King County

2003 Inventory of King County Air Emissions

Revision D – 28 December 2004

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With so many individuals involved, we have almost certainly forgotten to mention someone. So this thank-you paragraph is for those whom were unjustly omitted from this page.

Finally, this inventory would not have been possible without the groundwork laid by Justin Wettstein and Lindsay Halm, who bravely undertook the task of creating the first county inventory in 2001.

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Executive Summary

The King County Department of Natural Resources and Parks compiles the Inventory of King County Air Emissions to satisfy a County Executive order and County Council motion. The main purpose of the inventory is to monitor the county government's emissions of greenhouse gases and common air pollutants. The inventory also monitors some offsets (reductions) of greenhouse gases and the geographic emissions of greenhouse gases within county boundaries. Measuring the emissions is a prerequisite to managing them. This inventory provides a tool King County policymakers can use to identify sources of pollutants that can be reduced.

Reducing greenhouse gases is an important first step toward reducing the impacts of climate change. In the Pacific Northwest, climate change is likely to lead to reduced mountain snowpack and then to electricity shortages, freshwater shortages, and threats to river ecosystems including salmon runs.

Reducing common air pollutants directly reduces adverse effects on regional environmental health such as smog and acid rain, and it reduces threats to human health such as asthma.

The King County 2003 inventory consists of two parts: the government inventory and the geographic inventory. The **government inventory** indexes emissions caused by the operations of King County government, such as transit service, waste handling and processing, and county employee commuting. The **geographic inventory** compiles all emissions within the geographic boundaries of King County, regardless of the responsible party.

The 2003 inventory introduces improved accounting methodologies consistent with national and international greenhouse gas accounting standards.

Government Inventory

The government inventory includes greenhouse gases (GHGs), nitrogen oxides (NO_x), volatile organic compounds (VOCs) and particulate matter less than 10 microns in size (PM_{10}).

Greenhouse Gases

GHGs inventoried in 2003 come from the sources shown in Figure ES1. Quantities of GHGs are reported in metric tons of carbon dioxide equivalent, or $MgCO_2e$. The county's total, government inventory includes 420,031 $MgCO_2e$. For

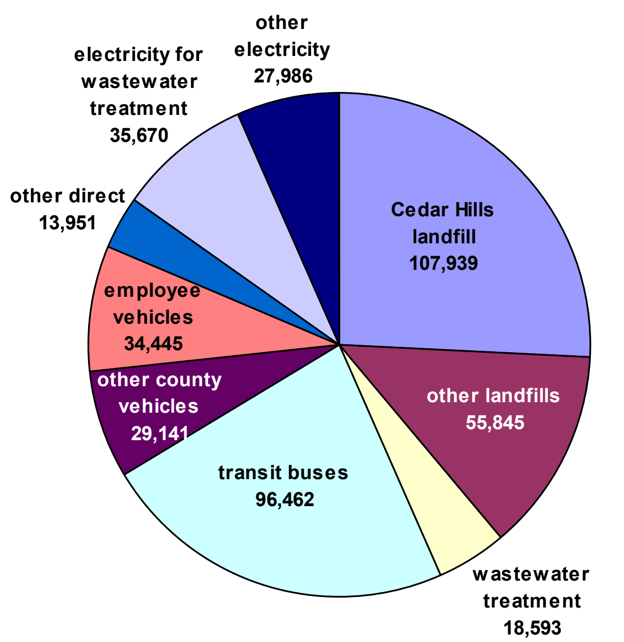

Figure ES1 – Sources of GHGs in the 2003 government inventory. All values are in $MgCO_2e$. The wedge "employee vehicles" includes emissions from vehicles used for commuting and personal vehicles used on county business.

comparison, a car emits about 4 $MgCO_2e$ in one year of typical use, so the inventory equals the GHG emissions from about 105,000 cars.

The county's landfills and vehicles account for 69 percent of the total GHG emissions recorded. Indirect emissions caused by electricity and steam use account for another 15 percent.

The government inventory tracks three GHGs: carbon dioxide (CO_2), methane and nitrous oxide. The most common GHG, CO_2, dominates most GHG inventories, but the King County government inventory is unique because it includes a very large quantity of methane. This methane comes from the county government responsibility for handling the majority of the county's solid waste and wastewater. The county's landfills and wastewater treatment plants emit large quantities of methane.

In 2000 King County GHG emissions were estimated to be 399,774 $MgCO_2e$. The apparent increase since 2000 is due mostly to improved accounting of indirect emissions from electricity use – the actual emissions have changed very little since 2000.

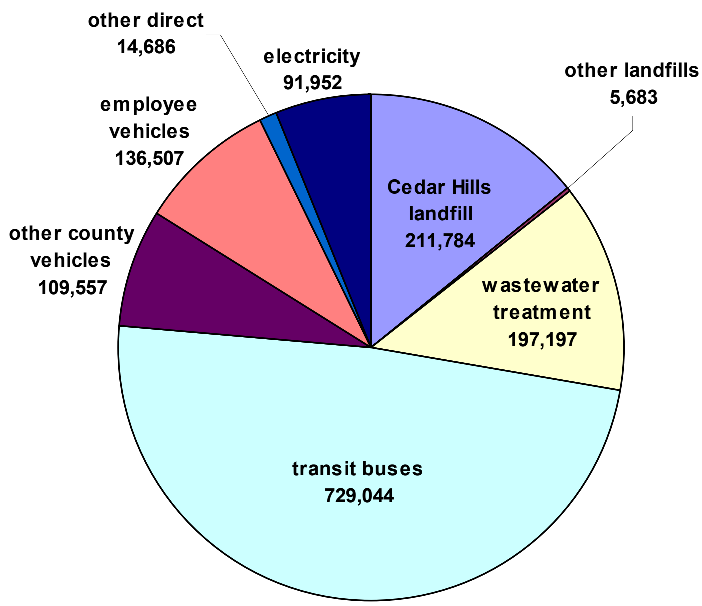

Figure ES2 – Sources of NO_x in the 2003 government inventory. All values are in kg.

Nitrogen Oxide Emissions

Figure ES2 shows the distribution of NO_x emissions in the county inventory. The total quantity of emissions is 1,496,410 kilograms (kg), an increase from the 2000 quantity of 1,253,231 kg.

Most NO_x is produced only in combustion processes, so the government's large transit fleet dominates the NO_x inventory. The other large quantities of NO_x are caused mainly by methane flaring at the Cedar Hills landfill and by electric generation at the West Point wastewater treatment plant, not by emissions escaping from the waste-handling processes.

Volatile Organic Compounds

Figure ES3 shows the distribution of 546,607 kg of VOC emissions in the 2003 inventory. By far the largest VOC contributor is gasoline-fueled lawn and garden equipment. The county's very large fleet of equipment with small, two- or four-stroke engines and no pollution control devices overwhelms other sources, most of which are regulated for pollution control. Employee vehicles, used for commuting (and to a much smaller degree for county business), are a surprisingly large contributor because the privately owned, gasoline-fueled cars have higher VOC emission rates than the commercially maintained fleet fueled mostly with ultra-low-sulfur diesel.

2003 VOC emissions are slightly down from the 587,699 kg calculated for 2000.

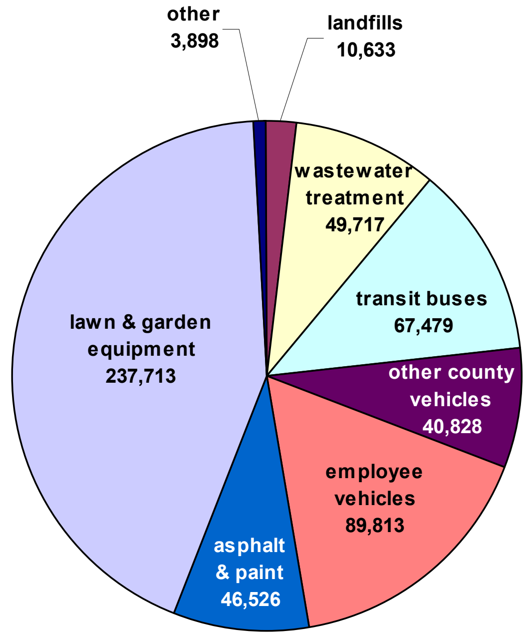

Figure ES3 – Sources of VOCs in the 2003 government inventory. All values are in kg.

Particulate Matter Less than 10 Microns

PM_{10} emissions caused by county government operations are distributed quite differently. Figure ES4 shows that the transit fleet is the only significant source of direct PM_{10} emissions. The majority of emissions – 68,728 kg out of 115,794 kg total – is indirect, from the use of electricity by county facilities. King County buys a significant amount of electricity from Puget Sound Energy, for which coal generation supplies about 34 percent of the delivered electricity. This coal-based electricity is the largest contributor to King County's government PM_{10} inventory.

The South wastewater treatment plant in Renton is responsible for most of the "electricity for wastewater treatment" wedge in Figure ES4. This plant and the sewer pumping stations that supply it are in the Puget Sound Energy service area. The county's other large wastewater treatment plant, West Point, is in the Seattle City Light service area. West Point is responsible for much lower PM_{10} emissions because Seattle City Light electricity includes almost no coal generation.

The 2003 PM_{10} inventory is significantly higher than the 2000 inventory of 50,017 kg, because the new inventory methodology assumes much higher emission rates from the coal-burning electric generators that supply Puget Sound Energy electricity.

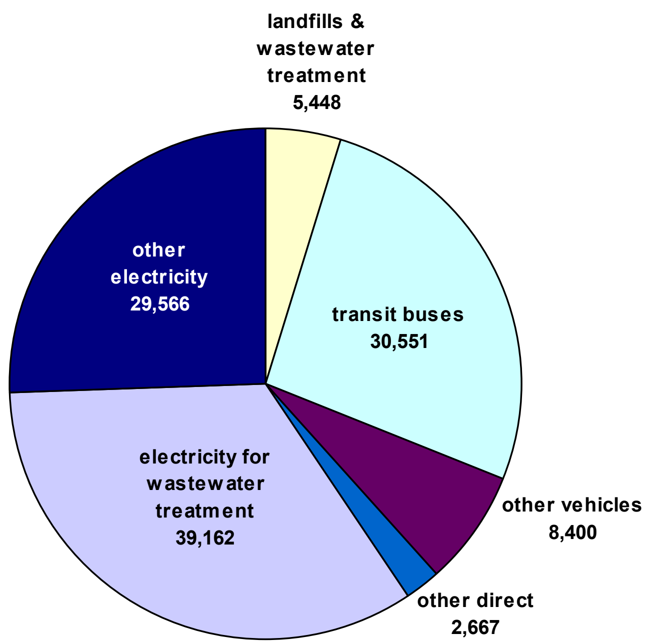

Figure ES4 – Sources of PM_{10} in the 2003 government inventory. All values are in kg.

Sequestration and Offsets

GHG **offsets** are processes that prevent GHGs which would otherwise have occurred, or that reduce GHGs in the atmosphere. A special category of offset is GHG sequestration. **Sequestration** happens when carbon that was or would become a greenhouse gas is buried underground, stored in trees, or otherwise kept out of the atmosphere. Sequestration occurs in the county's Cedar Hills landfill, because some of the waste buried there is food, yard waste and forest products made partially from carbon that once was in CO_2. Figure ES5 shows sequestration in the landfill, and two smaller offsets that occurred because of King County government operations in 2003.

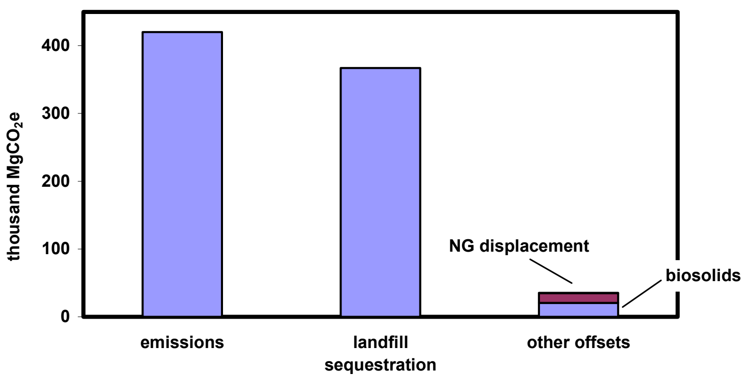

Figure ES5 – GHG emissions, sequestration and other offsets in the government inventory

Sequestration in the Cedar Hills landfill totaled about 367,246 $MgCO_2e$, nearly the value of the entire government inventory. The quantity of sequestration is expected to decrease sharply in future years as the county pursues more aggressive waste reduction, recycling and composting programs.

The biosolids program reduces use of manufactured, GHG-intensive fertilizers and sequesters some organic carbon in soil. Those environmental benefits offset total GHGs by 20,609 $MgCO_2e$. At the South Treatment Plant, injecting methane produced at the plant into the Puget Sound Energy pipeline displaces – or cuts – 14,055 $MgCO_2e$ of GHGs that would have been emitted through the combustion of natural gas, a fossil fuel.

Geographic Inventory

King County's geographic inventory of GHGs is based on the triennial geographic inventory conducted by the Puget Sound Clean Air Agency, which has jurisdiction over King County and three other counties in the Puget Sound region. The county's government GHG inventory makes up only about 1.6 percent of the county's geographic inventory of 22,961,951 $MgCO_2e$, despite including the majority of emissions from solid waste, wastewater and public transit.

Figure ES6 shows that the majority of GHG emissions in the geographic inventory (11,940,632 $MgCO_2e$, or 52 percent) comes from on-road vehicles– cars and trucks. That percentage contrasts considerably with the U.S. national inventory, to which on-road vehicles contribute only about 20 percent.

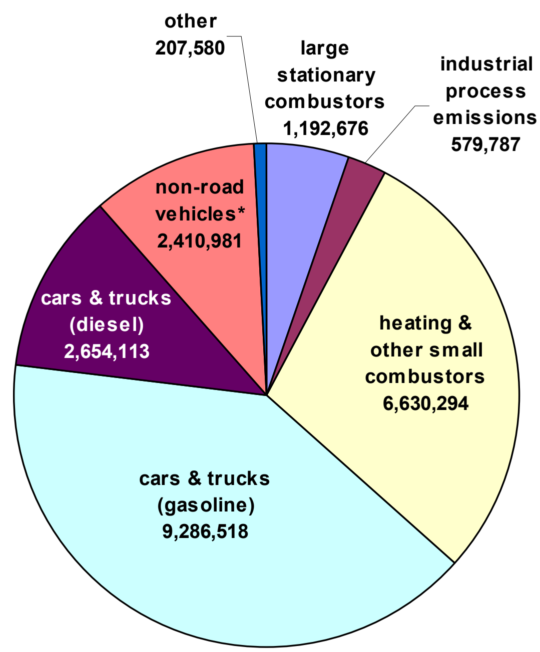

Figure ES6 – Sources of GHGs in the 2003 geographic inventory. All values are in $MgCO_2e$. The wedge "non-road vehicles" includes marine vessels and small aircraft.

