres	36612 SE 82nd St	Snoqualmie	2.5
Clear blackberries	12530 277th Pl NE	Snoqualmie	0.7
Remove alders to enlarge orchard	19270 303rd Pl NE	Snoqualmie	0.7
Cut and mulch saplings, brush		Snoqualmie	0.7
Remove hazard trees on 7 lots	32330 NE 32nd St	Snoqualmie	0.7
Remove hazard trees on 8 lots		Snoqualmie	0.8
Clear 6 acres for pastures	7130 Tolt Highlands Rd NE	Snoqualmie	6.0
Clear blackberries	308th Ave NE/NE Big Rock Rd	Snoqualmie	0.7
Clear pastureland	30112 SE 64th St	Snoqualmie	0.7
Remove trees	11505 Upper Preston Rd SE	Snoqualmie	0.7

A82: Continued

Description of Permit	Location Address	Area	Acres
Remove 1 dead hemlock	19605 330th Ave NE	Snoqualmie	0.1
Remove hazard trees	10709 East Lake Joy Dr NE	Snoqualmie	0.7
Legalize tree removal on 8 lots	15202 451st Ave SE	Snoqualmie	0.8
Clear 7 acres for homes	6227 Tolt Highlands Rd NE	Snoqualmie	7.0
Remove stumps on 1.3 acres	18724 320th Ave NE, Duvall	Snoqualmie	1.3
Legalize tree removal on 7 lots	SE 131st St/464th Ave SE	Snoqualmie	0.7
Remove 27000 sq ft of berries	35824 SE 49th St	Snoqualmie	0.6
Clear and mitigate on 7 lots	16427 466th Pl SE	Snoqualmie	0.7
Clear 10,020 sq ft of trees and brush	47129 SE 153rd	Snoqualmie	0.2
Log & clear 6 acres for pasture	Tolt Highlands Rd/60th St NE	Snoqualmie	6.0
Remove 6 trees on 7 lots	44725 SE 71st	Snoqualmie	0.6
Clear 0.35 acres and berries on 7 lots	44430 SE Edgewick Rd	Snoqualmie	0.4
Clear berries and saplings	17214 435th Ave SE	Snoqualmie	0.7
Clear blackberries	29615 SE 51st SE	Snoqualmie	0.7
Clear blackberries	31427 NE Tolt Hill Rd	Snoqualmie	0.7
Clear 4.5 acres for pastures	19045 296th Pl NE	Snoqualmie	4.5
Clear 2.2 acres for building	31555 NE Big Rock Rd	Snoqualmie	2.2
Clear blackberries	SE 151st St/444th Ave SE	Snoqualmie	0.7
Clear & remove trees, 9 lots	32010 162nd Ave SE	Soos Creek	0.9
Clear 0.5 acres on 9 lots	21214 143rd Ave SE	Soos Creek	0.5
Remove hazard trees, 9 lots	18432 SE 212 St	Soos Creek	0.9
Remove berries & bamboo	33709 146th Ave SE	Soos Creek	0.7
Remove berries & bamboo	317 Ave NE/134 St NE	Soos Creek	0.7
Remove trees on 9 lots	34207 183rd Ave SE	Soos Creek	0.9
Remove trees from 7 lots	Lake Alice Rd SE	Soos Creek	0.7
Remove trees on 8 lots	15441 SE Lk Money Smith Rd	Soos Creek	0.8
Remove trees around home	21124 143rd Ave SE	Soos Creek	0.2
Remove blackberries	24639 156th Ave SE	Soos Creek	0.7
Remove blackberries		Soos Creek	0.7
Remove hazard trees	31244 172nd Ave SE	Soos Creek	0.7
Clear trees to build homes on 9 lots	31033 157th Pl SE	Soos Creek	0.9
Remove trees on 9 lots	16404 SE 240th St	Soos Creek	0.9
Remove blackberries on 9 lots	19401 102nd Ave SE	Soos Creek	0.9
Clear blackberries	21417 192nd Ave SE	Soos Creek	0.7
Log, clear, & restore 9 lots in sensitive area		Soos Creek	0.9
Remove 17 hazard trees on 9 lots	21013 196th Ave SE	Soos Creek	0.9
Remove hazard tree	29233 Kent-B, Diamond Rd SE	Soos Creek	0.7
Remove trees, clear 0.75 acres on 9 lots	18035 SE 317th St	Soos Creek	0.8
Clear for horse pasture	19512 SE 183rd St	Soos Creek	0.7
Hazard tree removal on 9 lots	17732 SE 252nd St	Soos Creek	0.9
Remove 10 trees	212221 142nd Ave SE	Soos Creek	1.0
Remove trees on 9 lots	29420 164th Ave SE	Soos Creek	0.9
Grading, 9 lots, no burning	19036 SE Auburn-B Diamond Rd	SW B Diamond	0.9
Grading, no burning	20006 Jones Rd	Tahoma	0.7
Remove blackberries	255th Ave SE	Tahoma	0.7
Remove trees on 8 lots	13326 230th Ave SE	Tahoma	0.8
Blackberry removal	18645 Renton-Maple Valley	Tahoma	0.7
Remove blackberries	30235 196th Ave SE	Tahoma	0.7
Remove 11 trees on 8 lots	28524 208th St SE	Tahoma	1.1
Remove 3 trees on 8 lots	26004 SE 156th St	Tahoma	0.3
Clear blackberries	Between 299th Pl & Grass Lake	Tahoma	0.7
Remove trees, stumps, grade 9 lots	24403 256th SE	Tahoma	0.9
Clear downed trees	18005 252nd Ave SE	Tahoma	0.7

A82: Continued

Description of Permit	Location Address	Area	Acres
Remove trees from 8 lots	23425 SE 225th ST	Tahoma	0.8
Remove 4 trees from 9 lot-area	29420 157th Ave SE	Tahoma	0.4
Remove 11 trees around home	14526 255th Ave SE	Tahoma	1.1
Remove blackberries	29212 333rd Ave SE	Tahoma	0.7
Remove blackberries	25119 SE 262nd St	Tahoma	0.7
Remove 25 cottonwood trees	27902 173rd Pl SE	Tahoma	2.5
Remove trees 8 lots	23722 SE 127th St	Tahoma	0.8
Remove blackberries	19717 SE 212 St	Tahoma	0.7
Clear 2.5 acres for homes	SE 262nd St	Tahoma	2.5
Thin 190 acres of fir forest	Forestry (Tahoma/Ravensdale)	Tahoma	19.0
Restore area and buffers	18615 SE 272nd St	Tahoma	0.7
Clear for view	23632 SE 225th St	Tahoma	0.7
Clear 14 trees on 8 lots for view	23632 SE 225th St	Tahoma	0.8
Clear saplings and bushes on 9 lots	19717 SE 212 St	Tahoma	0.9
Clear within 25' of slope	24341 270th Ave SE	Tahoma	0.7
Remove trees from 8 lots	25913 SE 159th St	Tahoma	0.8
Mitigate clearing and restore	2929 SE 8th St	Tahoma	0.7
Remove 17 trees	25054 SE Mirrormont Way	Tahoma	1.7
Clear blackberries	Tahoma/Ravensdale Heights	Tahoma	0.7
Remove berries and saplings	13415 246th Ave SE	Tahoma	0.7
Remove berries and weeds	21010 Maxwell Rd SE	Tahoma	0.7
Remove 10 hazard trees	25914 SE 159th St	Tahoma	1.0
Remove hazard trees on 8 lots	13720 246th Ave SE	Tahoma	0.8
Remove and plant trees on 9 lots	33311 210th Ave SE	Tahoma	0.9
Clean and grade	27924 SE 268th St	Tahoma	0.7
Grading	9615 SW 171st St	Vashon Island	0.7
Clear, remove berries, no burning	10926 SW 204th St	Vashon Island	0.7
Clear blackberries		Vashon Island	0.7
Remove blackberries	10308 SW 204th St	Vashon Island	0.7
Remove trees on 9 lots	Cedarhurst/McCormick Pl	Vashon Island	0.9
Clear portion for agric	SW 220th St/123rd Av SW	Vashon Island	0.7
Clear and grade for road	143rd Ave SW	Vashon Island	0.7
Remove hazard trees	7103 SW Pt Robinson Rd	Vashon Island	0.7
Remove vegetation	9225 SW Summerhurst Rd	Vashon Island	0.7
Clear berries and scotch broom	9413 SW 171st St	Vashon Island	0.7
Clear blackberries	SW 285th St	Vashon Island	0.7
Clear and grade		Vashon Island	0.7
Clear 8 lots for residences	15742 203rd Ave SE	Woodinville	0.8
Average acreage = 204.6 acres/197 permits (approximately 1.04 acres/permit)		Total:	204.6

A83: Pierce County Land-Clearing Permits Issued in Unincorporated Areas

Housing Units (HU) in:	2005 HU	2006 HU		
Unincorporated	132,599	135,681		
County	305,957	312,496		
Increase in HU	**2005-2006**	**2005 Develop.**		
Unincorporated	3,082	241		
County	6,539	511		
Residential Dev. Permits				
Unincorporated	241			
County	511			
Period in 2005	**Residential Dev.**	**Grading**	**Clearing**	**Comm'l Dev.**
Burn zone	241	11	3	9

A84: Snohomish County Land-Clearing Permits Issued in Burn Areas, 2005

Address/Tax Account #	City	Description of Clearing in Burn Area	Acres
6517 100th Ave SE	Marysville 270	Clear-cut	7.7
320625-00300400	Arlington 223	Land use only, no cutting	6.5
280636-00101000	Monroe 272	Timber harvest	5.0
290536-00101900	Snohomish 290	Cut and clear 1 out of 5 acres	1.0
003935-10301300	Stanwood 292	Harvest and clear for home site	5.0
003935-10301300	Stanwood 292	10' x 10' burn pile fed by debris	5.0
320427-00100900	Stanwood 292	Clear-cut	107.3
20617 Dubuque Rd	Snohomish 290	Convert forest to pasture	5.3
1227 140th St NE	Marysville 270	Harvest 10,000 board-feet for homes	2.5
12501 227th Ave SE	Monroe 272	Cut, clear, de-stump 1 of 5 acres	1.0
59th Ave NE	Arlington 223	Timber harvest for future development	10.0
34006 Rte 530 NE	Arlington 223	Burn 5 30' x 30' pile fed by debris	15.0
22207 Dubusque Rd	Snohomish 290	40% cut 2.2 acres	0.9
006253-00002300	Snohomish 290	Timber harvest	42.2
Mt Loop Hwy	Granite Falls 252	Forest practice permit issued, no data	
310512-00100500	Arlington 223	100% cut, no acreage specified	
11515 84th St NE	Lake Stevens 258	Clear 2 20' x 20' burn piles, FD #17	13.3
4520 141st St SE	Snohomish 296	Clear-cut for Appletree Condos	5.0
609 134th St NW	Marysville 271	30% cut (1.5 out of 4.9 acres)	1.5
21019 116th St SE	Snohomish 290	Harvest 14 out of 47 acres	14.0
24324 131st Ave SE	Snohomish 296	Clear for pipelines, no acreage	
26626 28th Ave NW	Stanwood 292	Clear 1 out of 10 acres for homes	1.0
5524 123rd Ave SE	Snohomish 290	Clear 1 out of 5 acres for homes	1.0
23620 131st Ave SE	Snohomish 296	Clear for pipelines, no acreage	
16020 50th Ave NE	Snohomish 290	Clear site for single-family residences	
1510 154th Dr NE	Snohomish 290	Clear 20,000 board-feet for homes	4.0
8111 162nd St NE	Arlington 223	2% cut 5 acres for single residence	0.1
Lakewood Crest	Lakewood	Harvest 6 20' x 20' burning piles	39.5
310413-00100400	Arlington 223	Cut one 30' x 30' pile fed by debris	19.6
7125 83rd Ave NE	Marysville 270	Clear-cut for development	44.5
116 St NE	Marysville 271	Clear-cut	4.7
15901 35th Ave NE		Clear-cut for Pioneer Circle development	3.9
27321 Florence Acres Rd	Monroe 272	Clear-cut for single-family residences	10.0
320424-00300100	Job Site Lot A	Cut timber for Rose Run	19.7
320424-00300100	Job Site Lot A	Cut 25% of 13.2 acres for Rose Place	3.3
5530 220th St NW	Stanwood 292	Cut 65% of 5.29 acres	3.4
6811 218th NW	Stanwood 292	Thin 4.5 acres	4.5
24324 131st Ave SE	Snohomish 296	Clear for pipelines, no acreage	
28112 Grandview Rd	Arlington 223	85% cut 10 acres for 150,000 board-feet	8.5
32618 37th Ave NE	Arlington 223	Clear-cut for homes	5.0
2505 Soper Hill Rd	Lake Stevens 258	80% cut 5 acres for development	4.0
19209 8th Ave NW	Arlington 223	Cut 40% of 10 acres	4.0
18110 Russian Rd	Arlington 223	Clear 3 30' x 30' burn piles; FD 14	19.8
30300 Finn Settlement Rd	Arlington 223	No description of forest practice permit	
23105 135th Ave NE	Arlington 223	Harvest, no de-stumping or acreage	
2408 274th St NW	Stanwood 292	Clear-cut 1 out of 5 acres	1.0
1120 148th St NE	Arlington 223	Harvest and de-stump	18.0
320427-00200100	Stanwood 292	Clear-cut for Snowbird	40.2
36627 Mann Rd	Sultan	Forest practice permit open, no action	
23426 19th Ave NE	Arlington 223	Cut 1 out of 4.67 acres	1.0
1533 268th NW	Stanwood 292	Clear five 20' radius burn piles	36.5
Skinner Rd	Granite Falls 252	Clear-cut	2.0
Elliot Rd	Snohomish 296	75% cut 3.6 acres	2.7
18824 111th Pl SE	Snohomish 290	Clear 25% of 4.65 acres for SFR	1.2
8705 172nd St NW	Stanwood 292	Timber harvest	
4520 141st St SE	Snohomish 296	Clear-cut timber for Appletree Condos	5.0
290617-00300900	Lake Stevens 258	Clear-cut	5.8
Total acreage (for 47 w/acres data)			561.9
Average acres per permit			12.0

A85: Land-Clearing Burning Permits Issued by Fire Departments, 2005

(for information only)

Fire Department	Permits issued	Source of Data and Contact Information
Kent	4	Wayne LaVigne, wlavigne@ci.kent.wa.us
Woodinville	9	Arlene Jackson, arlene@wflsd.org, 425 483 7907
Duvall (KCFD #45)	94	Tana Blake, tblake@duvallfire45.com, 425 788 1625
Maple Valley	73	Winter Taylor, wintertaylor@maplevalleyfire.org
Redmond	22	Debbie Gentry, dgentry@redmond.org, 425 556 2200
Vashon Island	61	Barbara Cooper, bcooper@vifr.org
King Co total	263	
North Kitsap	173	Kathy Todd, 360 297 3619, todd@nkfr.org
Poulsbo	90	360 779 3997, jcooper@poulsbofire.org; kwlodarchak@poulsbofire.org
Central Kitsap	320	Roger Nordlander, 360 447 3630 / 3631, rnorlander@ckfr.org
South Kitsap	282	Shawn Shepherd, sshepherd@skfr.org; Nancy Honsey, (360) 871-2411 x 0
Kitsap Co total	865	Issuers reconfirmed that all these were land-clearing burn permits
Anderson Is., FD #27	72	James Bixler, airfr2701@centurytel.net, (253) 884-4040
Graham, PCFD #21	58	Kathy Hickok, khickok@grahamfire.org
Gig Harbor, PCFD #5	119	Eric Watson, ewatson@piercefire.org, (253) 851-3111
Ashford, FD #23	218,717 yd^3	Garry Olson, pcfr23@centurytel.net, (360) 569-2752
Bonney Lake, PCFD #22	1	Tricia Brown, tbrown@eastpiercefire.org, (253) 863-1800
South Prairie, FD #20	5	Tricia Brown, tbrown@eastpiercefire.org, (253) 863-1800
Buckley, FD #12	8	Tricia Brown, tbrown@eastpiercefire.org, (253) 863-1800
Pierce Co total	263	[*note: total does not include Ashford FD #23*]
Everett (98208), FD #1	none issued	Allows no burning, Terri Bart, Snohomish Co. Fire Marshal (SCFM)
Monroe, FD #3	30	Katherine Powers, (360) 794-7666, kpowers@monroefire.org
Snohomish, FD #4	none issued	Sharon Wilson, (360) 568-2141; sharon@snohomishfire.org
Snohomish, FD #7	none issued	Allows no burning, Terri Bart, SCFM
Lake Stevens, FD #8	31	(425) 334-3034, rmarshall@lakestevensfire.org,acaton@lakestevensfire.org
Marysville, FD #12[183]	(assumed) 31	(360) 363-8500, jjacobsen@ci.marysville.wa.us; Sandra Selvrom
Stanwood, FD #14	none issued	(360) 652-1246, Robert Eastman, beastman@northcountyfireems.com
Bryant, FD #18	18	(360) 435-9252, Robert Eastman, beastman@northcountyfireems.com
Silvana, FD #19	none issued	Keith Strotz, 360 652 827, kstrotzprd19@aol.com
Getchell, FD #22		www.getchellfire.com
Gold Bar, FD #26	none issued	(360) 793-1335, Wendy Enyart; 65 residential permits; no land-clearing
Gedney/Hat Is, FD #27	6	Mike Worthy, Assistant Chief, (360) 444-6886, scfpd27@hatisland.com
Index, FD #28	4	(360) 793-0866; Assistant Chief Ernie Walters, FD#28@premier1.net
Sultan/Startup, FD #5	0	Terri Bart, SCFM (425) 388-3557, tbart@co.snohomish.wa.us
Bothell, FD #10	0	Terri Bart, SCFM (425) 388-3557, tbart@co.snohomish.wa.us
Tulalip Bay, FD #15	0	Terri Bart, SCFM (425) 388-3557, tbart@co.snohomish.wa.us
Lk Roesiger, FD #16	1	Terri Bart, SCFM (425) 388 3557, tbart@co.snohomish.wa.us
Granite Falls, FD #17	1	Terri Bart, SCFM (425) 388 3557, tbart@co.snohomish.wa.us
Arlington, FD #21	9	Terri Bart, SCFM (425) 388 3557, tbart@co.snohomish.wa.us
Robe Valley, FD #23	1	Terri Bart, SCFM (425) 388 3557, tbart@co.snohomish.wa.us
Darrington, FD #24	0	Terri Bart, SCFM (425) 388 3557, tbart@co.snohomish.wa.us
Oso, FD #25	0	Terri Bart, SCFM (425) 388 3557, tbart@co.snohomish.wa.us
Other Stanwood area	8	Terri Bart, SCFM (425) 388 3557, tbart@co.snohomish.wa.us
Fire marshal total	20	Terri Bart, SCFM (425) 388-3557, tbart@co.snohomish.wa.us
Snohomish Co total	140	

[183] Marysville FD #12 issued some fire permits, but did not track them. Lake Stevens FD #8 issued 31 burn permits; it covers 46 square miles and serves 36,000 people. FD #12, adjacent to FD #8, covers 41 square miles and serves 33,000 people. The Agency assigned 31 burn permits to FD #12.