Small stationary combustors – mostly residential, commercial and industrial space heaters but also including some industrial equipment – make up the majority of the balance. Emissions from heavy industry can be estimated by adding emissions from large, stationary combustors and industrial processes. Together those sources produce 1,772,464 $MgCO_2e$, less than 8 percent of the county's geographic inventory.

The U.S. national inventory attributes nearly 19 percent of GHG emissions to industry (or 53 percent if electric generators are included). So the geographic GHG inventory suggests that King County has an unusually large proportion of vehicle use and an unusually small presence of heavy industry.

The Puget Sound Clean Air Agency also conducts geographic inventories of NO_x and VOCs; the county government inventory made up 1.7% and 0.7% of these two inventories respectively. The Agency does not conduct a PM_{10} inventory, but instead conducts a $PM_{2.5}$ inventory that records particulate matter under 2.5 microns in size, so that the government inventory is not directly comparable with the geographic inventory.

Supporting Legislation and Environmental Basis

The Inventory of King County Air Emissions and Sinks was first compiled for the year 2000, in response to King County Executive Order PHL 10-1 (January 1, 2002) and King County Council motion 2002-0020. This is the second edition of the inventory, compiling air emissions for calendar year 2003, and including comparisons to the original inventory of calendar year 2000 emissions.

The council motion makes the environmental basis for the inventory clear, pointing out that climate change "...would result in reduced snowpack and summer water supplies, increased flooding and glacial outbursts, higher sea levels, the spread of infectious diseases, increased smog and breathing-related illnesses, significantly changed conditions for agriculture and faster changes in our ecosystems than many animals and plants can adapt to...."

The inventory provides not only the measure with which to track progress in reduction of greenhouse gases, but also an opportunity to identify and target new areas for greenhouse gas reductions.

The executive order also mandates that the inventory include the ozone precursors nitrogen oxides and volatile organic compounds. The motion states, "...the central Puget Sound area currently meets federal standards for air quality, but is at risk of exceeding limits on ozone, which could trigger new regulations and the loss of important federal transportation funding." As with greenhouse gases, inventorying the ozone precursors reveals opportunities for the county government to reduce its contribution to the county's total emissions.

Lastly, the inventory includes particulate matter. According to the motion, "...airborne fine particulate matter, even when meeting federal standards, reduce visibility and include toxic chemicals that can be particularly harmful to children, asthmatics and the elderly...." Though the motion and executive order specify fine particulate matter with a diameter of 2.5 microns or under, at present the inventory tallies particulate matter 10 microns or under, a broader definition, because emission factors for fine particulate matter are not yet sufficiently widely available.

Note – Methodology is discussed here, even though it is customarily relegated to an appendix, because so many readers will need to familiarize themselves with the concepts that underlie greenhouse gas accounting. The reader should feel free to use this section as a reference, or to skip it entirely if they are already familiar with GHG accounting practice.

Methodology

<u>Inventory Protocol</u>

King County is a participant in the International Council for Local Environmental Initiatives (ICLEI) Cities for Climate Protection program (CCP). CCP assists cities and counties throughout the world with compiling GHG inventories, setting GHG reduction targets, and achieving those targets.

CCP recognizes two GHG inventory types: government and geographic.[1] The government inventory accounts all emissions that can be attributed to the actions of King County government in the course of normal business activity. This includes sources that may be outside the county's geographic boundary, not directly owned by the county, or both. For example the county inventories electricity used in its buildings, which in some cases is generated at natural gas-fired power plants located in other counties or even other states. In contrast, the geographic inventory compiles all emissions occurring within the borders of the county, irrespective of the county government's, or any entity's, responsibility for the source.

Wherever possible, King County applies the protocols prescribed for GHG inventories to the entire air emissions inventory.

For its government inventory, King County follows a hierarchy of four guidance documents. For each question of methodology in the government inventory, documents are consulted in order, until a clear directive is found. The documents are, in decreasing priority:

1. **WBCSD/WRI GHG Protocol, Revised Edition**

   The World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI) led a multi-stakeholder process to create what has become the *de facto* world standard guiding the assembly of corporate GHG inventories, the *GHG Protocol, Revised Edition*. The King County government inventory is a corporate inventory by definition. The *GHG Protocol* does not provide quantitative prescriptions for estimating emissions from specific sources, but rather provides high-level guidance for the definition, scope, organization and verification of the inventory.

2. **ICLEI and STAPPA/ALAPCO CACP software**

   The State and Territorial Air Pollution Program Administrators (STAPPA) and the Association of Local Air Pollution Control Officials (ALAPCO) are the two national associations representing air pollution control agencies in U.S. states, territories and metropolitan areas. STAPPA/ALAPCO and ICLEI collaborated to create the Clean

[1] CCP uses the nomenclature "community" inventory to refer to the geographic inventory. King County uses the term geographic in order to make the nature of this inventory clearer to lay readers.

Air and Climate Protection Software, or CACP software. The CACP software is the principal vehicle for calculating and reporting inventory data to the CCP. The software's built-in calculation methodologies and emissions factors serve as the county's principal quantitative protocol for the government inventory, unless the *GHG Protocol* dictates otherwise, or unless the county has access to measured data that is higher quality than the STAPPA/ALAPCO protocol would provide.

3. **EIIP Technical Reports**

   The U.S. EPA Emissions Inventory Improvement Program (EIIP) has published a suite of ten technical reports prescribing best practice for air emissions inventories. *Volume 8*, which treats GHGs, is designed principally to serve state-level, geographic inventories. However, its explicit treatment of quantitative issues that are largely ignored by the *GHG Protocol* makes it a useful supplement to the *GHG Protocol* for corporate (government) inventories as well. *Volume 8* closely follows the IPCC *Guidelines* (see #4 immediately below), but includes refinements specifically appropriate to the United States. The other volumes of the EIIP technical reports treat non-GHG air emissions.

4. **Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories**

   The Intergovernmental Panel on Climate Change (IPCC) guides international research on climate change science and provides the internationally-accepted, standard guidance for national GHG inventories. As with the EIIP technical reports, explicit quantitative methodologies can supplement the county's government inventory where the *GHG Protocol* or the CACP software does not provide sufficient guidance.

The County inherits its geographic inventory from the Puget Sound Clean Air Agency (PSCAA), and therefore does not assign a formal protocol to it. However, the PSCAA inventory is reviewed and edited to ensure conformance with the IPCC *Guidelines*.

GHG Gases Inventoried

King County inventories the three most common greenhouse gases; these are listed in Table 1.

gas	chemical formula	GWP
carbon dioxide	CO_2	1
methane	CH_4	21
nitrous oxide	N_2O	310

Table 1 – greenhouse gases inventoried by King County

The table lists the global warming potential (GWP) of each gas. The GWP indicates the mass units of carbon dioxide that effect the same amount of global warming as one mass unit of the gas. For instance, the GWP of methane is 21, so it requires 21 kilograms of carbon dioxide to produce the same global warming as just one kilogram of CO_2. The higher the GWP, the more potent the greenhouse gas. King County uses the GWPs printed in the IPCC's Second Assessment Report, released in 1996. IPCC released a Third Assessment Report in 2001 that includes slightly modified GWPs of 23 for methane and 296 for nitrous oxide. King County continues to use the Second Assessment values for consistency with countries under the United Nations Framework Convention on Climate Change (of which the U.S. is one), and with the CACP software. The Framework Convention on Climate Change countries do not plan to change the GWPs used for GHG accounting until after 2012, since the national baselines and corresponding Kyoto

Protocol commitments through 2012 were created before the Third Assessment was published.

Non-GHG air emissions inventoried by the county are:
- nitrogen oxides (NO_x),
- volatile organic compounds (VOCs) and
- particulate matter (PM_{10}).

As of this year, per a June 1, 2004 decision of the Air Quality Steering Team, SO_2 is no longer inventoried. There is no mandate in the Clean Air Initiative; and there are minimal emissions of SO_2, since ultra-low sulfur diesel is used consistently throughout the Metro Transit and Solid Waste Division fleets.

Units

Because greenhouse gases are a pollutant of international concern, common practice is to account their quantities in metric units. In this document, all values of GHG emissions and sequestration are reported in metric tons of greenhouse gas equivalent, or $MgCO_2e$. "Mg" is shorthand for "megagram" or one million grams, the definition of a metric ton. "CO_2e" is shorthand for CO_2-equivalent, or carbon dioxide-equivalent. The "equivalent" means that any non-CO_2 gases included in the total were weighted by their GWPs, as described in *GHG Gases* Inventoried above. A metric ton weighs 2,205 U.S. pounds.

Most energy values – quantities of fuel or electricity – are reported in the metric unit TJ. "TJ" is shorthand for "terajoule," a unit of 10^{12} joules. One TJ equal to about 278 MWh, 9,486 therms, 949 mmBtu or 7,325 gallons of gasoline equivalent.

Organizational Boundaries

King County follows the GHG Protocol's Operational Control option for setting the organizational boundaries that define the government inventory. The Harborview Medical Center lies outside the organizational boundary, since it is fully controlled by the University of Washington. The Washington State Major League Baseball Stadium Public Facilities District (PFD), the four Flood Control Zone Districts and the King County Library System lie within the boundary, however.

This document consistently spells out the names of divisions and groups within county government, but uses the common acronyms for departments (the top level in the organizational hierarchy):

DAJD	Department of Adult and Juvenile Detention
DCHS	Department of Community and Human Services
DDES	Department of Development and Environmental Services
DES	Department of Executive Services
DJA	Department of Judicial Administration
DNRP	Department of Natural Resources and Parks
DOA	Department of Assessments
DOT	Department of Transportation
DPH	Department of Public Health
KCC	King County Council
KCDC	King County District Court

KCEO King County Executive Office
KCSC King County Superior Court
PAO Prosecuting Attorney Office
King County Sheriff's Office
State Auditor

Note that the Sheriff’s Office and the State Auditor have no corresponding departmental abbreviation.

Outsourcing and Divestiture

King County is currently in the process of transferring significant facilities (swimming pools) and service areas (potential annexation areas) to the cities of King County. Hence, the organizational boundary is shrinking. When comparing air emissions from one year to the next, it is important to modify the inventories of prior years to include an equivalent set of facilities. This procedure is known as “baseline adjustment” and avoids false claims of emissions reductions based simply on the emissions’ transfer to a different owner.

Operational Boundaries

Even with the organizational boundary of King County well-defined, operational boundaries still need to be set. Toward this end, the government inventory is divided into three scopes defined by the *GHG Protocol*:

Scope 1 – direct emissions includes emissions that originate from equipment and materials owned or controlled by King County government. County-owned vehicles, natural gas-fired space heaters and waste treatment facilities are examples.

Scope 2 – electricity and steam includes emissions from facilities that generate electricity or steam used by King County. The emissions do not originate from county-owned facilities, but the county causes them through its purchases of electricity and steam.

Scope 3 – other emissions include any sources of emissions that are not included in Scope 1 or 2, for which the county wishes to take responsibility. An example is emissions from vehicles used by commuting employees.

Scope 1 emissions are perfectly defined by the government inventory’s organizational boundary. Scope 2 emissions are well defined by the organizational boundary, but parties may disagree on which generators are responsible for the specific electricity consumed by King County, and therefore on the exact values of Scope 2 emissions. Scope 3 emissions are not well defined by the organizational boundary; this scope must be defined by fiat by the inventory’s directorate.

Audit Trail

All data relating to the 2003 are emissions inventory are available in the directory <\\dnr-admin2\admin\Clean Air Initiative\2003 air emissions>. Source files are in the subdirectory <source documents> and are unaltered from their format as received, except for their filename. Each filename is of the format <03-*nnn.fff*>, where *nnn* is a 3-

digit serial number and *.fff* is a filename extension such as .doc or .xls. The subdirectory <source documents> also includes a file <03 index.xls> that lists the source's original filenames as received, and their origins.

A second subdirectory <calcs> contains all spreadsheets that supplement calculations performed by CACP. The most important file in <calcs> is <03 master.xls>, the master spreadsheet in which most CACP output is tabulated and formatted in preparation for this inventory document. <03 master.xls> also contains several emissions calculations that CACP was incapable of performing.

The CACP database files backed up in directory <\\dnr-admin2\admin\Clean Air Initiative\CACP software\2003 auditable data\>, serve as the ultimate repository for inventory values. Each CACP record includes a note "Source:" that indicates the source file(s) <03-*nnn.fff*> from which the record was derived. If intermediate calculations were needed a separate "Calcs:" note indicates the spreadsheet where such calculations can be found. Spreadsheets cited in the "Calcs:" notes can all be found in the <calcs> subdirectory.

Operator's Notes

Throughout this inventory, grey boxes with the heading *method detail* report operator's notes on the data sources used to generate the inventory, and on methods used for operating the software that calculated emissions. The *method detail*s will be of little interest to most readers, but they will assist operators assembling future inventories and provide convenient entryways for potential inventory auditors.

The first method detail box appears here, with general notes applicable to all phases of the inventory:

method detail

Relationship of the Inventory to other county systems and reports

Because most air emissions are calculated from the quantities of materials that cause them, county purchasing data can be of great use. All purchasing activity of the county is coordinated through one of two accounting data management systems: ARMS or IBIS. ARMS is the Archives, Records Management, & Mail Services system and is the older of the two systems. IBIS refers to Interactive Business Information Systems, Inc. Most purchase vouchers submitted for entry into ARMS or IBIS include an account number that describes the specific item or material being purchased. To find all purchases by the county under a specific account number, it is necessary to generate both an ARMS and an IBIS report to generate a complete accounting. Staff in DES Finance & Business Operations can assist with generating the reports.

Each year the county releases a *Comprehensive Annual Financial Report* (CAFR) that includes various county-wide statistics of use to the inventory operator. Also, the CAFR staff track the county's fixed assets in a system known as IVIS. The IVIS inventory can serve as an important check to assure that the inventory operator has surveyed all potential sources of emissions.