A86: Details of Land-Clearing Burning Permits issued by Snohomish Co. Fire Marshal, 2005

Description of Land-Clearing Burn Permit Piles (dimensions are in feet)	Area
15+ burn piles ranging from 10x10 to 30x30	Arlington
One 10x10 pile	Arlington
Four 10x10 pile, one 20x20 piles, three 30x30 piles	Arlington
Three 10x10 piles to be fed by debris, burning one pile at a time	Arlington
One 10x10 pile including small stumps and slash from land-clearing	Arlington
One 10x10 pile	Arlington
Three 10x10 piles, fed by clearing debris	Arlington
Three 30x30 piles to burn timber harvest on an undeveloped 57 acre parcel	Arlington
One 10x10 pile fed by stumps, blackberries, and brush	Arlington
88 + 30x30 piles, permit renewable every sixty days	Granite Falls
One 30x30 burn pile to burn debris from future single family residences	Granite Falls
30x30 piles to burn right of way debris from development	Snohomish
10x10 pile to burn debris from three large piles	Stanwood
One 20x20 pile, renewed from June 12 to August 12, 2005	Stanwood
One 10x10 pile fed by a larger pile	Stanwood
One 10x10 pile, fed by other piles	Stanwood
Nine 30x30 piles fed by debris from 23 acres	Stanwood
One 10x10 pile fed by clearing debris	Stanwood
One 10x10 pile, renewed three times	Stanwood
One 10x10 pile, renewed once	Stanwood

A87: Percent Distribution of Housing Units by Housing Type and Occupancy Rate[184]

	King	Kitsap	Pierce	Snohomish
1-unit	60.2%	70.1%	67.2%	65.8%
2-unit (duplex)	2.1%	3.2%	2.9%	2.7%
3- or 4-unit	4.2%	3.5%	4.1%	3.7%
>4 unit	30.8%	13.2%	17.6%	20.0%
Mobile homes	2.7%	10.0%	8.2%	7.8%
Occupancy rate	95.8%	93.3%	94.1%	95.2%

A88: Distribution of Housing Units in Rural Puget Sound[185]

	King	Kitsap	Pierce	Snohomish
1-unit	109,396	49,390	96,150	90,537
>1-unit	19,327	7,682	14,946	18,356
Mobile homes	7,523	9,524	21,503	13,922
Total	136,246	66,596	132,599	122,815

Multi-family units (>1-unit) are separated into 2-unit, 3- or 4-unit, and >4-unit by the equations:

# of 2-units = (fraction for 2-units)/(fraction for multi-units) x (# of multi-units)
# of 3- & 4-units = (fraction for 3- & 4-units)/(fraction for multi-units) x (# of multi-units)
# of eligible housing units = # of (2-unit + 3-unit + 4-unit) housing units
# of eligible households = (# of eligible housing units) x (occupancy fraction)

[184] Table DP-4: Profile of Selected Housing Characteristics and Table DP-1: Profile of General Demographics Characteristics, Census 2000.

[185] Table 8: 2005 Population Trends of Washington, published by the Forecasting Division of Washington State Office of Financial Management, Olympia, WA, http://www.ofm.wa.gov.

Single family homes, duplexes, triplexes, fourplexes, and mobile homes are eligible to subscribe to curbside pick-up. According to the data provided by the county waste management departments, units with more than four units do not subscribe to curbside pick-up; yard maintenance service is part of their rent or condominium fees.

A89: Housing Units and Households Eligible for Curbside Pick-Up

Description	King County	Kitsap	Pierce	Snohomish
1-unit	109,396	49,390	96,150	90,537
2-unit	1,094	1,235	1,762	1,877
3- or 4-unit	2,188	1,351	2,491	2,537
Mobile homes	7,523	9,524	21,503	13,922
All eligible units	120,201	61,500	121,906	108,909
Eligible households	115,153	57,380	114,713	103,681

A90: Yard Waste Characteristics for Unincorporated King County, 2005

Description	Quantity
Eligible subscriber households (hh), a	115,153
#of subscriber hh, b [provided by waste management reports]	41,360
# of hh not subscribing, c = (a - b)	73,793
% of eligible hh not subscribing, d = (c/a) * 100	64.1%
Lbs per subscriber hh, e [provided by waste management reports]	1,560
Tons uncollected, f = (c x e)/2000	57,559
% of hh that self-hauled, g [Bellwether Report, question #4]	7.0%
#of rural hh that self-hauled, h=(g/100*) a	8061
Tons self-hauled, j [see notes below]	6,287
% of hh composting, k [Seattle Public Utility (SPU), & Bellwether, question #4]	42.3%
# of hh composting, m = (k/100)* a	48,710
Lbs composted per composting hh, n (SPU data, assumed applicable)	320
Tons composted, p = (m * n)/2000	7,794
% of hh that grass-cycled, q (SPU data, assumed applicable for all areas)	36%
# of hh grass-cycling, r = (q/100) * a	41,988
lb grass-cycled per grass-cycling hh, s [SPU data]	352
Tons grass-cycled, t = (r * s)/2000	7,390
Tons available to burn or dump, u = (f - j - p - t)	36,088
% of hh that burned, v [Bellwether, question #4]	17%
# of hh that burned, w = (v/100) * a	19,921
Tons burned, y = (w * e)/2000	15,539

Notes:

b, e......... provided by 2005 King County Solid Waste Report[186]

g .... from Bellwether Survey

j .... j = (h * e)/2000

k .... unincorporated: Bellwether Survey

n .... SPU report (tons composted/composting hh)

q, s......... SPU report, Seattle assumed applicable for all areas. No other comparative data available

tons burned .... the estimate developed with the Bellwether Survey is used since the survey is applicable and directly asked about burning.

[186]Sheri Feld, Seattle Public Utilities solid waste data, sheri.feldsea.gov, March 8, 2006 e-mail; 2005 King Co. Solid Waste Annual Report, Tables A-2 & A-3, published by King Co. Dept. of Natural Resources & Parks, Seattle.

A91: Yard Waste Characteristics for Unincorporated Kitsap County, 2005

Description	Quantity
Households (hh) eligible to subscribe to curbside pick-up, a	57,380
% of eligible hh not subscribing, b [assumed King Co. 2005 Solid Waste Report data]	64.1%
# of hh not subscribing, c = (b/100) * a	36,781
Lbs per subscribing hh, d [assumed King Co. 2005 Solid Waste Report data]	1,560
Tons uncollected, e = (c * d)/2000	28,689
% of hh that self hauled to transfer station, f [Bellwether, question #4]	3%
# of hh that self-hauled, g = (f/100)* a	1,549
Tons self-hauled, h = (g * d)/2000; Incorporated	1,208
% of hh composting, j [Bellwether Report, question #4]	40%
# of hh composting, k = (j/100) * a	22,780
Lbs composted per composting hh, m [Seattle Public Utilities (SPU) data]	320
Tons composted, n = (m * k)/2000	3,645
% of hh grass-cycling [Seattle data], p [SPU data]	36%
# of hh grass-cycling, q = (p/100) * a	20,922
Lbs grass-cycled per grass-cycling hh, r [SPU data]	352
Tons grass-cycled, s = (r * q)/2000	3,679
Tons available to burn or dump, t = (e - h - n - s)	20,156
% of hh that burn [Bellwether Report, question #4], u	13.7%
# of hh that burned, v = (u/100) * a	7,861
Tons burned by hh (w = (v * e)/2000)	6132

A92: Yard Waste Characteristics for Unincorporated Pierce County, 2005

Description	Quantity
Eligible subscriber households (hh), a	117,713
% of hh not subscribing [King Co. Data]	64.1
# of hh subscribing, b	42,259
# of non-subscribers, c = (a - b)	75,454
Lbs per subscriber hh, d [Pierce Co. Solid Waste Reports][187]	875
Tons yard waste not collected, e = (c * d)/2000	32,995
Tons self-hauled, f, [Pierce Co. Solid Waste Reports]	10,508
% of hh composting, g [Bellwether]	31.4%
# of hh composting, h = (g/100) * a	36,962
Lbs composted per composting hh, j (Seattle Public Utilities data)	320
Tons composted, k = (j * h)/2000	5,763
% of hh grass-cycling, m (Seattle Public Utilities data)	36%
# of hh grass-cycling, n = (m/100) * a	42,921
Lbs grass-cycled per grass-cycling hh, p (SPU data)	352
Tons grass-cycled, q = (p * n)/2000	7,362
Tons available to burn or dump, r = (e - f - k - q)	9,189
% of hh that burn, s [Bellwether Report, question #4]	19.1%
# of hh that burned, t = (s/100) * a	21,910
Tons burned, u [incorporated: u = r; unincorporated: u = (t * d)/2000	9,756

[187] 2005 Tacoma Solid Waste Data provided by Bill Smith, City of Tacoma, wsmith2@ci.tacoma.wa.us, e-mail received April 11, 2006; and 2004 Pierce County Solid Waste Statistics provided by Craig Swanson, cswanso@co.pierce.wa.us, e-mail received August 5, 2004.