The county also releases an annual *King County Benchmark Report* designed to track the performance of the Countywide Planning Policies mandated by Washington State's 1990 Growth Management Act. The *Benchmark Report* tracks the following indicators related to GHG emissions: #10 Air quality, #11 Energy consumption, #12 Vehicle miles traveled (VMT) and #39 Acres in forest land and farm land. GHG emissions are not currently an indicator in these reports, though they are qualitatively discussed as a subcategory under Air quality. The four related indicators listed here report data on a geographic basis, not a corporate basis.

DNRP issues its own *Annual Performance Measure Report*. GHG emissions are reported quantitatively as a distinct measure (#4), but only for DNRP as a corporate entity. Other, GHG-related indicators in this document include #20 Biogas recycled, #21 Methane to usable energy, #22 Waste stream recycled and #29 Forest plans. #20 and #21 relate to corporate operations (the sewage treatment plants and Cedar Hills landfill) but #22 and #23, as in the Benchmark Report, relate to county-wide performance.

Data sources

Data sources cited in the *method detail* boxes appear as boldface, five-digit call numbers, *e.g.* **03-086**. Such citations are simply shorthand for the corresponding file in the <source documents> subdirectory; for example the citation above refers to file <03-086.rtf> in
<\\dnr-admin2\admin\Clean Air Initiative\2003 air emissions\source documents>.

Managing GHG Protocol scopes in the ICLEI CACP software

The *GHG Protocol* requires the segregation of the inventory into three scopes, but the CACP software does not provide utility for doing so. In the 2003 inventory the scopes are simulated with the "Location" field available in each CACP record screen, under the "Categories" tab. Four "locations" are defined: "Scope 1," "Scope 2," "Scope 3" and "Scope 4: optional information." The unconventional "Scope 4" was prefixed to "optional information" simply so that the optional information appeared *after* Scope 3 in the CACP reports, which are arranged alphabetically. All CACP reports were generated with the "Group First by Location" option to enforce the segregation by *GHG Protocol* scope.

Note that this method required creating two records for some sources, especially buildings that exhibit some Scope 1 emissions through natural gas combustion, and some Scope 2 emissions through electricity purchases.

Defining electricity and steam coefficients in the ICLEI CACP software

The ICLEI software provides default emissions coefficients for electricity in the Northwest Power Pool, an area that includes (parts of) eight states and two Canadian provinces. Because King County purchases all of its electricity from only two utilities, defining custom emissions factors for these two utilities can create more accurate emissions estimates. The custom factors are based on the specific mix of generators used to generate electricity in 2003 by Seattle City Light (SCL) and Puget Sound Energy (PSE). The factors are based on the fuel mix data posted by the state of Washington at
http://www.cted.wa.gov/DesktopDefault.aspx?TabId=73 (**03-020**), as follows:

state fuel mix report category	Seattle City Light	Puget Sound Energy
coal	0.74%	34.39%
natural gas	4.99%	4.28%
oil	0.00%	0.08%
(all others)	94.27%	61.25%
totals	100.00%	100.00%

For SCL a custom fuel was defined in CACP named "Electricity (SCL 2003)" under the Settings --> Emissions Factors --> User Defined menu. Likewise, for PSE the custom fuel "Electricity (PSE 2003)" was defined. Emission factors for the two custom fuels are assembled from CACP's technology-specific electricity emissions factors, using the fuel mix fractions acquired from the state. The state fuel mix categories are mapped onto the CACP electric generation technologies as follows:

state fuel mix report category	CACP electricity category
coal	Electricity from Coal: Electricity from Bituminous: Pulverized Coal: Dry Bottom (Tangential Fired): Scrubbers
natural gas	Electricity from Gas: Electricity from Natural Gas: Tangential Firing: Selective Catalytic Reduction
oil	Electricity from Oil: Electricity from Heavy Fuel Oil: Tangential Firing: Scrubbers

When the "Electricity (SCL 2003)" custom fuel was defined, the electricity was additionally defined as a transportation fuel, so that it could be used to calculate emissions attributable to the trolley buses.

All steam used by the county comes from a single vendor, Seattle Steam. The associated custom emissions factor is "Steam (Seattle Steam)", and was calculated by assuming that 1.75 times the steam's heating value (at 10 therms/pound) is burned in the form of natural gas to generate the steam (based on 57% efficiency per **03-037**).

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Special Issues

CO_2 from Biological Products

Two important GHG sources in the county's GHG inventory are landfills and wastewater treatment plants. Both sources emit CO_2 and CH_4, and wastewater treatment plants can emit significant quantities of N_2O as well. In the 2000 inventory, CO_2, CH_4 and N_2O emissions for these sources were included in the inventory. In the 2003 inventory, CO_2 is omitted in order to conform with standard GHG accounting practice set by the Intergovernmental Panel on Climate Change (IPCC).

The IPCC dictates that inventories account specifically *anthropogenic* GHGs. Anthropogenic GHGs are those that are demonstrably caused by human intervention, rather than by natural cycles. For example, CO_2 generated by combusting fossil fuels is anthropogenic, because humans are responsible for extracting the fuels from wells and mines, and subsequently burning them. On the other hand, CO_2 generated by decaying forest detritus is not considered anthropogenic, because it occurs as a part of the natural ecosystem, uncontrolled by humans. GHGs like CO_2 from forest decay that are a part of the natural carbon cycle are referred to as *biogenic*. The natural carbon cycle is a balance of emissions and absorption, keeping the quantity of GHGs in the atmosphere constant and the planet's temperature stable. Anthropogenic GHGs tip the natural balance, destabilizing the natural cycle by causing more to be emitted than absorbed.

The waste in landfills and wastewater treatment plants that eventually decays into GHGs is all of biological origin, meaning that it is derived from living plants and animals. Paper and wood products in the landfill originate from trees; food scraps in the landfill and sewage in the treatment plant originate from food crops and animals. All these biological resources, if left to nature instead of being harvested for human use, would die on their own and would mostly decay in the open air to CO_2. Hence, if human intervention causes decay to CO_2 at only a different location or time, that CO_2 is not considered an anthropogenic greenhouse gas. The global climate system is not sensitive to the location or precise timing of GHG emissions. For that reason, we don't tabulate CO_2 among the landfill and wastewater treatment plant GHG emissions.

However, if human intervention causes a biological product to decay into a different GHG more potent than CO_2, then the more potent GHG is considered anthropogenic because it tips the natural balance toward excess emissions. Landfills and wastewater treatment plants are both artificially anaerobic environments that support the generation of CH_4 instead of CO_2. For that reason, we tabulate CH_4 with the GHGs – and likewise for N_2O from wastewater treatment plants. But if the CH_4 or N_2O is successfully oxidized through combustion to CO_2, then the CO_2 is again considered GHG-neutral, since it would have been released at the biological source's natural death anyway.

Before human intervention the CO_2 budget of the atmosphere was balanced, because for each amount of CO_2 released through decay, an equivalent amount of CO_2 was absorbed by newly growing plants. Similarly, in a sustainable human culture, for each harvested crop that eventually becomes CO_2, a new, equivalent crop re-absorbs the same amount of CO_2.

If the harvest that supports the product is unsustainable, then the harvest may be generating a biological waste stream that bears anthropogenic responsibility for CO_2

after all. For instance, some wood products are made from un-replanted forest that contained 100 tons of carbon per acre. If after harvest the forestland degrades to pastureland sustaining only five tons of carbon per acre, then most of the CO_2 emitted by decaying or combusted wood products is never reabsorbed, and the CO_2 is anthropogenic. Fortunately, in the United States this is rarely the case: food crops come principally from lands in continuous agricultural use, and forest products come principally from tree plantations. So in King County, the biogenic assumption for landfill and wastewater treatment CO_2 is appropriate.

Uncertainty in Wastewater Emissions

CH_4 and N_2O emissions from wastewater treatment, and especially from sewer systems, are very poorly understood. There is only one published, quantitative study of these emissions from an aerobic-process wastewater treatment plant similar to the type of plants used in King County. There is no published study of these emissions from a sewer system. Accordingly this inventory estimates emissions from wastewater treatment plants using emissions factors derived from the published study. It makes no estimates of emissions from sewer systems.

However, the potential for emissions from wastewater treatment plants and sewer systems is enormous. This inventory estimates the total CH_4 emissions from wastewater treatment plants with the published emission factors, and arrives at a value slightly under 17,000 $MgCO_2e$. But if the inventory had used the U.S. EPA's simplified assumption that 5% of the plant's influent decays anaerobically, the datum would have been some 320,000 $MgCO_2e$ instead, nearly the size of the entire inventory!

Because the published factors are based on measured data instead of the expert guess that underlies the EPA assumption, the published factors are more likely to be accurate. However, they are singular and uncorroborated. Since the wastewater treatment plants have the potential to be a very large component of the inventory, it is essential that the methodology for estimating their emissions be improved. Doing so would include, at a minimum, a coordinated effort to measure emissions at several representative wastewater treatment plants, and incorporation of the implied emission factors into standard inventory tools stewarded by the U.S. EPA Emissions Inventory Improvement Program and by ICLEI. A similar effort around emissions from sewer systems is also in order.

Uncertainty in Landfill Emissions

A landfill is a simpler system than a large wastewater treatment plant, so we can make somewhat more accurate estimates of landfill emissions potential. Furthermore, methane has been collected at landfills for years, so a substantive history of data is available to verify theories behind emissions factors.

Yet, the efficiency of landfill methane collection systems is not well known. Most landfill covers may be slightly permeable (especially at seams); ruptures in the cover as well as in gas pipes occur as the landfill settles; growing roots rupture the cover or pipes; gas escapes from the active, uncovered portion of the landfill; gas creeps through the sides of the landfill. Together these factors lead to more or less fugitive emissions (leakage) depending on the quality of cap construction, leak detection and management. There are no quantitative rules for relating these practices to numeric estimates of leakage. Each time that emissions from a landfill are calculated, the responsible party must make or solicit an expert estimate of the leakage rate. Most such estimates range from 10 percent to 30 percent leakage for capped landfills, though lower and higher values have been used.

In this inventory experts estimate a leakage rate of 10 percent for the county's largest and only active landfill, Cedar Hills. A few experts might be comfortable with a leakage rate of 5%, and many might be comfortable with 20%. These alternative guesses would halve or double the Cedar Hills emissions estimate, respectively. Because Cedar Hills alone constitutes 26 percent of the county's GHG inventory, such a correction would have a large impact on the whole inventory.

Inaccessible Portions of the Corporate Boundary

The *GHG Protocol* offers a "control" criterion for the corporate boundary that defines the government inventory's domain. Two large entities, the Washington State Major League Baseball Stadium Public Facilities District (the baseball stadium) and the King County Library System, satisfy this criterion because the majority of their board members are appointed by the county executive. Yet, these two entities are financially and operationally entirely independent from the rest of the county government. Sharing of the close data necessary to calculate the inventory is not customary between the county and these two entities. As an example, a request in 2004 to obtain electricity consumption data from the Mariners baseball team, which manages the baseball stadium under contract, was denied.

Obtaining data from either of these two entities has a high administrative cost, because each request is viewed with suspicion and typically requires involvement of supervisory personnel (both at DNRP and at the entity in question). For this reason, the baseball stadium and library have not been included in the air emissions inventories to date.

Government Inventory

Overview

The 2003 government inventory tabulates 420,031 metric tons of greenhouse gases, 1,496,410 kilograms of nitrogen oxides, 546,607 kg of VOCs and 115,794 kg of particulate matter, as documented in Table 2.

	GHGs $MgCO_2e$	**NO_x** kg	**VOCs** kg	**PM_{10}** kg
Scope 1 - direct emissions				
Buildings	10,336	14,044	770	433
Vehicle Fleet	125,603	838,601	108,307	34,708
Wastewater	18,593	197,197	49,717	2,503
Solid Waste	163,783	217,467	10,633	2,945
Other	3,615	642	286,399	2,234
Scope 1 totals	321,931	1,267,951	455,826	42,823
Scope 2 - electricity & steam				
Buildings	15,897	22,173	260	16,512
Vehicle Fleet	751	375	29	226
Streetlights	2,074	3,233	26	2,435
Wastewater/Solid Waste	38,936	57,400	564	42,991
Other	5,998	8,771	89	6,564
Scope 2 totals	63,656	91,952	968	68,728
Scope 3 - other emissions				
Employee Commute	30,586	111,142	85,038	3,188
Other	3,859	25,365	4,775	1,055
Scope 3 totals	34,445	136,507	89,813	4,243
Total emissions	**420,031**	**1,496,410**	**546,607**	**115,794**

Table 2 – Overview of the 2003 government inventory.

The government inventory constitutes only a small fraction of the geographic inventory of the entire county. To compare the government and geographic inventories, one must pare the government inventory down to only two of its three scopes: Scope 1 (direct emissions) and Scope 3 (indirect emissions except electricity & steam). The emissions reported under Scope 2 (electricity & steam) are due mostly to electricity generated with fossil fuel resources located outside of King County. Since the geographic inventory is defined to include only sources inside the county boundary, only the government Scope 1 and Scope 3 emissions are a valid part of this tally.

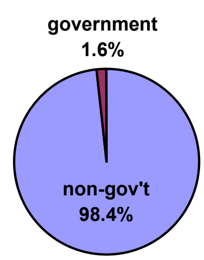

Figure 1 – Contribution of the government GHG inventory to the geographic GHG inventory

Figure 1 demonstrates graphically how the county's government GHG inventory accounts for only 1.6% of the geographic GHG inventory. The relative sizes of the criteria pollutant inventories are similarly small: county government emits about 1.7% of the geographic county's NO_x inventory, 0.7% of the geographic county's VOCs inventory and less than 0.6% of the geographic county's $PM_{2.5}$ inventory.[2] (The absolute values of the geographic inventory are discussed in section *Geographic Inventory* beginning on page 58.)

Figure 2 shows how each of the four inventoried pollutants is distributed among the three scopes. GHGs fall primarily under Scope 1 (direct emissions) because of the large, direct emissions from the county's landfill and the Metro Transit bus system. NO_x emissions are distributed similarly; most of the direct NO_x emissions originate from the Metro Transit bus system, though substantial quantities are also emitted by landfill flares and electric generators at the West Point wastewater treatment facility. VOCs are typically associated with gasoline-fueled passenger vehicles, so the Scope 3 (indirect emissions except electricity & steam) wedge of the VOCs chart is considerably larger, because Scope 3 includes employee commuting and other private vehicle use. PM_{10} emissions occur mostly under Scope 2 (electricity & steam), due to the coal-fired power plants that contribute to Puget Sound Energy electricity.