A93: Yard Waste Characteristics for Unincorporated Snohomish County, 2005

Description	Single-Family	Multi-Family
Households (hh) eligible for curbside pick-up, a	99,445	4,236
% of hh subscribing , z (see note below)	35.7%	35.7%
# of subscribers, b = (z/100) * a	35,512	1,513
# of non-subscribers, c = (a - b)	63,933	2,723
Lbs per subscriber hh, d [2004 Snohomish Co. Solid Waste]	1,242	1,242
Tons not collected at curb, e = (c * d)/2000	39,710	1,691
% of hh that self-hauled, f [Bellwether Report, question #4]	3%	3%
# of hh that self-hauled, g = (f/100) * a	3,282	140
Tons self-hauled to transfer station, h = (g * d)/2000	2,038	87
% of hh composting, j [unincorporated: Bellwether]	38%	38%
# of hh composting, k = (j/100) * a	37,690	1,605
Lbs composted per composting hh, m [SPU data]	320	320
Tons composted, n = (m * k)/2000	6,752	257
% of hh grass-cycling, p [SPU data]	36%	36%
# of hh grass-cycling, q = (p/100) * a	36,260	1,545
Lbs grass-cycled per grass-cycling hh, r [SPU data]	352	352
Tons grass-cycled, s = (q * r)/2000	6,382	272
Tons available to burn or dump, u = (e - h - n s)	25,259	1,076
% of rural hh that burn [Bellwether Survey], v	22%	22%
# of hh that burn, w = (v/100) * a	21,878	932
Tons burned, x = (w * d)/2000	13,589	579

Note:

z.........2004 Snohomish Co. solid waste data gives the countywide yard-waste subscription rate as 42%. The incorporated King Co. rate of 49.5% was assigned to the incorporated area of Snohomish. To keep the county rate at 42% as given by the Snohomish report, the unincorporated subscription rate comes to 35.7%.

A94: Forest Wildfires
(as reported by Washington DNR)

Township (King)	Range	Section	Date in 2005	Cause	Acres Burned
20	7E	30	28 September	Unknown	0.5
21	11E	25	27 July	Unknown	0.01
22	10E	17	05 July	Unknown	0.5
25	8E	36	24 August	Recreation	0.1
26	10E	2	15 June	Miscellaneous	0.1
King Co. Total					1.21
Township (Kitsap)	**Range**	**Section**	**Date in 2005**	**Cause**	**Acres Burned**
24	1W		14 August	Smoker	0.1
27	2E	5	31 August	Children	0.25
Kitsap Co. Total					0.35
Township (Pierce)	**Range**	**Section**	**Date in 2005**	**Cause**	**Acres Burned**
16	3E	18	20 July	None	0.33
16	4E	21	15 August	Miscellaneous	0.06
17	2E	26	26 August	Miscellaneous	0.25
17	11E		19 July	None	0.01
17	3E	12	21 July	Lightning	0.01
17	3E	15	14 March	Smoker	2.3
17	7E	4	25 July	None	0.01
17	7E	4	23 August	Recreation	0.01
17	1W	3	04 August	None	0.1
18	4E	2	01 September	None	20
18	7E	32	13 August	Recreation	0.5
19	6E	27	10 August	Recreation	0.01
21	4W	26	07 August	Miscellaneous	0.75
Pierce Co. Total					24.34
Township (Snohomish)	**Range**	**Section**	**Date in 2005**	**Cause**	**Acres Burned**
27	7E	27	25 April	Recreation	0.1
27	7E	27	31 August	Recreation	0.1
28	7E	8	05 August	Debris burn	0.1
28	7E	13	14 October	Recreation	0.1
28	9E	6	06 September	Recreation	0.1
29	9E	22	20 October	Debris burn	2
32	6E	25	05 March	Debris burn	0.1
32	12E	19	14 July	None	0.25
32	5E	14	19 September	Miscellaneous	0.1
Snohomish Co. Total					2.95

A95: Forest Management Burning (as reported by Washington DNR)

Tons Burned in King Co.	Tons $PM_{2.5}$	Burn Date in 2005	Permit #
10	0.07	05 October	69000
5	0.03	13 September	77212
9	0.06	06 October	77492
King Co. Total: 24	0.16		
Tons Burned in Pierce Co.	**Tons $PM_{2.5}$**	**Burn Date in 2005**	**Permit #**
30	0.2	25 May	77211
176	1.19	11 November	77214
281	1.9	21 December	77215
37	0.25	27 September	77216
67	0.45	27 September	77217
750	5.06	27 December	77218
434	2.93	22 December	77220
253	1.71	04 November	77221
294	1.98	30 December	77222
648	4.37	21 December	77223
500	3.38	20 December	77224
402	2.71	21 December	77451
98	0.66	27 September	77452
87	0.59	27 September	77453
538	3.63	11 November	77455
432	2.92	07 November	77456
480	3.24	07 November	77457
1,130	7.63	27 December	77460
245	1.65	10 November	77461
125	0.84	07 November	77462
495	3.34	29 December	77463
234	1.58	22 December	77464
379	2.56	30 December	77465
771	5.2	04 November	77466
467	3.15	05 November	77467
249	1.68	04 November	77468
649	4.38	04 November	77469
386	2.61	11 November	77470
150	1.01	12 November	77472
304	2.05	12 November	77477
304	2.05	05 November	77478
619	4.18	05 November	77479
473	3.19	10 November	77480
500	3.38	12 November	77481
100	0.68	04 Nov ember	77482
715	4.83	12 November	77483
140	0.95	29 December	77484
226	1.53	11 November	77485
50	0.34	07 November	77487
480	3.24	29 December	77487
240	1.62	29 December	77488
120	0.81	22 December	77489
Pierce Co. Total: 15,058	101.64		
Tons Burned (Snohomish Co)	**Tons $PM_{2.5}$**	**Burn Date in 2005**	**Permit #**
3	0.02	07 October	69052
3	0.02	22 September	69090
8	0.05	22 September	69091
Snohomish Co. Total: 14	0.09		

A96: Tons of VOC Emitted from Point Source Coating Segments, 2005

Coating Segments (King Co. Sources)	Lbs of VOC	Type of Industry
Trojan Lithograph	36,556	Printing
Armstrong Lumber	34,520	Prefab wood products
Foss Maritime	28,806	Water freight transportation
Ball Metal Containers	284,625	Metal can manufacturing
Coatings Unlimited	37,369	Paintings and coverings
Capital Industries	56,210	Miscellaneous fabrication
Aero-Lac	151,020	Millwork
Hexcel	6,279	Aerospace
Industrial Containers	68,194	Metal containers
Puget Sound Coatings	50,704	Metal coating
Hytek Finishes	39,465	Metal finishing
Todd Shipyards	32,168	Ship building
Boeing Auburn	64,946	Aerospace
Boeing Renton	57,131	Aerospace
Boeing Plant 2	41,995	Aerospace
Trim Systems	26,588	Plastic products
Color Tech	10,829	Metal coating
Comprehensive Prefinish	21,432	Wood cabinets
Contour Laminates	30,466	Furniture manufacturing
Numatic Finishing	12,126	Wood preservation
Quality Finishing	15,121	Metal coating
Protective Coatings (16328)	55,869	Metal furniture
Kenworth Trucks	211,097	Heavy-duty vehicles
ColorGraphics	54,911	Printing
Pacific Crest	143,119	Locker manufacturing
Genie (18357)	39,142	Construction machinery mfg.
Protective Coatings (18601)	7,539	Aerospace
Rexam Beverage Can	285,976	Metal can manufacturing
Professional Coatings (26303)	126,958	Upholstery and furniture
Mikron	19,845	Spray coating
Delta Marine Industries, Inc.	9,719	Boat building
Genie Industries (28653)	160,706	Construction machinery mfg.
Exotic Metals	11,670	Aerospace
Western Pneumatics	40,692	Pipe and fittings fabrication
Asko	14,198	Metal finishing
Total King County Sources	2,196,524	

A96: Continued

Coating Segments (Pierce Co. Sources)	Lbs of VOC	Type of Industry
Professional Coatings (10911)	126,761	Wood products
Jet Door	58,662	Wood products
Lianga	122,720	Millwork
American Reinforced Plastics	9,271	Plastics manufacturing
Boeing Frederickson	58,523	Aerospace
Delta Prefinish	43,374	Wood products
Precision Prehung	61,252	Sawmill
Total Pierce County Sources	480,563	
Coating Segments (Snohomish Co. Sources)	**Lbs of VOC**	**Type of Industry**
Boeing Everett	93,695	Aerospace
Dunbar Doors	59,665	Wood products
Woodstone Building Products	78,600	Wood products
Western Pacific	39,109	Millwork
Roof Truss	19,511	Wood products
American Millwork	324,454	Wood products
Goodrich	44,650	Aerospace
Tiz's Door	90,688	Doors and windows
Artisan	21,591	Metal finishing
Ameron Poles	5,475	Concrete poles
Canyon Creek	192,849	Wood cabinets
International Designer Transitions	77,616	Wood pallets
Glacier Bay Catamarans	93,525	Boat building
Brunswick Family Boat	175,543	Boat building
HCl Steel Building	46,491	Structural metal mfg.
Total Snohomish County Sources	1,357,987	

A97: Permits Issued to Auto Body Shops (January 1, 1999-June 30, 2000)

Auto Body Shop (King Co.)	City	Reg No.	NOC No.	Gal/Year
Airport Collision	SeaTac	17165	7813	200
Auto Trim Design	Tukwila	12076	8220	530
Auto Restoration	Auburn	18049	8104	105
Bel-Red Auto Rebuild	Bellevue	17197	7756	450
Bratch's Autobody	Seattle	12066	8205	598
Burien Honda Auto Body	Seattle	10524	7651	422
Collision Care Auto Body	Burien	12040	8141	320
Complete Collision Center	Fed Way	17252	7804	598
Corvettes of Auburn	Auburn	11944	7857	300
DeGrazia's Auto Body	Seattle	18168	7991	878
Doug's Auto	Bellevue	12033	8120	173
Eastside Collision Center	Redmond	18672	7699	681
Gilman Auto Body	Issaquah	17304	7741	261
Ken's Redmond Auto Body	Redmond	17340	7694	125
Michael's Collision Center	Seattle	18229	7711	345
Mycon's Auto Body	Seattle	17378	8049	545
National Auto Body Repair	Seattle	18318	7831	36
National Truck & Paints	Kent	18665	7683	1,440
National Truck & Paints	Kent	18665	7773	1,274
Norm's Refinishing	Pacific	14444	7729	500
Precision Autocraft	Newcastle	10215	7885	729
Ravenna Volvo Inc.	Seattle	17416	7736	600
RNR Auto Refinishing	Bellevue	18692	7754	562
Robert's Auto Body	Auburn	17545	7652	397
Sonic Collision Center	SeaTac	17435	7973	1,800
TAS Precision Rebuild	Renton	17460	7821	430
Univ VW-Audi-Subaru	Seattle	17297	7972	536
Northshore Auto Body	Kenmore	24976	----	102
Average King County Shop				533
Auto Body Shop (Pierce Co.)	**City**	**Reg No.**	**NOC No.**	**Gal/Year**
#1 Collision Auto Body	Tacoma	18683	7725	12
A & B Auto Body	Puyallup	17558	7884	170
Auto Collision Center	Fife	18321	7760	387
Uto Collision Center	Fife	18321	7915	415
Autocraft	Sumner	12070	8211	103
Premium Fleet Service Inc.	Tacoma	11991	8017	100
Russ Dunmire Oldsmobile	Tacoma	17581	7788	350
Average Pierce County Shop				220
Auto Body Shop (Snohomish Co.)	**City**	**Reg No.**	**NOC No.**	**Gal/Year**
Auto Dev (Pence Corp)	Snohomish	11911	7800	96
Bravo Auto Body	Everett	11906	7789	25
Brothers Auto Body	Lynnwood	12011	8090	60
Charlie's State Ave Shop	Marysville	17496	8126	798
D & L Restorations	Everett	11961	7944	228
Dent Destroyer	Everett	12007	8064	10
Express Auto Paint Inc.	Lynnwood	12059	8177	68
Funderburke Auto Body	Stanwood	12044	8148	68
Gibson Auto Body	Everett	11994	8026	150
Main Street Auto Body	Monroe	12031	8119	50
Monroe Auto Body	Monroe	17512	7946	90
Northend Truck Inc.	Marysville	18000	7908	500
Original Lines Collision 1	Everett	17392	8040	503
Precision Collision	Arlington	12047	8155	728
Professional Collision	Mukilteo	12051	8157	500
Roy Robinson Body Shop	Marysville	17518	8139	732
Twin City Collision	Stanwood	12025	8110	60
Average Snohomish County Shop				274

A98: VOC Emissions from Aircraft Refueling

1,000 gallons of fuel loaded into aircraft at airports[188]

Fuel Loaded at Airport	King	Kitsap	Pierce	Snohomish	Data Source
Jet A at Sea-Tac	423,700				Sea-Tac Airport
Jet A at Boeing Field	21,500				Boeing Field
Jet A at Paine Field				2,673	Paine Field
Aviation gas at Sea-Tac	10				Sea-Tac Airport
Aviation gas at Boeing Field	896				Boeing Field
Aviation gas at Paine Field				245	Paine Field
Aviation gas at small airports	1,015	113	235	324	EDMS run
JP-8 at McChord AFB			5,862		
JP-8 at Fort Lewis Army Base			521		
Jet A at all airports	445,200			2,673	
Aviation gas at all airports	1,921	113	235	569	
JP-8 at all airports			6,383		

Emission factors for aircraft refueling (lbs/million gallons loaded)[189]

Emission Factor	Jet A	Aviation Gas	JP - 8	Data Source
Lbs/million gallons	26	415	26	Sea-Tac, McChord, AP-42

Lbs of VOC emitted at airports during aircraft refueling

Fuel Loaded at Airport	King	Kitsap	Pierce	Snohomish	Region
Jet A at all airports	11,575			69	11,645
Aviation gas at all airports	797	47	98	236	1,178
JP-8 at all airports			166		166
All fuel at all airports (Total)	12,372	47	263	306	12,988

Maggie Corbin of Sea-Tac Airport advised the Agency to ignore emissions from aircraft refueling because of the fuel's low volatility and effective controls.

[188]Gallons of aircraft fuel:
- Sea-Tac: Russ Simonson , simonson.r@portseattle.org, (206) 988-5569, July 17, 2006 e-mail.
- Ft Lewis: Terry Lee, Environmental Engineer, Air Program, (253) 966-1782, February 7, 2006 fax.
- McChord: Kevin Shupe, kevin.shupe@McChord.af.mil, July 14, 2003 e-mail.
- Boeing Field: Cynthia Stewart, Airport Manager, (206) 296-7380.
- Paine Field: Andrew Rardin, andrew.rardin@co.snohomish.wa.us, October 3, 2005 e-mail.
- Small Airports: EDMS4.5 modeling for LTO fuel (see Section 2.1: Aircraft).

[189]AP-42 Equation, L = 12.46 ((SPM)/T)(effective control efficiency), page 5.2-7. Sea-Tac Airport: Maggie Corbin, corbin.m@portseattle.org, July 10, 2002 e-mail for Jet A and aviation gas factors; McChord AFB: Mike Grenko, for JP-8 factors as given in Draft 1994 McChord Emission Report.

A99: Characteristics of Wastewater Plants in Agency Jurisdiction

Reg #	Wastewater Plants (King Co.)	Location City	Millions Gal/Day	Odor Control Flow, cf
10088	KCNR Wastewater Plant (Metro)	Seattle	145	75,000
10125	Lakehaven Utility District	Federal Way		1,745
10747	KCNR Wastewater Plant	Seattle	5	
10839	KCNR Wastewater Plant	Seattle		5,400
10844	KCNR Wastewater Plant	Seattle		1,000
10847	KCNR Wastewater Plant	Seattle		100
10848	KCNR Wastewater Plant	Seattle		100
11063	North Bend Wastewater Plant	North Bend		400
11066	Midway Sewer District	Des Moines		9,800
11067	Enumclaw Sewage Plant	Enumclaw	5	
11078	Duvall City Wastewater Plant	Duvall	5	
12054	KCNR Wastewater Plant (Denny)	Seattle	5	
12072	KCNR Wastewater Plant	Auburn		2,500
14665	KCNR Wastewater Plant	Seattle	5	
14790	Lakehaven Wastewater (Redondo)	Des Moines		22,545
15189	KCNR Wastewater Plant	Seattle		7500
15190	KCNR Wastewater Plant	Shoreline		32000
17781	KCNR Wastewater Plant	Shoreline		2000
18458	Snoqualmie Wastewater	Snoqualmie	2	
18673	KCNR Wastewater Plant	Bellevue		5,000
28503	KCNR Wastewater Plant	Renton	204	64,000
28504	KCNR Wastewater Plant	Seattle	5	
28505	KCNR Wastewater Plant	Shoreline		4,600
28506	KCNR Wastewater Plant	Seattle		6,515
28707	SW Suburban Sewer, Miller Creek	Seattle		37,000
28782	SW Suburban Sewer, Salmon Creek	Burien	5	
Reg #	**Wastewater Plants (Kitsap Co.)**	**Location City**	**Millions Gal/Day**	**Odor Control Flow, cf**
11046	Karcher Creek Sewer	Port Orchard		14,000
11047	Kitsap Co Central Sewage Plant	Poulsbo		17,300
11049	Kitsap DPW Wastewater Plant	Manchester	5	
18395	Messenger House Care Center	Bainbridge Is	5	
28579	Bremerton City Wastewater Plant	Bremerton		25,200
Reg #	**Wastewater Plants (Pierce Co.)**	**Location City**	**Millions Gal/Day**	**Odor Control Flow, cf**
11068	Tacoma Public Works Sewer #3	Tacoma		8,500
11069	Chambers Creek Wastewater Plant	Univ Place		10,000
11070	Sumner Sewage Treatment Plant	Sumner	5	
11073	Orting Sewage Treatment Plant	Orting	2	
11075	Gig Harbor Sewage Treatment	Gig Harbor		2,000
11076	Buckley Sewage Treatment Plant	Buckley	2	
11077	Eatonville Wastewater Plant	Eatonville	1	
11915	Pierce Co. Public Works & Utilities	Lakewood		5,040
11916	Pierce Co. Public Works & Utilities	Lakewood	5	
11918	Pierce Co. Public Works & Utilities	Lakewood	5	
16330	Tacoma Public Works & Utilities	Tacoma		21,500
18453	Puyallup Sewer Treatment Plant	Puyallup		16,200
28528	Lakewood Water District	Tacoma	5	
Reg #	**Wastewater Plants (Snohomish Co.)**	**Location City**	**Millions Gal/Day**	**Odor Control Flow, cf**
10947	Stanwood Sewage Treatment Plant	Stanwood	5	
11054	Sultan Sewage Treatment Plant	Sultan	1	
11055	Granite Falls Wastewater Plant	Granite Falls	1	
11056	Snohomish City Wastewater Plant	Snohomish	2	
11057	Alderwood Wastewater District	Edmonds		200
11058	Arlington City Sewage Plant	Arlington	5	
11060	Marysville Sewage Treatment Plant	Marysville	5	
11061	Monroe Wastewater Treatment Plant	Monroe	3	3,500
11062	Lake Stevens Sewer District	Everett	5	
14063	Edmonds Wastewater Treatment	Edmonds		20,000
14559	Everett Water Pollution Control Plant	Everett		25,200
18493	Everett City Public Works	Everett		1,800
18494	Everett City Public Works	Everett		1,200