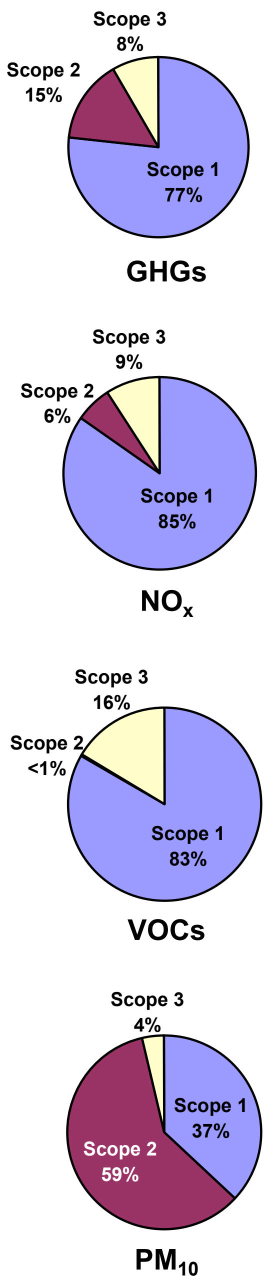

Figure 2 – Distribution of each of the four pollutants among the three government inventory scopes.

Historical Review

The King County government air inventory has been compiled only once before, in 2000.

The 2003 inventory shows some substantial differences from the 2000 inventory, as summarized in Table 3.

	2000 uncorrected	2000 corrected	2003	% change
GHGs ($MgCO_2e$)	634,650	399,774	420,031	5.1%
NO_x (kg)	1,244,665	1,253,231	1,496,410	19.4%
VOCs (kg)	722,054	587,699	546,607	(7.0%)
PM_{10} (kg)	49,310	50,017	115,794	131.5%

Table 3 – Historical overview of pollutant quantities in King County government inventories. % change is calculated from the corrected 2000 values to the 2003 values.

The table repeats the 2000 inventory as originally reported, but also presents a corrected 2000 inventory that conforms to the improved accounting protocols used in

[2] The county government's particulate matter inventory includes particles 10 microns and under (PM_{10}) while the geographic inventory conducted by the Puget Sound Clean Air Agency includes only particles 2.5 microns and under ($PM_{2.5}$). Though these inventories are not directly comparable, they do allow the calculation of an upper limit. Since all particles that meet the definition of $PM_{2.5}$ also meet the definition of PM_{10}, the county's PM_{10} emissions form a maximum value for $PM_{2.5}$ emissions. Hence we know that the county government is responsible for less than 0.6% of the geographic county's $PM_{2.5}$ emissions.

2003. This allows a more meaningful comparison between the 2000 and 2003 values. Even so, most of the changes between the 2000 corrected inventory and the 2003 inventory are still due to minor changes in methodology, rather than to actual increases or decreases in emissions. These minor changes in methodology could not be applied to the 2000 inventory retroactively.

A detailed treatment of the changes to the GHG inventory is shown in Table 4.

	2000 uncorrected	2000 corrected	2003
Scope 1 - direct emissions			
Buildings	13,767	13,767	10,336
Vehicle Fleet	124,101	124,101	125,603
Wastewater	42,359	18,065	18,593
Solid Waste	374,439	157,978	163,783
Other	5,484	5,484	3,615
Scope 1 totals	560,149	319,394	321,931
Scope 2 - electricity and steam			
Buildings	--	--	15,897
Vehicle Fleet	--	--	751
Streetlights	--	--	2,074
Wastewater/Solid Waste	--	--	38,936
Other	--	--	5,998
Scope 2 totals	49,038	49,038	63,656
Scope 3 - other emissions			
Employee Commute	22,585	30,477	30,586
Other	2,877	865	3,859
Scope 3 totals	25,463	31,342	34,445
Total emissions	**634,650**	**399,774**	**420,031**

Table 4 – Historical comparison of 2000 and 2003 GHG inventories.

There are two principal adjustments between the uncorrected and corrected versions of the 2000 inventory:

1. CO_2 emissions from landfills are not counted in the corrected inventory; only CH_4 emissions are counted. This is a change in methodology made to comply with the protocols being followed by the county for this inventory. This change was discussed in detail in *CO2 from Biological Products* above.

2. A technology-specific methodology was used for calculating fugitive emissions from wastewater. The methodology is likely to be more accurate than the national-average methodology used in the uncorrected 2000 inventory. This change is discussed in detail in *Uncertainty in Wastewater Emissions* above.

Even with these adjustments, the 2000 inventory cannot be compared without caveat to the 2003 inventory. The 2003 inventory includes a top-down correction to electricity emissions that captures electricity usage missed by the bottom-up inventory. The higher, 2003 emissions for electricity are very likely to be more accurate due to this correction; many electric bills received by the county are not well-tracked and were likely missed during the 2000 bottom-up approach.

For NO_x, adjustments to the 2000 inventory were negligible.[3] The 19% increase between the corrected 2000 values and 2003 is due to a combination of a real increase in NO_x emissions from the Cedar Hills landfill flares, and a methodological change incorporating higher emissions factors for digester gas combustion at the wastewater treatment plants.

The large downward adjustment to 2000 VOC emissions is due to a methodological change. In the 2000 inventory, “indirect emissions” were defined to include VOC emissions due to some of the county’s contractors, most notably those performing roads maintenance and construction. As of the current inventory, such indirect emissions are not being accounted due to the very low level of accuracy, and the very high cost (in person-hours) for gathering this small portion of the inventory. The 7% decrease from corrected 2000 values to 2003 is probably real, and due in part to increased use of low-VOC paint and cleaning products.

Adjustments to the 2000 PM_{10} inventory were negligible. The very large increase from 2000 to 2003 is due to a combination of increased PSE electricity consumption, and a higher emissions factor. The increase in PSE electricity consumption may be artificial, because in 2003 a top-down report of total PSE electricity purchases was used in order to check for a thorough inventory. This was not done in 2000. The higher emission factor is due to a higher proportion of PSE’s generation being fired by coal in 2003, combined with a higher coal-related emissions factor used by the CACP software than used in the Seattle City Light document that supports the 2000 inventory.

[3] Tables of NO_x, VOCs and PM_{10} inventory adjustments, similar to Table 4 for GHGs, are available in spreadsheet <03 master.xls>.

Scope 1 – Direct Emissions

Scope 1 emissions, or direct emissions, originate from *equipment and materials owned or controlled by King County government*. The Scope 1 emissions make up the majority of the inventory for all pollutants except PM_{10}. Scope 1 GHG emissions are distributed among sources as shown in Figure 3.

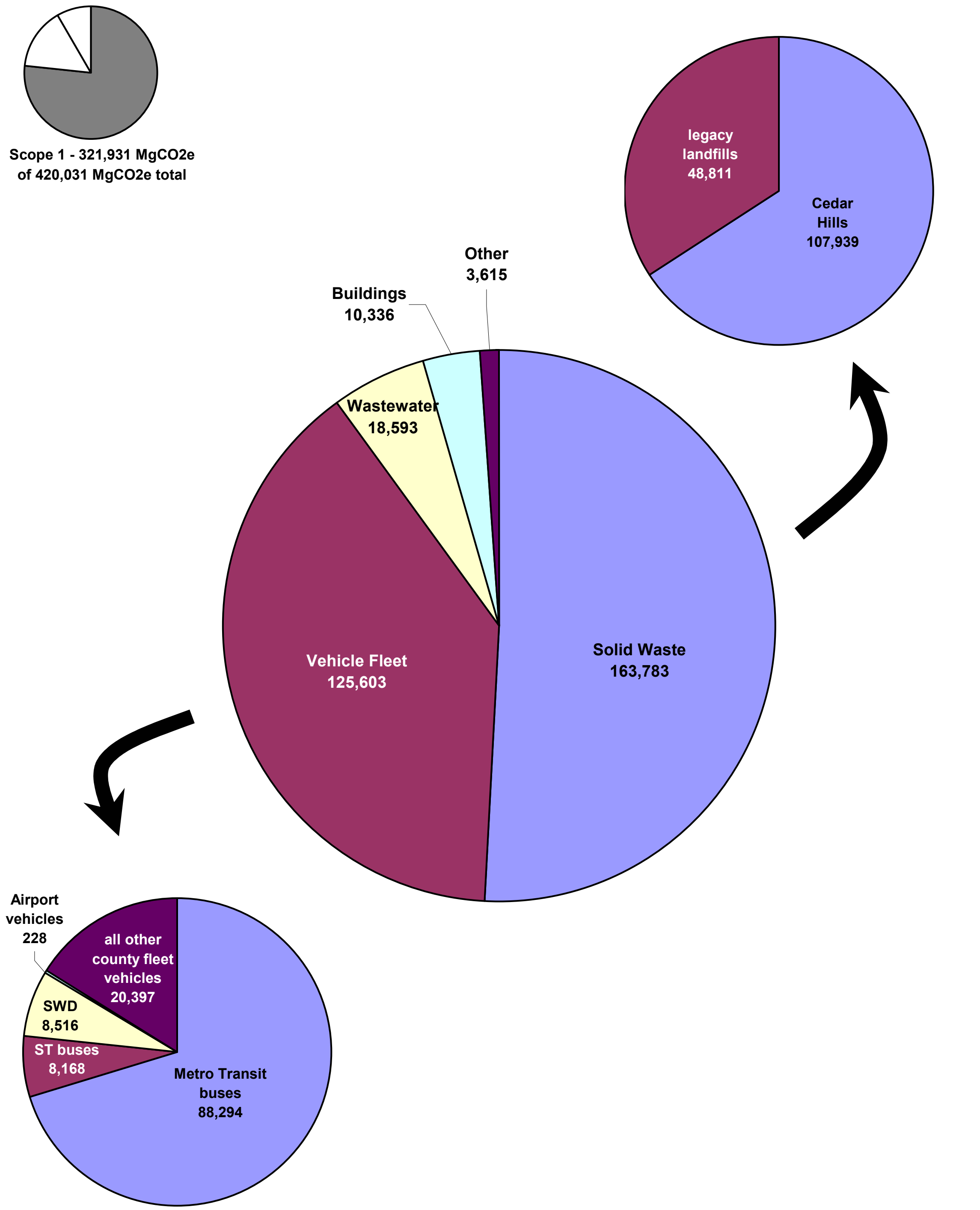

Figure 3 – 2003 Scope 1 (direct) GHG emissions. All values are in units of $MgCO_2e$.

Roughly half of the county's 2003 Scope 1 GHG emissions are due to fugitive methane emissions from landfills, mostly from Cedar Hills. The other principal contributor to Scope 1 GHG emissions is the county's vehicle fleet, dominated by the Metro Transit bus system.

The distribution of the Scope 1 GHGs among the three gases CO_2, CH_4 and N_2O is shown in Figure 4. CO_2 makes up 43% of the county's direct GHG emissions; CH_4 makes up 56% and N_2O the remaining 1%. The King County government inventory is unusual in being dominated by a non-CO_2 gas, methane. In the U.S. national inventory for example, CO_2 swamps the inventory with 84% of the total, and methane contributes only 9%. The reason for the unusual distribution of gases in the King County government inventory is that the county government takes responsibility for emissions from the handling of solid waste and wastewater generated by the majority of the county's population. Both of those processes create significant, direct emissions of CH_4.

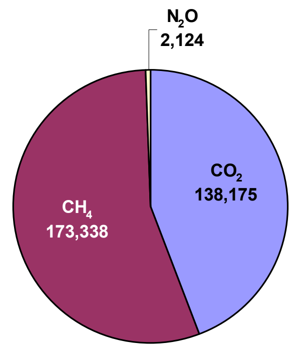

Figure 4 – Contributions of the three inventoried GHGs to total Scope 1 GHGs. All values are in $MgCO_2e$.

Scope 1 emissions of the three criteria pollutants are shown in Figure 5.

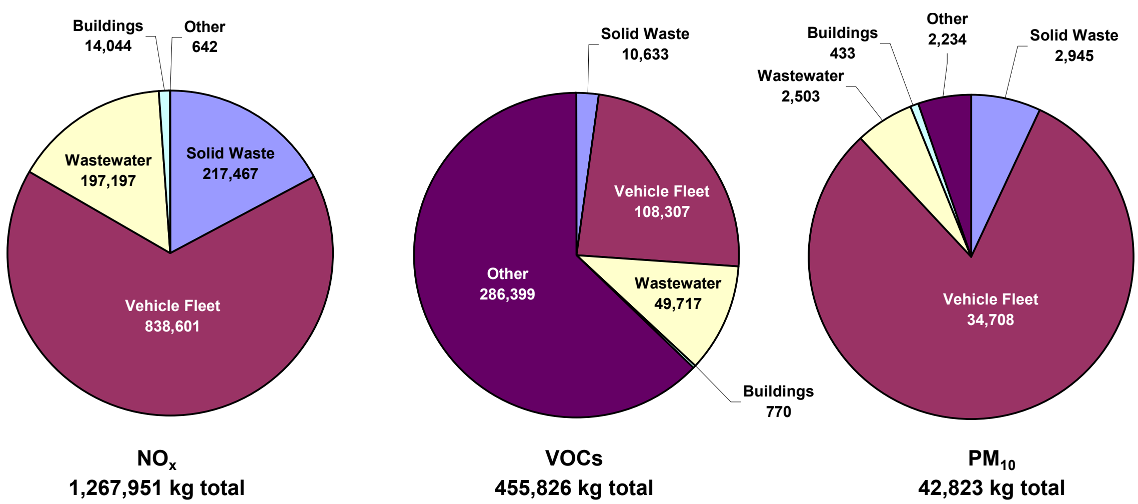

Figure 5 – Scope 1 NO_x, VOC and PM_{10} emissions in 2003. All values are in kg.

For NO_x and PM_{10}, the county's vehicle fleet is the dominant source of direct emissions. The large "other" wedge in the VOCs pie is due partially to paints and asphalt, but mostly to emissions from small gasoline engines in lawn & garden equipment. The significant NO_x emissions in the Solid Waste and Wastewater sectors are due principally to combustion – flaring and cogeneration. Predictably, the Wastewater sector shows a much larger wedge than Solid Waste in the VOCs pie, due to the volatilization of sewage in the open-air treatment processes.

A sector-by-sector discussion of Scope 1 emissions follows. The sectors are treated in the order they are catalogued in the CACP software. That is:

1. Buildings,
2. Vehicle Fleet,
3. Wastewater,
4. Solid Waste and
5. Other (includes four subcategories: volatile substances, other gas purchases, biosolids application, and lawn & garden equipment).

Buildings

Buildings cause direct emissions of GHGs when on-site combustion of fossil fuels provides space heating or hot water heating. King County combusts natural gas in most buildings it owns or rents. The county also combusts fuel oil in a few facilities but the quantities are very small.