A100: Characteristics of Soil & Groundwater Remediation Projects (approved after December 31, 2001)

Reg #	NOC #	Approval Date	City (King Co.)	Lbs VOC/ Year	Zip Code
16004	8698	July 12, 2002	Seattle	9,923	98134
16153	9113	March 4, 2005	Woodinville	20	98072
12104	8300	August 5, 2003	Maple Valley	251	98038
12042	9070	August 24, 2004	Renton	374	98057
18661	7674	February 21, 2002	Tukwila	38	98188
21159	9887	April 10, 2002	Federal Way	375	98003
19699G	9711	July 18, 2002	Renton	2,214	98055
21271	8905	August 20, 2003	Seattle	573	98101
21413	8819	July 8, 2003	Renton	915	98055
16320	9151	August 17, 2005	Seattle	1,870	98108
21344	9119	January 28, 2005	Seattle	1,234	98112
25159G	8759	December 4, 2002	Seattle	1,715	98103
24941	8922	November 4, 2003	Kent	1,080	98032
24942	8923	November 4, 2003	Lake Forest Park	1,133	98155
19451G	8871	July 29, 2003	Kent	1,870	98031
21346	9124	August 30, 2005	Federal Way	636	98023
24973	9003	April 27, 2004	Seattle	1,402	98144
18429G	8810	May 8, 2003	Seattle	573	98134
18960G	9123	December 23, 2004	Seattle	885	98118
21360	9158	July 13, 2005	Kent	346	98032
28946	9267	September 28, 2005	Seattle	1,842	98109
28934	9205	August 31, 2005	Des Moines	3,205	98198
28941	9055	October 6, 2004	SeaTac	530	98188
28944	9309	November 17, 2005	Burien	46	98005
28953	9340	December 16, 2005	Mercer Island	36	98040
28962	8873	July 15, 2003	Auburn	1,685	98002
10773G	8729	August 28, 2002	Seattle	712	98108
Reg #	**NOC #**	**Approval Date**	**City (Pierce Co.)**	**Lbs VOC/ Year**	**Zip Code**
10320	8852	June 13, 2003	Gig Harbor	112	98332
Reg #	**NOC #**	**Approval Date**	**City (Snohomish Co.)**	**Lbs VOC/ Year**	**Zip Code**
18482	8587	January 28, 2005	Lynnwood	123	98036
24991	9014	June 4, 2004	Bothell	117	98012
11211G	8868	July 15, 2003	Monroe	1,581	98272

A101: Summary of Emissions from Stationary Area Evaporative Sources, tons VOC, 2005

General Category	King	Kitsap	Pierce	Snohomish	4-Co. Region
Architectural coating	3,177	387	1,201	1,043	5,808
Original equipment mfg coating	3,673	141	965	2,143	6,922
Special coating	1,613	70	344	684	2,711
Auto refinishing	527	21	77	77	702
Cold metal cleaning	3,287	301	1,075	1,040	5,703
Vapor degreasing	517	20	75	223	835
Gasoline distribution	2,875	347	1,166	1,078	5,466
Vessel loading and unloading	114		296		410
Printing	1,116	156	491	425	2,189
Home and commercial baking	615	74	269	213	1,171
Pesticide application	91	5	39	681	816
Asphalt application	1,711	345	1,030	807	3,893
Consumer products	7,089	942	2,963	2,571	13,565
Commercial meat cooking	134	12	32	30	208
Wastewater treatment	14	3	4	3	24
Soil and groundwater remediation	18			1	19
Paint manufacturing	5		4		9
Total Evaporation	26,575	2,824	10,031	11,020	50,450

A102: Summary of Fugitive Dust Emissions, tons $PM_{2.5}$, 2005

General Category	King	Kitsap	Pierce	Snohomish	4-Co. Region
Road fugitive dust	1,300	800	902	1,272	4,274
Construction fugitive dust	962	173	801	811	2,747
Quarrying dust	31	15	35	76	157
Commercial meat cooking	931	85	221	203	1,440
Total Fugitive Dust	3,224	1,073	1,959	2,362	8,618

A103: Methane Emissions from Manure Management
(expressed in tons CO_2 eqv/year)

Type of Animal	King	Kitsap	Pierce	Snohomish	Region
Beef cattle	43,972	239	5,284	64,225	113,720
Beef cow	7,123	1,773	26,282	11,422	46,600
Milk cow	68,372	66	25,582	93,397	187,416
Horse	29,485	5,181	26,066	27,680	88,412
Sheep	946	181	1,069	890	3,086
Swine	374	166	753	436	1,728
Goat	65	61	213	403	741
Mink	182	2	40	100	324
Poultry	166	28	7,798	12,041	20,033
Total	150,684	7,697	93,086	210,594	462,061

A104: Nitrous Oxide Emissions from Manure Management
(expressed in tons CO_2 eqv/year)

Type of Animal	King	Kitsap	Pierce	Snohomish	Region
Beef cattle	1,510	8	181	2,206	3,906
Beef cow	260	65	961	418	1,704
Milk cow	2,361	2	883	3,225	6,472
Horse	505	89	446	474	1,514
Sheep	39	8	45	37	129
Swine	6	3	12	7	28
Goat	3	3	11	20	37
Mink	9	0	2	5	16
Poultry	48	8	2,244	3,465	5,765
Total	4,742	186	4,786	9,858	19,572

A105: Landfill Gas Collected at Puget Sound Landfills[190]
million cubic feet per year (mcf/yr)

Name of Landfill	City	Rated Million Cubic Feet per Year	LFG Collected (mcf/yr)	CH_4 Collected/Year (mcf/yr)
King Co. Solid Waste	Kirkland	1,104	662	364
Cedar Hills	Maple Valley	7,884	4,730	2,602
King Co. Solid Waste	Enumclaw	215	129	71
King Co. Solid Waste	Federal Way	894	536	295
King Co. Solid Waste	Vashon Is.	210	126	69
King Co. Solid Waste	Hobart	526	315	174
Seattle Parks & Rec	Seattle	336	202	111
Seattle SW, Kent	Kent	1,051	631	347
Seattle SW, Midway	Kent	1,025	615	338
Port of Seattle	West Seattle	53	32	17
Olympic View	Port Orchard	3,522	2,113	1,162
Kitsap Solid Waste	Hansville	173	104	57
Pierce Co. Recycling	Graham	4,730	2,838	1,561
Pierce Co. Recycling	Puyallup	788	473	260
Puyallup Public Works	Puyallup	315	189	104
Tacoma Solid Waste	Tacoma	1,756	1,054	580
MM Tacoma Energy	Tacoma		47	26
Energy Recovery	Puyallup		87	48
Snohomish SW	Snohomish	2,523	1,514	833
Snohomish SW	Lake Stevens	894	536	295
Bryant	Arlington	32	19	11
Snohomish SW	Everett	95	57	31

[190] Rated million cubic feet data extracted from Agency permit database, September 20, 2007. Cedar Hills and Pierce Co. Recycling (Graham) are active landfills that currently receive waste. The other landfills are closed.

A106: GHG Emissions from Fugitive Methane Escaping from Landfills[191]

Name of Landfill	City/Area	MCF CH_4/year	1,000 m^3 CH_4/year	Tons CO_2 Eqv/year
King Co Solid Waste	Kirkland	64	1,820	27,902
Cedar Hills	Maple Valley	459	13,000	199,288
King Co Solid Waste	Enumclaw	13	360	5,447
King Co Solid Waste	Federal Way	52	1,470	22,586
King Co Solid Waste	Vashon Island	12	350	5,313
King Co Solid Waste	Hobart	31	870	13,288
Seattle Parks & Rec	Seattle	20	550	8,502
Seattle Solid Waste, Kent	Kent	61	1,730	26,571
Seattle SW (Midway)	Kent	60	1,690	25,910
Port of Seattle	West Seattle	3	90	1,327
South Park, Seattle	Seattle			10,174
Bow Lake, SeaTac	SeaTac			772
Cedar Falls (E of Maple V)	East M Valley			7,105
Corliss, Shoreline	Shoreline			772
Duvall	Duvall			5,734
Interbay, Judkins, Genessee	Seattle			109,148
Olympic View	Port Orchard	205	5,810	89,028
Kitsap Solid Waste	Hansville	10	290	4,373
Pierce Co. Recycling	Graham	276	7,800	119,563
Pierce Co Recycling	Puyallup	46	1,300	19,919
Puyallup Public Works	Puyallup	18,300	520	7,962
Tacoma Solid Waste	Tacoma	102	2,900	44,387
MM Tacoma Energy	Tacoma	5	130	1,980
Energy Recovery	Puyallup	8	240	3,665
Snohomish Solid Waste	Snohomish	147	4,160	63,775
Snohomish Solid Waste	Lake Stevens	52	1,470	22,598
Bryant	Arlington	2	50	809
Snohomish Solid Waste	Everett	6	160	2,401

[191] Calculated from estimation equations. GHG emissions for Interbay, Judkins Park, and Genessee are from Table A of the City of Seattle report: Inventory and Report, Seattle's Greenhouse Gas Emissions, September 2002. King County estimated GHG emissions for the closed landfills that are not in the Agency database. South Park, Bow Lake, Cedar Falls, Corliss, and Duvall GHG are from the 2003 Inventory of King County Air Emissions, Revision D, December 28, 2008, Table 10; compiled by Roel Hammerschlag for King Co. Department of Natural Resources and Parks.

Appendix B:
2005 Highway Performance Monitoring System Miles and Vehicle Miles Traveled by County, June 21, 2006 (from HPMS database)

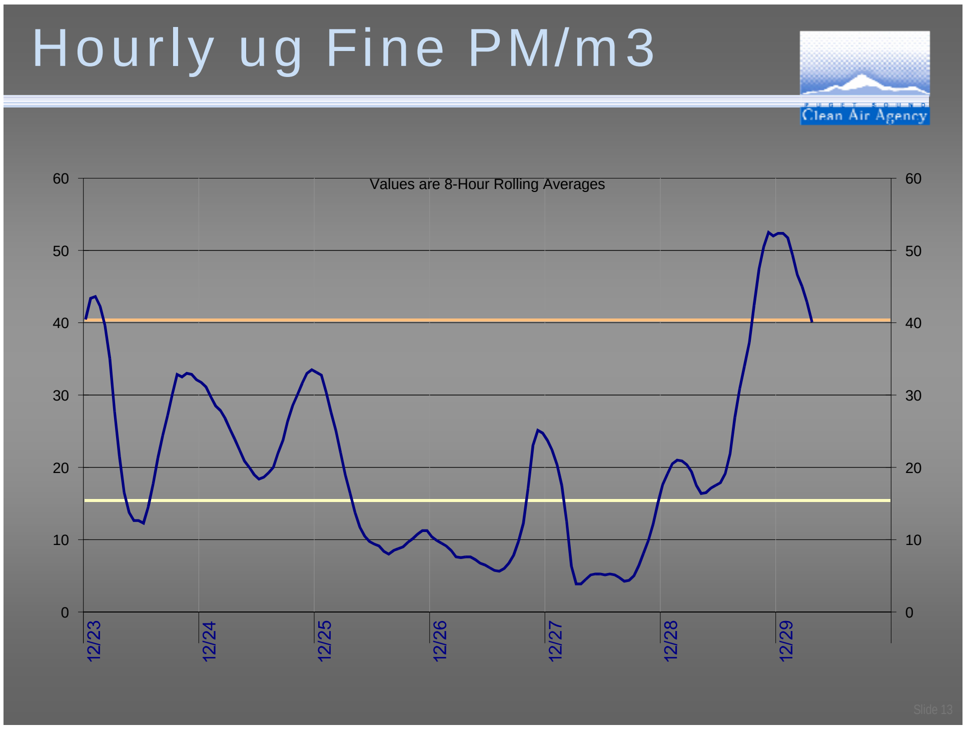
		Local		Total		
County Name	**County Number**	**Centerline Miles**	**Lane Miles**	**Centerline Miles**	**Lane Miles**	**AVMT in 1,000s**
Adams	1	1,622.31	3,244.62	2,559.45	5,281.98	540,353
Asotin	3	410.79	821.58	632.20	1,275.36	104,103
Benton	5	1,265.93	2,531.86	1,946.73	4,163.00	1,337,261
Chelan	7	1,746.32	3,492.64	2,190.07	4,466.63	629,727
Clallam	9	789.15	1,578.30	1,141.37	2,316.35	449,208
Clark	11	1,984.08	3,968.32	2,736.31	5,838.39	2,747,776
Columbia	13	568.16	1,136.32	845.60	1,696.10	74,658
Cowlitz	15	708.31	1,416.62	1,176.50	2,549.21	1,197,743
Douglas	17	2,343.25	4,686.50	3,011.63	6,052.28	404,738
Ferry	19	1,426.28	2,852.56	1,814.87	3,629.74	123,111
Franklin	21	1,254.19	2,508.38	1,799.88	3,758.59	649,684
Garfield	23	342.20	684.40	601.02	1,209.62	65,033
Grant	25	2,443.10	4,886.20	3,791.78	7,761.22	943,090
Grays Harbor	27	1,094.74	2,189.48	1,610.57	3,302.18	670,808
Island	29	1,091.14	2,182.28	1,378.85	2,783.59	405,364
Jefferson	31	630.57	1,261.14	915.63	1,835.00	318,028
King	33	5747.69	11,495.39	7,976.52	17,992.73	16,500,283
Kitsap	35	1214.52	2,429.04	1,721.34	3,625.63	1,604,175
Kittitas	37	1823.08	3,646.16	2,354.60	4,941.57	1,063,619
Klickitat	39	900.68	1,801.36	1,464.24	2,947.04	243,081
Lewis	41	1143.41	2,286.82	1,733.14	3,555.16	1,025,249
Lincoln	43	1592.87	3,185.74	2,515.58	5,063.52	327,693
Mason	45	528.42	1,056.84	940.91	1,904.88	433,804
Okanogan	47	2599.28	5,198.56	3,419.05	6,839.10	437,396
Pacific	49	426.96	853.92	733.05	1,471.64	212,508
Pend Oreille	51	1301.58	2,603.16	1,587.11	3,186.44	148,401
Pierce	53	3644.85	7,289.70	5,030.08	10,826.45	6,060,184
San Juan	55	256.23	512.46	344.23	688.46	32,998
Skagit	57	915.56	1,831.12	1,563.85	3,256.80	1,221,032
Skamania	59	734.30	1,468.60	858.96	1,718.64	97,247
Snohomish	61	2910.64	5,821.28	3,954.12	8,488.65	5,266,845
Spokane	63	3118.84	6,237.69	4,604.30	9,877.19	3,541,718
Stevens	65	1530.77	3,061.54	2,361.03	4,731.69	383,102
Thurston	67	1031.74	2,063.48	1,601.84	3,457.23	2,177,444
Wahkiakum	69	61.85	123.70	187.93	379.54	45,522
Walla Walla	71	657.10	1,314.20	1,311.13	2,700.94	427,946
Whatcom	73	1221.66	2,443.32	1,896.45	3,909.22	1,382,020
Whitman	75	1486.59	2,973.18	2,421.39	4,868.18	428,179
Yakima	77	3422.23	6,844.46	4,647.05	9,614.93	1,766,170
Total		57,991.38	115,982.92	83,380.37	173,964.87	55,487,301

Local roads are assumed to have two lanes.

A multiplication factor was applied to DVMTs & AVMTs to adjust the county totals for "local" traffic.

Appendix C:
Variation of Hourly $PM_{2.5}$ Concentrations for a Typical December Week

Generally, it shows fine PM levels start rising from late afternoon until midnight. After midnight, levels start to drop.



Appendix D1:
2005 Geographic Criteria Pollutant Emissions and GHG Emissions from Electricity Consumption for King County (tons/year)

General Category	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Diesel school buses	50	250	20	10	20	32,400
Other diesel on-road vehicles	5,100	19,370	530	480	930	2,213,970
Gasoline on-road vehicles	366,010	26,100	260	430	29,080	8,204,210
LPG & CNG on-road vehicles	60	140	10	0	10	169,860
Aircraft & airport equipment	15,490	2,150	50	170	1,540	628,090
Locomotives & maritime vehicles	1,510	6,790	320	1,860	330	421,420
Misc. gasoline non-road equipment	139,990	1,420	220	60	7,780	317,460
LPG & CNG non-road equipment	9,550	2,020	10	0	510	199,030
Misc. diesel non-road equipment	3,440	6,580	550	190	760	621,540
Recreational boats	9,830	500	10	30	2,070	79,500
Electricity production sources	120	440	10	20	10	206,360
Other large sources	2,950	5,110	230	680	2,010	514,310
Area source fossil fuels	1,760	3,643	260	310	160	4,169,230
Indoor wood burning	15,120	280	1,990	40	8,000	49,280
Land-clearing burning	1,800	40	230	10	150	36,420
Yard waste burning	870	30	300	10	220	3,070
Other open burning	160		30		30	7,700
Architectural coating					3,180	
Industrial & other surface coating					5,810	
Metal cleaning					3,800	
Petroleum products distribution					3,000	
Consumer & household items					7,090	
Other evaporation sources					3,560	
Wastewater treatment					10	5,790
Road dust & other fugitive dust			2,290			
Commercial charbroiling			930		130	
Livestock enteric						57,770
Manure management						155,430
Nitrous oxide from soils						65,830
Landfills						469,840
Natural gas distribution						193,180
Fuels not used for energy						1,926,060
Cement & steel production						526,470
Power equip sulfur hexafluoride						99,100
Direct use of nitrous oxide						31,780
Miscellaneous manufacturing						540,160
Electricity consumption (GHG)						6,408,180
King County Total	573,790	74,840	8,230	4,290	80,173	28,353,440