The significant energy-consuming buildings in King County are under four separate jurisdictions. First, the DES Facilities Management Division (FMD) operates and maintains most of the county's office buildings. Second, the DOT Metro Transit division operates seven bases. The bases include large, high-bay buildings used for bus maintenance that consume large amounts of energy for lighting and space heat. Third, DNRP Parks operates approximately 175 parks and pools. Though most parks consume relatively little energy, the pools are significant energy consumers due to water heating. The pools are included in the Buildings sector because it is the most appropriate sector allowed by the CACP software. Fourth and last, the DOT Airport division operates a two-runway airfield that includes energy consumption from lighting and other equipment as well as buildings, but is inventoried under the Buildings sector for lack of any more appropriate choice.

Buildings associated with wastewater treatment plants are not included here, but are inventoried together with plant equipment in the Wastewater sector. Buildings associated solid waste collection and landfills are inventoried together with process equipment in the Solid Waste sector.

Table 5a tabulates the fossil fuel use in FMD buildings and the associated air emissions. Table 5b and Table 5c tabulate the same for the Metro Transit bases and Parks facilities, respectively.

FMD-managed building	**energy** TJ	**GHGs** $MgCO_2e$	**NO_x** kg	**VOCs** kg	**PM_{10}** kg
Cedar Hills Alcohol Treatment Facility	0.1	5	6	0	0
Eastgate Public Health Center	0.4	19	26	1	1
Federal Way Public Health Center	0.8	44	60	3	2
Issaquah Courthouse	0.7	39	52	3	2
Kent Animal Control Center	0.9	49	67	4	2
Kent Regional Justice Center	60.9	3,238	4,403	242	135
King County Correctional Facility	0.4	21	29	2	1
Northshore Public Health Center	0.7	37	51	3	2
Precinct 2 (Kenmore)	0.3	14	19	1	1
Precinct 4 (Burien station)	0.4	21	28	2	1
Precinct 4 (Vashon substation)	0.0	1	2	0	0
Redmond Courthouse	0.3	18	24	1	1
Regional Communications and Emergency Coordination Center	3.4	179	243	13	7
Renton Public Health Center	0.8	42	57	3	2
Vashon District Court	0.1	7	9	0	0
Yesler Building	0.7	35	47	3	1
totals	**70.9**	**3,768**	**5,123**	**282**	**157**

Table 5a – Energy consumption and GHG emissions from natural gas use in buildings under Facilities Management Division jurisdiction.

Metro Transit base	**energy** TJ	**GHGs** $MgCO_2e$	**NO_x** kg	**VOCs** kg	**PM_{10}** kg
Atlantic Base	13.2	702	954	53	29
Bellevue Base	0.7	38	52	3	2
Central Base	9.9	527	716	39	22
East Base	19.1	1,016	1,381	76	42
North Base	8.5	452	615	34	19
Ryerson Base	3.8	202	274	15	8
South Base	20.2	1,072	1,458	80	45
totals	**75.4**	**4,009**	**5,450**	**300**	**167**

Table 5b – Energy consumption and GHG emissions from natural gas use in Metro Transit bus bases.

Parks facility	energy TJ	GHGs $MgCO_2e$	NO_x kg	VOCs kg	PM_{10} kg
Auburn Pool	0.7	38	52	3	2
Enumclaw Pool*	1.2	63	85	5	3
Evergreen Pool	5.9	311	423	23	13
Kenneth Jones Pool*	3.8	204	277	15	8
Kent Pool*	1.5	79	108	6	3
Lake Washington Pool*	1.4	74	101	6	3
Mount Rainier Pool	6.2	330	449	25	14
Renton Pool	3.6	193	263	14	8
Si View Pool	1.1	58	78	4	2
Tahoma Pool	4.1	218	297	16	9
Vashon Pool	0.8	43	59	3	2
Weyerhauser KCAC Pool	7.8	417	567	31	17
White Center Park	0.3	18	24	1	1
small facilities	3.9	221	291	14	12
totals	**42.4**	**2,267**	**3,074**	**166**	**97**

*Indicates that this pool has been transferred to a city jurisdiction as of August, 2004.

Table 5c – Energy consumption and GHG emissions from natural gas, oil and propane use in Parks facilities. The last line-item, "small facilities," lumps together all Parks facilities except the thirteen major facilities listed above it.

In Table 5a, the Kent Regional Justice Center exhibits remarkably high emissions. The Justice Center includes a 1,388-bed detention facility that is also responsible for laundry and kitchen support of the county's other principal detention facility, the 1,697-bed King County Correctional Facility in downtown Seattle. The Seattle facility is also a significant consumer of energy, but does not stand out in Table 5a because almost all energy is imported as electricity or steam and is reported under Scope 2, below.

For Table 5c, the major facilities are those that consumed at least 1.0 TJ combined Scope 1 and Scope 2 energy during 2003. Some of the facilities listed show less than 1.0 TJ in the "energy" column because this table includes only the Scope 1 contribution.

Grand total, direct emissions from county buildings and facilities are summarized in Table 6 below.

facility	energy TJ	GHGs $MgCO_2e$	NO_x kg	VOCs kg	PM_{10} kg
FMD buildings	70.9	3,768	5,123	282	157
Metro Transit bases	75.4	4,009	5,450	300	167
Airport facilities	5.5	292	397	22	12
Parks facilities	42.4	2,267	3,074	166	97
grand totals	**194.3**	**10,336**	**14,044**	**770**	**433**

Table 6 – Energy consumption and GHG emissions from natural gas use in all county facilities.

method detail

FMD tracks energy use in buildings for the purpose of monitoring energy efficiency programs. Energy bills received for buildings under FMD's purview are handled centrally, and are recorded in a database in the *Metrix* software package that is used by FMD for efficiency analysis. *Metrix* is usually operated by an intern (Boyd Fackler as of July, 2004) working under Ron Quist's direction.

Boyd provided source document **03-022**, which lists building natural gas, electricity and steam use for 2003, and incompletely for 2000-2002 as well. Boyd imported the data in this spreadsheet from *Metrix*, and then corrected for data entry errors. Data from **03-022** was extracted into calculation workbook <03 buildings.xls>. Data that had been successfully correlated in *Metrix* was extracted from the **03-022**'s 'Natural Gas' worksheet of first, and then facilities that had not been successfully correlated were extracted from the 'Organized Non-correlated' worksheet. Finally, data from <03 buildings.xls> was entered into CACP records, one for each building. No massaging of CACP output was necessary.

Gas usage for Metro Transit facilities was provided in tabular form **03-049** by Joyce McEwen. Gas usage for Parks facilities was provided via departmental accounting records **03-041** by Kathleen Kamel. Gas usage for the airport was provided in spreadsheet **03-094** by Michael Colmant.

All reported Buildings sector emissions are as output by CACP.

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Vehicle Fleet

Metro Transit's buses account for nearly 70% of the county's vehicle fuel use, and therefore for the bulk of the vehicle fleet air emissions. Metro also operates and maintains a smaller fleet of buses owned by Sound Transit, under contract with Sound Transit. Since King County uses the control criterion for its corporate boundary, these buses also fall under the county's inventory and account for about 6% of the county's vehicle fuel use.

The DNRP Solid Waste Division (SWD) operates a fleet of trucks and heavy equipment, and tracks its fuel use separately from Metro Transit or the rest of the county fleet. The SWD fleet consumes about 7% of the county's fuel. Most vehicles in the Metro and SWD fleets are diesel vehicles; all diesel fuel used in these fleets is ultra-low sulfur diesel (ULSD).

The remaining 17% of fuel consumption is due to the balance of fleet, a wide assortment of cars, light trucks and heavy equipment serving all of the agencies and using a variety of fuels including diesel, gasoline, natural gas and propane. The balance of the fleet is managed principally by the DOT Fleet Administration Division, though the King County Airport manages its small fleet of vehicles separately.

DNRP's Waste Treatment Division owns a fleet of 27 trucks that consume 300,000 gallons of diesel fuel per year. The trucks are used for hauling biosolids from waste treatment facilities to application sites, but are included in the Scope 3 inventory (see p. 51) because the trucks' operation and maintenance are contracted out.

The county also operates a sizable fleet of electric trolley buses. The associated emissions are inventoried separately under Scope 2, below.

Table 7 reports energy consumption and air emissions for each fleet, calculated by CACP on the basis of gallons or cubic feet (for natural gas) of fuel used.

fleet	**energy** TJ	**GHGs** $MgCO_2e$	**NO_x** kg	**VOCs** kg	**PM_{10}** kg
Metro Transit buses	1,183.5	88,294	666,789	61,768	27,967
Sound Transit buses	109.5	8,168	62,255	5,711	2,584
SWD fleet	114.2	8,516	63,309	6,430	2,629
Airport vehicles	3.1	228	498	490	26
all other county fleet vehicles	294.8	20,397	45,750	33,908	1,502
totals	**1,705.1**	**125,603**	**838,601**	**108,307**	**34,708**

Table 7 – Energy consumption and air emissions due to county fleets.

Some employees use their private vehicles for county business; the county reimburses them on a per-mile bases. Emissions due to private vehicle use on county business are reported under Scope 3.

<u>method detail</u>

For both the Metro Transit Fleet and the Sound Transit fleet operated under contract, Jim Boon provided source document **03-002**, containing diesel fuel volumes from the automated fueling system database. Fleet numbers 11 through 50 are county-owned; fleet numbers 90 to 95 are Sound Transit-owned. Fuel volumes were input directly from **03-002** into corresponding CACP records.

For the SWD fleet, Lisa Huntley provided four reports from the automated fuel tracking system: 2003 diesel consumption **03-023**, 2003 gasoline consumption **03-014**,
2003 propane consumption **03-015** and a current equipment list **03-016**. The vast majority of SWD fuel use is diesel. The four reports were imported into separate worksheets of calculation workbook <03 SWD fleet.xls>. The equipment list was used to correlate each vehicle number appearing on the fuel consumption reports with a vehicle type, and then the worksheet for each fuel was grouped by vehicle type. This grouped data was entered into a single CACP record "DOT Fleet" that holds separate fields for each fuel-vehicle type combination.

For the balance of the county vehicle fleet, DOT Fleet maintains a fuel use database that is updated automatically from county-controlled fuel pumps where fleet vehicles refuel, and from purchase reports on the Voyager fuel card system. Tom Wise provided a 2003 summary report from this database, which arrived as a single worksheet **03-006**. In calculation workbook <03-006 modified.xls> the data was segregated into six separate worksheets for gasoline, diesel, CNG, propane, electricity and passive equipment. Within each worksheet the records were grouped by vehicle class to match the vehicle classes available in CACP.

Finally, fuel quantity was totaled for each fuel-vehicle class pair and entered into a single CACP record named "DOT Fleet."

All reported Vehicle Fleet sector emissions are as output by CACP.

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Wastewater

King County operates three sewage treatment plants: West Point, South Plant and Vashon. The quantity of waste input to the county's treatment plants is measured in biochemical oxygen demand, or BOD_5. BOD_5 is the total quantity of oxygen required by bacteria, over a period of five days, to break down the organic waste suspended in the influent. Five days is a standard value used to represent significant, though not necessarily complete, consumption of the organic matter. For any particular sewage treatment plant design, the direct GHG emissions are approximately proportional to BOD_5 input.

The county's two major treatment plants, West Point and South Plant, both follow the same basic process. For the sake of understanding the related GHG emissions one can think of both plants as being divided into a water side and solids side. The water side is in principle aerobic, and the solids side is in principle anaerobic. The explanation that follows is highly simplified, but is appropriate for understanding the basic sources of GHGs at the two plants.

The water side includes five important stages. First, an initial grit chamber extracts heavy materials like small stones and metal particles. Second, the wastewater enters a primary process in which it is allowed to rest for one to 1½ hours, during which about 60% of the suspended solids either float to the top or sink to the bottom, and are removed to the solids side. Third, the wastewater is mixed with activated sludge – a combination of bacterial cultures and some recycled, waste biomass – and aerated to promote aerobic digestion of the waste biomass. Fourth, the wastewater rests in secondary clarifiers for several hours, allowing the activated sludge to settle to the bottom. Some of the settled sludge is recycled into the aeration tanks, and some is removed to the solids side. Fifth and last, the water (now with about 95% of suspended solids removed) is put into contact with sodium hypochlorite in a chlorine contact channel for ½ to 1½ hours, before being discharged into Puget Sound through a 12-mile long outfall main.

The solids side includes two important stages. First, a thickening system increases the fraction of solids in the sludge to 5%-7%. Second, the thickened sludge is moved into anaerobic digesters where it resides for approximately 28 days. The digester produces a flammable gas that is approximately 65% methane and 35% carbon dioxide; and a nutrient-rich effluent sludge that is used as a fertilizer.

Methane and nitrous oxide tend to form attached to the biological material in the less aerobic portions of the waste treatment system, and escape to the atmosphere when the wastewater is subsequently agitated, bringing the formed gas into contact with escaping air. Hence, the three most likely sources of fugitive emissions are the grit chambers, where gases generated in the final sewer system pipelines are released; the aeration tanks, where gases entrained with the return activated sludge are released; and in the sludge thickening process, where gases entrained with the activated sludge are also released.

There are two sources of direct emissions of the digester gas to the atmosphere. First, most of the digesters are designed with floating lids to accommodate changes in volume. Some digester gas leaks to the atmosphere through the annular seal between the floating lid and the side of the tank. Second, on rare occasions the plant staff need to “pop” gas that cannot be flared or otherwise disposed of, directly to the atmosphere.

Table 8 lists BOD_5 and nitrogen inputs, as well as total emissions of greenhouse gases from all of these sources combined. Emissions of VOCs are also listed.

	input		emissions			
waste treatment plant	**BOD_5** Mg	**N** Mg	**CH_4** Mg	**N_2O** Mg	**GHGs** $MgCO_2e$	**VOCs** kg
South Plant	25,197	4,558	665.3	3.2	14,979	37,852
West Point	26,677	4,826	104.0	3.4	3,250	4,895
Vashon	57	10	1.7	0.2	86	
totals	**51,931**	**9,394**	**771.0**	**6.9**	**18,315**	**42,747**

Table 8 – Inputs, and GHG and VOC emissions from the county’s wastewater treatment plants.

South Plant has high CH_4 emissions relative to West Point, because South Plant’s system for injecting digester gas into the pipeline may suffer significant leakage. The wet scrubber used to remove CO_2 from the digester gas also strips some fraction of the CH_4. The scrubber effluent becomes secondary treatment influent, so the entrained CH_4 is released to the atmosphere by the secondary aeration tanks.

The emissions values in the table are based on emissions factors of fairly low quality, and improvements to the inventory methodology could change the wastewater process emissions by as much as an order of magnitude. The values are especially sensitive to the quantity of nitrous oxide emissions, since the GWP of nitrous oxide is approximately 300.

The sewage collection system is also a potentially enormous, but poorly understood source of GHGs. Conditions in the sewer system are fairly anaerobic (the flow is not very turbulent or aerated) and in the case of the East Section that is served by the South Plant, raw sewage can reside in the system for up to 24 hours. No published emissions factors are known, and hence no estimate is made here, but if emissions factors develop their application could add a significant new component to the King County GHG inventory.

The wastewater treatment plants also create emissions related to combustion. The plants themselves combust biogas, but in addition some of the sewer pumping stations burn natural gas. The CO_2 resulting from biogas combustion is considered GHG-neutral, but the combustion also yields some traditional pollutants, that are accounted for here. Of course, the CO_2 resulting from any natural gas combustion is accounted as a GHG. All combustion-related emissions at the plants and pumping stations are tabulated in Table 9.

combustion process	**fuel burned** TJ	**GHGs** $MgCO_2e$	**NO_x** kg	**VOCs** kg	**PM_{10}** kg
South Plant					
biogas flaring	11.5	2	227	3,057	1,052
biogas-fired equipment	2.0	0	13	0	0
purchased natural gas*	0.4	20	28	2	1
West Point					
biogas flaring	80.5	11	3,395	187	258
biogas cogeneration	267.4	38	179,897	3,519	1,129
biogas-fired equipment	21.8	3	13,359	190	54
purchased natural gas*	3.8	204	278	15	8
Totals	**387.4**	**278**	**197,197**	**6,970**	**2,503**

* Purchased natural gas is burned at pumping stations, not at main plants

Table 9 – Combustion emissions at wastewater treatment plants.

In December 2003 South Plant began firing a boiler for heating the digesters, so the emissions of biogas-fired equipment can be expected to rise in coming years. Currently, South Plant sells most of its biogas to Puget Sound Energy, though a small amount is flared when the PSE pipeline cannot accept gas or when the plant's gas purification system is not operating. South Plant is testing a 1 MW fuel cell-based cogeneration plant on site, and will additionally be installing an 8 MW cogeneration plant in the near future, so the footprint of combustion-related emissions can be expected to change over the next few years.

West Point currently generates electricity with the bulk of its biogas, and will be installing a larger cogeneration plant in the near future. Hence, West Point's combustion emissions footprint is also likely to shift.

method detail

Betsy Cooper provided records of BOD_5 input to each plant (**03-024** and **03-025**). For South Plant and West Point, these were used to scale emission factors for CH_4 and N_2O provided in academic literature (**03-078** and **03-079**) derived from measurements at an activated sludge wastewater treatment plant in Durham, NH. These estimates account for emissions from the water side of the plant and from sludge thickening, but not from digester gas.

To estimate CH_4 emissions from the digesters, Carol Nelson of South Plant calculated that the annular seals in the floating lid digesters leak a maximum of 1% of the total methane generated (**03-071**). (It is notable that a different approach by Dick Finger of West Point **03-086** arrived at a figure of 0.02%; but 1% is being used as a conservative, default value until direct measurements are available.) Carol also estimated that less than 0.2% of the total methane generated is popped directly to the atmosphere (**03-073**). At South Plant it was estimated that 1% + 0.2% of the total gas produced (**03-074**) escapes to the atmosphere as a GHG.

At West Point, a single pop incident occurred in October and released 675,000 ft^3 of digester gas (**03-086**). Additionally, it was estimated that (5/6 x 1%) of the total gas generated (obtained from Dick Finger, **03-056**) escapes from the digester lid seals to the atmosphere. The factor 5/6 is due to one of the six digesters at West Point having a fixed lid.

Since Vashon uses a more primitive technology, more general EIIP methodology was used instead. To estimate CH_4 emissions the BOD_5 value was multiplied by 16.25% prescribed by EIIP to represent the default fraction of waste digested anaerobically, and then by the emission factor of 0.6 mass units of CH_4 per mass unit BOD_5 anaerobically digested. To calculate N_2O emissions, the population served by the Vashon plant was estimated from the WTD's "At a Glance" document **03-030** and the relative BOD_5 inputs (see <03 master.xls>). The population served was multiplied by EIIP's U.S. per capita nitrogen consumption rate of 6.71 kg; then by the fraction of nitrogen evolving into N_2O, .01; then finally by the mass ratio of N_2O to N_2, 1.57.

Process VOC emissions were extracted from the 2003 EPA air emissions reports submitted by South Plant (**03-088**) and West Point (**03-085**).

All calculations relating to process emissions from the wastewater plants were performed in <03 master.xls>; CACP does not provide mechanisms for estimating these process emissions.

For combustion processes quantities of digester gas flared and otherwise combusted were obtained from Carol Nelson for South Plant (**03-071**) and from Dick Finger for West Point (**03-056**), and entered into corresponding CACP records, one for each group of combustors. CACP provided the (very small) values for GHG emissions from the combustors. Criteria air pollutant quantities were extracted directly from the 2003 EPA air emissions reports, which presumably are more accurate than the CACP estimate.

Quantities of natural gas burned in pumping stations were obtained from Edie Lackland for the East section (**03-028**) and Nancy Robbins for the West section (**03-019**). These quantities were provided in dollar values and needed to be pre-processed in <03 master.xls> to generate corresponding energy quantities that could then be entered into CACP. Values for all emissions from natural gas combustion were generated with CACP.

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Solid Waste

King County operates a single active landfill, Cedar Hills. The Cedar Hills landfill handles all King County waste, except that generated in the city of Seattle. The county also stewards a number of closed (legacy) landfills. Two of these legacy landfills are capped and flare their methane; the remaining landfills do not flare.

Greenhouse gases due to the landfills consist primarily of unflared methane. For those landfills with caps and flaring systems, a fraction of the methane is assumed to escape unflared. For the Cedar Hills landfill, 10% of the methane is assumed to escape; this is the rate typically assumed for the most sophisticated landfills. For the other two flared landfills in King County, it is assumed that 30% escapes; and for landfills without flaring systems, all generated methane is assumed to escape.

Landfill gas includes very small quantities of NO_x and PM_{10}, and significant quantities of VOCs. Flaring the gas reduces VOCs, but increases the NO_x and PM_{10} emissions. These effects are clearly visible in Table 10.

landfill	**CH_4 evolved** Mg	**CH_4 fugitive** Mg	**CH_4 fugitive** $MgCO_2e$	**NO_x** kg	**VOCs** kg	**PM_{10}** kg
Bow Lake	33	33	700	0	45	0
Cedar Falls^C	307	307	6,444	1	417	0
Cedar Hills^F	51,398	5,140	107,939	211,784	6,988	2,869
Corliss	33	33	700	0	45	0
Duvall^V	248	248	5,201	1	336	0
Enumclaw^F	840	252	5,288	2,692	358	36
Hobart^F	930	279	5,849	2,982	396	40
Houghton^C	443	443	9,298	2	602	0
Puyallup^V	147	147	3,082	1	199	0
South Park	439	439	9,228	2	597	0
Vashon^C	479	479	10,054	2	650	0
totals	**55,297**	**7,800**	**163,783**	**217,467**	**10,633**	**2,945**

Table 10 – Emissions from King County landfills. Only the Cedar Hills landfill is currently accepting waste. ^{C} indicates an impermeable cap without flaring, ^{F} indicates an impermeable cap with flaring, ^{V} indicates a vegetative cover only.

In the table, the first column of data, "CH_4 evolved," indicates the total quantity of methane created in 2003 by the landfill, regardless of whether the landfill is being flared. In the second column "CH_4 fugitive," the evolved CH_4 is adjusted to reflect any methane that is captured and combusted. So for unflared landfills, the second column is equal to the first. But for Cedar Hills, capturing at 90% efficiency, the second column is 10% of the first. For the flared, legacy landfills capturing at 70% efficiency, the second column is 30% of the first. In the third column, the fugitive CH_4 emissions reported in the second column are simply converted to the standard units of $MgCO_2e$.

As mentioned above, flaring can elevate NO_x and PM_{10} levels, and this is clear in the table, for the four flared landfills. But note that the flared landfills emit a smaller proportion of VOCs, compared to their gross landfill gas generation (measured as the quantity of methane, in the first column). This is because the flares destroy more VOCs than they create.

method detail

For the legacy landfills, the fugitive methane generated each year is estimated using the waste-in-place methodology available in CACP, based on the quantity of waste buried and years the landfill was open (from **03-080**). For the three flared legacy landfills Enumclaw, Hobart and Vashon, the CACP software was instructed to assume a 70% methane capture rate. For the remaining legacy landfills, the CACP software was instructed to assume a 0% methane capture rate.

For Cedar Hills, the total methane flared each year can be calculated from values measured directly at the flare inlets. Each year King County files an air emissions report with the U.S. EPA, that includes the total quantity of landfill gas flared, and the total VOCs emitted from the flare. The county also measures the composition of landfill gas daily at several measurement points, and keeps an ongoing log of the reduced data. Jamey Barker provided a copy of the 2003 EPA report **03-012** and the gas composition log **03-031**. In <03-031 modified.xls> the 2003 average fraction of methane in the gas is calculated to be 52.3%, and multiplied by the total reported volume of flared landfill gas to calculate the quantity of methane flared. Finally, the quantity of fugitive methane is obtained by multiplying the flared quantity by $\frac{10\%}{100\% - 10\%} = 11.1\%$ to reflect a 90% capture rate, in <03 master.xls>.

The CACP waste-in-place calculator does not estimate traditional pollutants from landfills, so these were calculated in <03 landfills.xls> for both Cedar Hills and the legacy landfills. The calculations for fugitive emissions from all of the landfills rely on emission factors compiled in an Environment Canada study and reported by the Natural Resources Defense Council in document **03-081**. (This document is the only known systemic study of such emissions factors; the other resources in our protocol hierarchy do not include any such factors.) Traditional pollutants from the landfill flares were calculated with emissions factors provided by the same document, except VOC emissions from the Cedar Hills flare which were taken directly from measured quantities in **03-012**.

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Note – the following four sections, Volatile Substances, Other Gas Purchases, Biosolids Application, and Lawn & Garden Equipment are all grouped together under CACP's "Other" sector of Scope 1 in the inventory summary, Table 2.

Volatile Substances

Of the three traditional pollutants being inventoried, most NO_x and PM_{10} emissions originate from the same sources as the greenhouse gases: combustors. However, VOCs due to county operations also originate from a different set of sources – volatile compounds such as asphalt, paint and cleaners. These are estimated here. All three products – asphalt, paint and cleaners – are purchased in small quantities, from a variety of vendors, and by a wide variety of divisions and groups within the county. The cost (in person-hours) required to accurately inventory volatile substance purchases are unfortunately too high to offset the value of the resulting data. Hence the values in this sector of the Scope 1 inventory should be considered order-of-magnitude estimates only.

Asphalt comes in two fundamentally different varieties. Hot-mix asphalt is too thick to work at ambient temperature, and is therefore heated prior to application. It is the most common type and constitutes the vast majority of asphalt used in major road projects. It is not considered a significant source of VOCs. Cold-mix asphalt is a thinner consistency, and can be applied at ambient temperature. It is used for patchwork and sometimes for tack or seal layers in large projects. The raw asphalt's consistency is reduced with a diluent, which may either be water or a volatile organic compound. If water, the cold-mix asphalt is referred to as emulsified and is not considered a significant source of VOCs. If a volatile organic compound, the cold-mix asphalt is referred to as cutback, and is a significant source of VOCs.

division or group	**cutback asphalt** Mg	**emulsified asphalt** Mg	**VOCs** kg
DOT Transit	0	104	2,746
DOT Roads	38	113	10,470
DOT Airport	n/r	n/r	n/r
DOT Roads store	0	1	18
totals	**38**	**217**	**13,217**

Table 11 – VOC emissions from cold-mix asphalts. The Airport division reported only hot-mix asphalt use during 2003.

Table 11 tabulates VOCs estimated to be released from cold-mix asphalt purchased by King County.

Paint, like cold-mix asphalt, comes in two fundamental varieties: water-based and oil-based. King County purchases substantially more water-based than oil-based paint. Water-based paint releases about one fifth the VOCs of oil-based paint, hence our favoring of water-based paints has a positive, lowering effect on the VOC inventory. Table 12 provides a summary of paint purchases and the associated VOCs expected from their use.

vendor	**water-based paint** gal	**oil-based paint** gal	**VOCs** kg
Alpine Products	53,890	0	30,599
Kelly Moore	4,224	86	1,569
Miller Paint	490	54	260
Parker Paint	1,659	184	880
totals	**60,264**	**325**	**33,309**

Table 12 – VOC emissions from paint purchased by King County. Paint from Alpine Products is traffic line paint, all other vendors represent primarily purchases of interior and exterior wall paints.

Cleaners and solvents are the most difficult VOC source to inventory. Unlike asphalt, their use is not restricted to a few departments. And unlike paint, their purchase is not mostly through a few, single-product vendors. Though it is prohibitively time-intensive to inventory all such purchases made by the county, a substantive fraction of the purchases made can be captured by inventorying the quantities purchased from the county's two largest janitorial suppliers. The quantities for six of the most important categories of solvents are listed in Table 13.

substance class	**quantity purchased** gal	**VOCs** kg
adhesives	100	49
solvents	153	137
fabric & carpet cleaners	521	123
hard surface cleaners	11,775	821
windshield de-icers	50	24
lubricants	4	4
totals	**12,603**	**1,157**

Table 13 – VOC emissions from cleaners and other solvents

Pesticides are, conveniently, inventoried each year to comply with the Integrated Pest Management (IPM) program that was created by county executive order in 1999. Hence this is probably the most precise category in the inventory of VOCs from volatile compounds, though not one of the largest. Table 14 lists emissions from pesticides used by the county.

substance class	quantity applied kg	VOCs kg
pesticides	1,217	1,003

Table 14 – VOC emissions from pesticides

method detail

All calculations relating to VOC emissions from volatile substances were performed in <03 master.xls>; CACP does not provide mechanisms for estimating these process emissions.

The calculations assume that all purchased product is ultimately used by the county. The 2003 inventory accounts for product purchased from January 1 through December 31, 2003. This constitutes a reasonable estimate of 2003 emissions, because actual use will include some product purchased in prior years, that is offset by a portion of product purchased in 2003 left unused until future years.

asphalt

On-the-ground paving staff are typically aware of the distinction between hot-mix and cold-mix asphalts, but not necessarily between emulsified and cutback cold-mix asphalts. Where staff were not able to differentiate between cutback and emulsified asphalts, it was assumed that 25% of the consumption was cutback and 75% emulsified.