Appendix D2:
2005 Geographic Criteria Pollutant Emissions and GHG Emissions from Electricity Consumption for Kitsap County (tons/year)

General Category	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Diesel school buses	10	40				5,380
Other diesel on-road vehicles	490	1,860	50	50	90	212,060
Gasoline on-road vehicles	35,580	2,540	30	40	2,830	797,622
LPG & CNG on-road vehicles		10				16,510
Aircraft & airport equipment	330				10	1,330
Maritime vehicles	260	2,150	110	830	80	115,690
Misc. gasoline non-road equipment	11,920	120	20	10	780	27,560
LPG & CNG non-road equipment	240	50			10	5,320
Misc. diesel non-road equipment	400	770	60	20	90	72,700
Recreational boats	2,180	110		10	450	17,690
Electricity production sources						
Other large sources	40	90	90		150	60,160
Area source fossil fuels	150	320	20	20	10	341,530
Indoor wood burning	2,720	50	370	10	1,215	8,930
Land-clearing burning	11,030	240	1,390	40	900	222,580
Yard waste burning	340	10	120		90	1,210
Other open burning	30					1,050
Architectural coating					390	
Industrial & other surface coating					230	
Metal cleaning					320	
Petroleum products distribution					350	
Consumer & household items					942	
Other evaporation sources					580	
Wastewater treatment						1,200
Road dust & other fugitive dust			990			
Commercial charbroiling			90		10	
Livestock enteric						6,020
Manure management						7,880
Nitrous oxide from soils						13,860
Landfills						93,400
Natural gas distribution						14,050
Fuels not used for energy						43,340
Cement & steel production						
Power equip sulfur hexafluoride						13,174
Direct use of nitrous oxide						1,890
Miscellaneous manufacturing						10,840
Electricity consumption (GHG)						861,510
Kitsap County Total						2,974,480

Appendix D3:
2005 Geographic Criteria Pollutant Emissions and GHG Emissions from Electricity Consumption for Pierce County (tons/year)

General Category	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Diesel school buses	30	140	10		10	18,620
Other diesel on-road vehicles	1,860	7,050	190	180	340	803,530
Gasoline on-road vehicles	134,430	9,580	100	160	10,681	3,013,220
LPG & CNG on-road vehicles	20	50				62,390
Aircraft & airport equipment	1,200	170	10	10	400	51,340
Locomotives & maritime vehicles	610	3,370	150	1,150	160	231,970
Misc. gasoline non-road equipment	42,900	420	80	20	2,670	99,670
LPG & CNG non-road equipment	1,710	360			90	35,110
Misc. diesel non-road equipment	1,770	3,420	280	100	380	323,130
Recreational boats	4,430	190		10	1,010	33,610
Electricity production sources	440	270	20	80	10	292,872
Other large sources	1,250	810	160	360	660	304,140
Area source fossil fuels	590	1,170	80	60	50	1,296,190
Indoor wood burning	4,990	100	680	10	1,990	16,670
Land-clearing burning	7,450	160	940	30	610	150,450
Yard waste burning	550	20	190		140	1,930
Other open burning	2,040	40	130	10	150	6,750
Architectural coating					1,200	
Industrial & other surface coating					1,390	
Metal cleaning					1,150	
Petroleum products distribution					1,460	
Consumer & household items					2,960	
Other evaporation sources					1,830	
Wastewater treatment						1,470
Road dust & other fugitive dust			1,740			
Commercial charbroiling			220		30	
Livestock enteric						50,930
Manure management						97,870
Nitrous oxide from soils						56,900
Landfills						197,480
Natural gas distribution						67,220
Fuels not used for energy						409,990
Cement & steel production						
Power equip sulfur hexafluoride						41,420
Direct use of nitrous oxide						14,245
Miscellaneous manufacturing						295,617
Electricity consumption (GHG)						1,289,522
Pierce County Total	206,300	27,300	5,000	2,200	29,400	9,224,287

Appendix D4:
2005 Geographic Criteria Pollutant Emissions and GHG Emissions from Electricity Consumption for Snohomish County (tons/year)

General Category	CO	NOx	$PM_{2.5}$	SOx	VOC	CO_2 Eqv
Diesel school buses	30	120	10		10	15,850
Other diesel on-road vehicles	1,620	6,130	170	150	300	698,810
Gasoline on-road vehicles	116,830	8,330	80	140	9,280	2,618,760
LPG & CNG on-road vehicles	20	40				54,220
Aircraft & airport equipment	1,600	70		10	100	18,250
Locomotives & maritime vehicles	560	3,640	150	290	150	219,210
Misc. gasoline non-road equipment	40,250	420	70	20	2,540	94,660
LPG & CNG non-road equipment	4,390	920	10		240	83,740
Misc. diesel non-road equipment	1,060	2,140	170	60	230	197,250
Recreational boats	4,290	170		10	970	31,530
Electricity production sources	240	600	10	320		24,440
Other large sources	690	270	30	110	1,360	81,460
Area source fossil fuels	500	1,090	80	80	40	1,184,770
Indoor wood burning	5,153	130	710	20	2,080	17,700
Land-clearing burning	6,020	130	760	20	490	121,580
Yard waste burning	790	30	270		200	2,800
Other open burning	90		10		10	3,380
Architectural coating					1,040	
Industrial & other surface coating					2,900	
Metal cleaning					1,260	
Petroleum products distribution					1,080	
Consumer & household items					2,570	
Other evaporation sources					2,131	
Wastewater treatment						1,200
Road dust & other fugitive dust			2,160			
Commercial charbroiling			200		30	
Livestock enteric						60,190
Manure management						220,450
Nitrous oxide from soils						74,470
Landfills						89,590
Natural gas distribution						52,370
Fuels not used for energy						802,550
Cement & steel production						
Power equip sulfur hexafluoride						35,940
Direct use of nitrous oxide						4,060
Miscellaneous manufacturing						32,060
Electricity consumption (GHG)						618,312
Snohomish County Total						7,435,140

Appendix E:
Surrogates Used to Separate 2005 Electricity Consumption in PSE Area[192]

Service Area	Zip Code	Power Supplier	# of Households	Comm'l Employees	Indust'l Employees	Total Employees
King Co.	All County	PSE, SCL	744,729	999,320	97,525	1,096,845
Seattle		City Light	267,258	424,293	41,407	465,700
Shoreline	98177, 98155	City Light	20,318	6,040	589	6,629
Other King Co.		PSE	457,154	568,988	55,528	624,516
Pierce Co.	All County	PSE, Tacoma Power	283,010	223,240	20,300	243,540
Fircrest	98466	Tacoma Power	2,498			6,095
Univ. Place	98467, 98466	Tacoma Power	12,229			1,877
Fife	98424	Tacoma Power	2,103			15,723
Steilacoom	98388	Tacoma Power	2,545			1,456
Lakewood	98498, 98499	Tacoma Power	24,004			23,500
Roy	98580	Tacoma Power	280			470
Tacoma City		Tacoma Power	77,409			101,200
Ft. Lewis CDP	98433	Tacoma Power	5,090			1,737
McChord CDP	98438	Tacoma Power	1,184			226
Other Pierce Co.		PSE	155,669	83,649	7,607	91,256
Jefferson Co.	All County	PSE, other	12,875	6,007	750	6,757
Pt. Townsend	98368	PSE	4,127	4,387	548	4,935
Pt. Ludlow CDP	98365	PSE	954	332	42	374
Pt. Hadlock CD	98339	PSE	1,407	743	93	836
Brinnon CDP	98320	PSE	413	84	10	94
Jefferson PSE		PSE	6,901	5,546	693	6,239
Skagit Co.	All County	PSE	42,270	38,163	5,475	43,638
Island Co.	All County	PSE	30,954	11,750	609	12,359
Kitsap Co.	All County	PSE	91,751	56,511	1,972	58,483
Thurston Co.	All County	PSE	91,206	60,513	3,010	63,523
Kittitas Co.	All County	PSE	14,744	9,345	474	9,819
Whatcom Co.	All County	PSE	72,565	68,075	9,115	77,190
All PSE Area		PSE	963,214	902,541	84,482	987,023

[192]Households = (housing units)(occupancy rate); occupancy rate = fraction of housing units occupied.
- Housing Units: Table 8, 2005 Population Trends, State of Washington, September 2005.
- Occupancy Rate: American Factfinder; htto://factfinder.census.gov/home/saff/main.html; December 27, 2007.
- Employment: County Business Patterns, http://www.census.gov/epcd/cbp/view/cbpview.html, December 27, 2007.
- Seattle, Lakewood, and Tacoma Employment: Puget Sound Trends, No. E2, July 2007 published by the Puget Sound Regional Council, http://www.psrc.org/publications/pubs/trends/e2jul08.