DOT Transit reported asphalt used as a sealer, in units of surface area treated, in **03-053**. To convert to mass, a nominal coverage of 50 ft^2/gal was assumed, along with a product density of 8.3 lb/gal. The calculations are documented in <03 master.xls>.

DOT Roads reported asphalt used directly in mass units, as documented in source **03-054**. The DOT Roads store does not sell general-purpose, cold-mix asphalt, but does sell loop filler (**03-084**) which was inventoried as an emulsified asphalt.

The total masses of emulsified and cutback asphalt were multiplied by VOC emission factors provided in Volume 3, Chapter 17 of the EIIP Technical Reports.

paint

The county's largest paint supplier, Kelly Moore, was unable to provide quantities sold (though they will be able to from January 1, 2005 onward). Hence paint quantities for all suppliers were estimated from the dollar values of purchases. Karen Hamilton provided these from the ARMS and IBIS purchasing databases, see **03-083**. The average price of paint was derived from U.S. Census Bureau Data **03-082**; it was assumed that 90% of dollars paid to paint suppliers went directly to paint (rather than painting equipment), and that of these purchases 10% were oil-based paint while 90% were water-based.

Kelly Moore Paint reported that County purchases were only 2% oil-based (**03-064**), so for this vendor only, the 10% assumption was superseded. Alpine Products was able to itemize product sales and supplied per-gallon costs (**03-090**) so for this vendor only, both the 10% assumption and the U.S. Census Bureau average cost were superseded.

The total volumes of oil- and water-based paint thus calculated, were multiplied by emission factors provided in Volume 3, Chapter 3 of the EIIP Technical Reports.

cleaners and solvents

Northwest Janitorial, the county's largest janitorial supplier, provided an inventory of 2003 sales to King County of "chemical" products (**03-087**). Rosalie Ciummo of DES Finance & Business Operations provided a usage report for county purchases from Stellar Industrial Supply (**03-100**). A few automotive products not purchased through the janitorial suppliers were inventoried in a report from the DOT Store **03-084**. All three reports were grouped and sorted according to the most relevant categories of solvents listed in Appendix A to Volume 3, Chapter 5 of the EIIP Technical Reports. Average VOC emission factors for each category were calculated from the national data reported in the EIIP appendix. As with all other volatile substances, the emissions calculations are documented in <03 master.xls>.

pesticides

2003 pesticide use is documented in the annual Integrated Pest Management inventory **03-107**. This report conveniently segregates the masses of the active ingredients, which were totaled and multiplied by the emission factor 2.45 {kg VOC}/{kg active ingredient} and evaporation factor 0.9, both taken from the EIIP Technical Reports, Volume 3, Chapter 9, Section 4.2.1.

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Other Gas Purchases

King County's sole supplier of natural gas, Puget Sound Energy, reports a larger total quantity of gas purchased by King County, than reported from the county's fuel tracking systems. This inventory reports natural gas use in the jails, major administrative buildings, the

	gas delivered therm	**GHGs after combustion** $MgCO_2e$
PSE-reported sales	2,409,884	
bottom-up gas inventory	2,019,797	
gas unaccounted for	390,087	**1,958**

Table 15 – Emissions from natural gas purchases unaccounted for in county tracking systems.

airport, parks facilities, CNG vehicles, and sewer pumping stations. About 390,000 therms, 16% of the total reported by PSE, remains unaccounted for. This quantity is included in the inventory until an opportunity occurs to reconcile PSE's accounts with those actually paid at the county. See Table 15.

method detail

Julia Green of Puget Sound Energy supplied the total 2003 gas purchases by email, **03-036**. Gas accounted for elsewhere is the sum of the CNG and Natural Gas line items in the CACP "Report by Source," as of October 18, 2004. Calculation of net emissions are documented in <03 master.xls>.

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Biosolids Application

A portion of the nitrogen contained in biosolids applied as fertilizer, volatizes to N_2O (see Appendix D for an explanation of the process through which this happens). This is inventoried as a direct emission, though in the Other sector rather than the Wastewater sector, since the biosolids have been removed from the wastewater treatment plant by the time that emissions occur. The N_2O emissions are only accounted where the biosolids are not displacing a different nitrogen fertilizer. Where the biosolids are displacing a commercial or other nitrogen fertilizer, the N_2O emissions may have occurred anyway and it would be inappropriate to attribute the emissions to King County.

	biosolids applied dry Mg	**N_2O emissions** Mg	**GHG equivalent** $MgCO_2e$
wet-climate, non-displacing	4,778	5	1,657

Table 16 – GHG emissions from biosolids applications in wet climates where another nitrogen fertilizer is not displaced.

Table 16 shows GHG emissions attributable to applications of biosolids in wet climates (where N_2O formation is likely) but only where the biosolids do not displace a different nitrogen fertilizer. Despite the very high GWP of N_2O, the amount of N_2O generated is so small that biosolids are a negligible contributor to the Scope 1 inventory.

method detail

2003 quantities of biosolids applied in various applications were provided in a spreadsheet **03-045** by Peggy Leonard. Those applications in wet climates that did not displace other fertilizers were selected for analysis. Nitrogen content in the biosolids was assumed to be 7%, of which 19% is assumed to volatize directly (in compounds other than N_2O), per data gathered for the 2000 inventory **03-080**. The unvolatized nitrogen was then multiplied by an N_2O emission factor provided in Volume 8, Chapter 10 of the EIIP Technical Reports. CACP does not provide a mechanism for calculating these emissions; they are computed directly in <03 master.xls>.

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Lawn & Garden Equipment

Table 17 shows the contributions of lawn and garden equipment operated by various divisions, to the NO_x, VOC and PM_{10} inventories. GHG emissions are not listed, because some of the fuel purchased for this equipment may already be included in the inventory of fuel purchases that form the foundation of the vehicle fleet emissions estimates.

	NO_x kg	**VOCs** kg	**PM_{10}** kg
DNRP Parks	297	166,411	1,543
DNRP Solid Waste	18	5,177	46
DNRP Wastewater Treatment	45	1,786	17
DOT Roads	75	24,158	183
DOT Transit	139	29,970	371
DOT Airport	56	9,762	69
DPH	11	449	4
totals	**642**	**237,713**	**2,234**

Table 17 - NO_x, VOC and PM_{10} emissions from lawn and garden equipment.

The inventory of emissions from lawn & garden equipment has not been adjusted since the 2000 inventory. An adjustment requires a comprehensive survey of equipment stock and use, which is a sufficiently time-intensive effort that it cannot be repeated in every inventory year.

method detail

Data for 2000 emissions from lawn and garden equipment were copied from tab ‘Lawn’ in the 2000 inventory workbook <Emissions Estimates-Final.xls>. The emissions data were manipulated in calculations spreadsheet <03 lawn & garden.xls> in order to segregate emissions from the various divisions (which were not distinguished in the 2000 inventory report).

Scope 2 – Electricity and Steam

Scope 2 emissions originate from *steam, heat and electricity purchased by King County government*. King County purchases electricity from Seattle City Light (SCL) for facilities located in the City of Seattle, and from Puget Sound Energy (PSE) for facilities located outside the City of Seattle. The county purchases steam from Seattle Steam Co. for the Administration Building, Courthouse and Jail in downtown Seattle, and for the Department of Youth Services on 12th Avenue and E. Alder St. in Seattle.

SCL electricity has very low associated emissions; in 2003 the mix included less than 1% coal and 5% natural gas; the balance was hydroelectric. PSE electricity, in contrast, entails substantial emissions. In 2003 the mix included 34% coal and 4% natural gas. Seattle Steam operates a natural gas-fired boiler, so though substantial emissions are associated with steam, they are still less than from most steam plants.

Figure 6 shows the distribution of GHG emissions only, in Scope 2 of the inventory. Note in the upper right pie chart, that emissions associated with the South Plant wastewater treatment plant are much larger than those associated with the West Point plant even though West Point is the slightly larger facility. This is because South Plant is located in PSE service territory, which delivers GHG-intensive electricity, while West Point is in SCL service territory, which delivers very clean electricity.

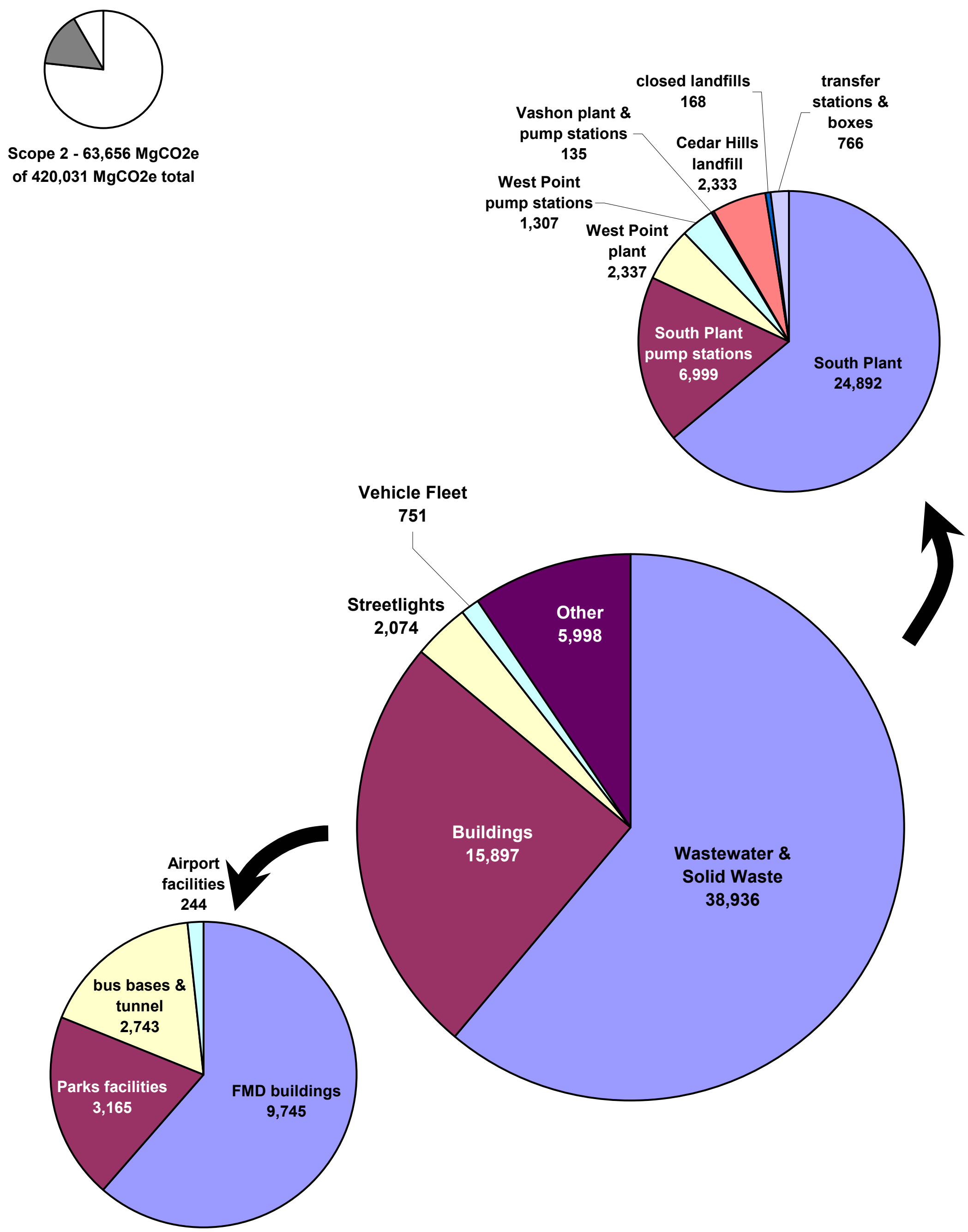

Figure 6 – 2003 Scope 2 (electricity and steam) GHG emissions. All values are in units of $MgCO_2e$.

Buildings

Emissions associated with electricity use in FMD-managed buildings, Metro Transit bus bases and Parks facilities are detailed in Table 18a, b and c, respectively.

Four of the FMD-managed buildings listed in Table 18a receive energy in the form of steam. The steam is generated by Seattle Steam at a natural gas-fired generating plant located on Western Avenue at University Street in downtown Seattle.

Table 18b lists, in addition to the seven Metro Transit bases previously mentioned, the bus tunnel. The quantity of energy reported in the table is due principally to lighting; electricity delivered to the trolley buses passing through the tunnel is not reported here, but rather in the *Vehicle Fleet* sector below.

Facility	**electric energy** TJ	**steam energy** TJ	**GHGs** $MgCO_2e$	**NO_x** kg	**VOCs** kg	**PM_{10}** kg
Auburn Public Health Center	0.6		74	115	1	87
Bellevue Courthouse	2.5		285	444	4	334
Black River Community Service Center	5.5		633	988	8	744
Burien Courthouse	1.9		22	11	1	7
Cedar Hills Alcohol Treatment Facility	1.3		147	230	2	173
Department of Youth Services	10.7	7.1	502	63	5	38
Eastgate Public Health Center	2.5		290	453	4	341
Federal Way District Court	0.4		50	77	1	58
Federal Way Public Health Center	1.6		185	289	2	217
Goat Hill parking lot	0.1		1	1	0	0
Issaquah Courthouse	0.8		94	146	1	110
Kent Animal Control Shelter	0.8		94	146	1	110
Kent Courthouse	0.9		106	166	1	125
Kent Regional Justice Center	52.3		6,021	9,388	75	7,069
King County Administration Building	13.7	2.5	290	79	6	48
King County Correctional Facility	21.5	24.6	1,555	124	10	75
King County Courthouse	39.3	36.4	2,386	227	17	137
Lake Youngs	0.1		16	24	0	18
North Public Health Center	2.1		24	12	1	7
Northshore Public Helth Center	1.5		172	269	2	202
Precinct 2 (Kenmore)	0.8		97	152	1	114
Precinct 2? (Fall City substation)	0.1		10	16	0	12
Precinct 3 (Maple Valley)	1.5		172	268	2	202
Redmond Courthouse	0.4		51	80	1	60
Renton Courthouse	0.4		41	64	1	48
Renton Public Health Center	0.5		54	84	1	63
Shoreline Courthouse	0.8		9	5	0	3
Vashon District Court	0.0		5	7	0	5
White Center Public Health Center	1.5		18	9	1	5
Yesler Building	7.5		87	44	3	26
totals	**173.8**	**218.3**	**9,745**	**13,977**	**151**	**10,440**

Table 18a – energy consumption and air emissions from electricity use in buildings under Facilities Management Division supervision.

facility	energy TJ	GHGs $MgCO_2e$	NO_x kg	VOCs kg	PM_{10} kg
Atlantic Base	2.2	26	13	1	8
Bellevue Base	3.5	397	619	5	466
Central Base	17.0	197	98	8	59
East Base	11.3	1,302	2,030	16	1,529
North Base	16.5	191	95	7	57
Ryerson Base	8.4	97	49	4	29
South Base	19.0	220	109	8	66
bus tunnel	27.1	313	156	12	94
totals	**105.0**	**2,743**	**3,169**	**61**	**2,308**

Table 18b – Electric energy use and associated emissions from major Metro Transit facilities.

Facility	energy TJ	GHGs $MgCO_2e$	NO_x kg	VOCs kg	PM_{10} kg
Auburn Pool	0.4	42	65	1	49
Enumclaw Pool*	0.3	32	50	0	38
Evergreen Pool	1.0	11	6	0	3
Kenneth Jones Pool*	0.5	61	95	1	72
Kent Pool*	0.2	18	28	0	21
Lake Washington Pool*	0.2	21	32	0	24
Mount Rainier Pool	1.4	164	255	2	192
Renton Pool	1.4	166	260	2	195
Si View Pool	-	-	-	-	-
Tahoma Pool	1.4	156	243	2	183
Vashon Pool	0.3	32	50	0	37
Weyerhauser KCAC Pool	14.3	1,650	2,572	21	1,937
White Center Park	0.8	9	4	0	3
small facilities	7.4	803	1,245	10	937
totals	**29.4**	**3,165**	**4,905**	**39**	**3,691**

Table 18c – Electric energy use and associated emissions from Parks facilities.

The quantities of greenhouse gases do not necessarily correlate with the quantities of electric energy, since some facilities receive electricity from Seattle City Light having smaller emissions factors, while others receive electricity from Puget Sound Energy having larger emissions factors. The specific energy sources can be found in the CACP database.

Table 19 summarizes energy consumption and Scope 2 emissions for the Buildings sector. In addition to the three major groups of facilities detailed in Table 18a-c, Table 19 also incorporates energy and emissions due to the airport.

Facility	**electric energy** TJ	**steam energy** TJ	**GHGs** $MgCO_2e$	**NO_x** kg	**VOCs** kg	**PM_{10}** kg
FMD buildings	173.8	218.3	9,745	13,977	151	10,440
Metro Transit bases & tunnel	105.0	-	2,743	3,169	61	2,308
Airport facilities	21.1	-	244	122	9	73
Parks facilities	29.4	-	3,165	4,905	39	3,691
totals	**329.3**	**218.3**	**15,897**	**22,173**	**260**	**16,512**

Table 19 – Energy consumption and GHG emissions from electricity and steam consumption in all county buildings.

method detail

The data sources for steam and electric use in the Buildings sector are essentially identical to those for natural gas use. See the Buildings sector under Scope 1 for the related method detail.

All reported Buildings sector emissions are as output by CACP.

Vehicle Fleet

King County maintains a fleet of electric trolley buses that are fueled with SCL electricity. Their energy use and associated emissions are in Table 20.

	electric energy TJ	**GHGs** $MgCO_2e$	**NO_x** kg	**VOCs** kg	**PM_{10}** kg
all trolley buses	65.0	751	375	29	226

Table 20 – Energy and emissions attributable to Metro Transit trolley buses.

method detail

Bus electricity use data **03-038** was provided by Joyce McEwen of DOT Metro Transit.

All reported Vehicle Fleet sector emissions are as output by CACP.

county contact

Joyce McEwen – see Scope 1 Buildings sector.

Streetlights

King County supplies streetlighting for portions of unincorporated King County. There is also a smaller amount of streetlighting in some cities that is operated by King County. Almost all electricity for streetlighting is sold by Puget Sound Energy, since very little of the lighting, if any, is within Seattle city limits. Table 21 tabulates electric energy consumed for streetlighting, and the associated emissions assuming that all electricity is purchased from PSE.

	electric energy GJ	GHGs $MgCO_2e$	NO_x kg	VOCs kg	PM_{10} kg
all streetlighting	18.0	2,074	3,233	26	2,435

Table 21 – Energy and emissions attributable to electricity powering streetlighting.

method detail

King County receives bills for streetlight electricity on a large number of accounts. Streetlight electricity is typically billed per lamp, and therefore many bills do not include energy quantities. Hence streetlight energy use is estimated from financial data.

Bill Blackburn of DOT's Road Services division has built a query for the county accounting system to retrieve total dollars spent in a given year on streetlighting. He reported $531,219.23 spent on streetlight electricity in 2003 (**03-034**). PSE's Schedule 53, for 250 watt bulb size, provided a nominal electric rate of 10.6¢/kWh assuming 4,200 hours/year of lamp operation. This calculation and the resulting estimate of 5,003,410 kWh energy consumption are documented in <03 master.xls>; this energy value was input to CACP to generate the final estimates of emissions.

county contact

Bill Blackburn
DOT / Road Services / Traffic Engineering / Administration and Budget
206-263-4703, bill.blackburn@metrokc.gov

Wastewater

The wastewater treatment plants and landfills all run electrical equipment, including heat & light for facility buildings, pumps, and other process equipment. The landfill electricity use is included here in the Wastewater sector because the CACP data structure does not allow the registration of electricity-related emissions in the Solid Waste sector.

At the wastewater treatment plants, the effluent pumps are typically the largest single consumer of electric energy. At South Plant in particular, discharging up to 280 million gallons per day through a 12-mile force main that ends 580 feet below sea level in the Puget Sound, consumes substantial energy. Additional energy is consumed by the off-site pumping stations that handle raw sewage on its way to the treatment plants. Table 22 summarizes electricity and emissions related to landfills and wastewater treatment plants.

plant	energy TJ	GHGs $MgCO_2e$	NO_x kg	VOCs kg	PM_{10} kg
Cedar Hills landfill	20.3	2,333	3,637	29	2,739
transfer stations and drop boxes	7.2	766	1,186	10	893
closed landfills	1.5	168	262	2	197
South Plant	216.2	24,892	38,812	309	29,226
East Section offsite systems	62.5	6,999	10,889	88	8,198
West Point plant	202.0	2,337	1,165	89	703
West Point offsite systems	69.9	1,307	1,239	36	876
Vashon plant	0.7	81	126	1	95
Vashon offsite systems	0.5	54	85	1	64
totals	**580.8**	**38,936**	**57,400**	**564**	**42,991**

Table 22 – Electricity consumption and related air emissions from waste processing.

method detail

South Plant and Vashon electricity use information was provided in a financial spreadsheet **03-027** by Edie Lackland at South Plant. West Point information was obtained from similar spreadsheets **03-017** and **03-019** maintained by Nancy Robbins. Greg Pelton supplied the electricity used by the landfill and other solid waste operations in **03-029**. All electric consumption data was entered into the Wastewater sector in CACP, to yield the reported emissions.

county contacts

Edie Lackland (South Plant) – see Wastewater sector of Scope 1.

Nancy Robbins (West Point) – see Wastewater sector of Scope 1.

Greg Pelton (landfills)
DNRP / Solid Waste / Finance and Administration
206-296-8467, greg.pelton@metrokc.gov

Other Electricity Purchases

The county is unable to precisely track all of its energy purchases. As a check on the upper bound of the inventory, gross purchase estimates are obtained from PSE and SCL. Table 23 shows the total quantities of gas and electricity the two vendors claim to have sold to King County, and the total quantities accounted for in the inventory. Table 24 tabulates the emissions associated with the unaccounted-for portions of electricity.

Electricity quantities in GJ	PSE	SCL
purchased according to vendor	497.8	735.9
accounted for in Inventory	450.5	547.3
unaccounted for in Inventory	**47.3**	**188.6**

Table 23 – Energy purchases unaccounted for in the bottom-up inventory.

	energy TJ	**GHGs** $MgCO_2e$	**NO_x** kg	**VOCs** kg	**PM_{10}** kg
Puget Sound Energy	47.3	5,450	8,498	68	6,399
Seattle City Light	188.6	548	273	21	165
totals	**236.0**	**5,998**	**8,771**	**89**	**6,564**

Table 24 – Emissions associated with unaccounted for electricity purchases.

This top-down check is not performed for steam purchases, because there are few enough facilities receiving steam that the county has an accurate estimate of the total steam use.

method detail

The gross values for electricity and gas use are retrieved from each vendor by contacting the county's account representative. Julia Green provided PSE sales data in **03-036**. Leighton Stewart provided SCL sales data.

vendor contacts

Julia Green (PSE) – see Other Fuel Purchases under Scope 1.

Rachelle Lewis (PSE – alternate)
Puget Sound Energy / Major Accounts
425-456-2856

Leighton Stewart (SCL)
Seattle City Light / Account Executive's Office
206-386-9153, leighton@pobox.com

Scope 3 – Other

Scope 3 emissions originate from any source that does not meet the requirements for being included in either Scope 1 or 2. The *GHG Protocol* leaves it to the discretion of the inventoried organization to define which sources will be included in Scope 3. Though this definition is highly flexible, it is important that once a decision is made, the same sources be included in Scope 3 each inventory year to allow comparable inventories. As of 2003, King County will be including the following three sources in Scope 3:

1. Employee commute (an ICLEI-required sector),
2. Employee private auto use and
3. Biosolids hauling.

Employee Commute

Most of King County's administrative offices are located in downtown Seattle with easy access to its own bus system. By providing bus system access as a benefit of employment, the county enjoys especially heavy use of mass transit by its staff for commuting, with roughly half of all passenger miles traveled (PMT) occurring in high-occupancy vehicles (HOVs). Table 25 details emissions attributable to employee commutes.

	PMT thousand miles	**energy** TJ	**GHGs** $MgCO_2e$	**NO_x** kg	**VOCs** kg	**PM_{10}** kg
SOV commuters	40,934	306.4	22,604	63,980	71,422	1,375
HOV commuters	41,704	107.5	7,982	47,162	13,616	1,813
totals	**82,637**	**413.9**	**30,586**	**111,142**	**85,038**	**3,188**

Table 25 – Emissions attributable to employee commutes.

In the table, commuters driving cars alone are labeled "SOV commuters" – single occupancy vehicle commuters. Commuters using carpools, vanpools, buses or trains are included among "HOV commuters" – high occupancy vehicle commuters. Those who walk, ride bicycles or telecommute are not included, as they are presumed not to cause air emissions.

method detail

Washington State's Commute Trip Reduction (CTR) law requires the county to survey facilities with 100 or more employees; the Washington State Department of Transportation (WSDOT) then processes the survey data to provide King County with statistics about these facilities and about the County's offices in general. King County performs its commuter survey in even-numbered years, and releases the data in the fall of the affected year. Respondents report their activity during the week in which they respond; the results therefore are nominally current-year.

Spreadsheet **03-010** was provided by Nina Schnell, and provides the CTR data from the most recent available survey, fall of 2002. The data was massaged in calculation file <03-010 modified.xls> to provide vehicle miles traveled (VMT) data for each vehicle type. The VMT data were entered into CACP, which then reported the associated emissions.

<u>**county contact**</u>

Nina Schnell
DOT / Transit / Service Development / Market Development
206-263-6084, nina.schnell@metrokc.gov

Employee Private Auto Use

In addition to their work commute, some King County employees use their vehicles for county business. King County reimburses these employees at the federal mileage reimbursement rate, which is designed to cover both fuel costs and automobile depreciation. Hence, employee vehicle use is similar to “outsourcing” a portion of the county’s transportation fleet needs, and the related emissions are therefore inventoried. The values appear in Table 26.

	VMT	**energy** TJ	**GHGs** $MgCO_2e$	**NO_x** kg	**VOCs** kg	**PM_{10}** kg
employee private auto use	1,529,059	11.4	844	2,390	2,668	51

Table 26 – Emissions attributable to employee private auto use. VMT is vehicle miles traveled.

<u>**method detail**</u>

Both ARMS and IBIS include records for employee auto use on county business; the corresponding account number is 53318. Mileage reported in the ARMS system was summarized in an “Account Selection Expense/Revenue Report” **03-001** generated at the intranet site <arms.metrokc.gov>.

Mileage reported in the IBIS system was summarized in report **03-004** generated by Lita Foster. Data from both accounting systems was converted from dollars to VMT using the federal reimbursement rate, as documented in <03 master.xls>. The VMT data were then entered into the CACP software.

<u>**county contacts**</u>

Kathy Washington (ARMS operation assistance)
see *Methodology - Operator’s Notes* above

Lita Foster (IBIS)
see *Methodology - Operator’s Notes* above

Biosolids Hauling

County-owned trucks haul biosolids from the wastewater treatment plants to farms and forestlands that benefit from the fertilizer value. The receiving lands include sites in the Cascades and eastern Washington, so emissions associated with biosolids trucking are substantial. In 2003, the fleet of 27 trucks hauled a total of 3,911 loads away from the treatment plants.

Though the biosolids hauling trucks are owned by the county, they are operated and maintained by a contractor. Hence the emissions associated with their use are not recorded in Scope 1 of the inventory. Table 27 below reports their Scope 3 emissions.

	VMT thousand miles	**energy** TJ	**GHGs** $MgCO_2e$	**NO_x** kg	**VOCs** kg	**PM_{10}** kg
biosolids hauling	1,350,000	40.4	3,015	22,975	2,107	1,004

Table 27 – Emissions due to contracted biosolids hauling

method detail

2003 fuel use for the biosolids haulers was provided by Mark Lucas in **03-109**. The resulting emissions were calculated in CACP.

county contact

Mark Lucas
DNRP / Wastewater Treatment / Planning & Compliance / Technology Assessment & Resource Recovery
684-1248, mark.lucas@metrokc.gov

Optional Information

Optional information is an inventory section formally defined by the *GHG Protocol*. It may include estimates of GHG emissions that are alternative to (*i.e.* they duplicate) estimates presented in Scopes 1, 2 or 3; estimates of GHG sequestration; values of GHG offsets purchased, sold or otherwise traded; or other, ancillary information that does not indicate a specific quantity of GHGs. *Optional Information* in this inventory includes the following items:

1. Emissions from contracted construction and operations,
2. Sequestration in solid waste,
3. Energy displacement credits from biogas,
4. Fertilizer displacement and soil carbon sequestration due to biosolids, and
5. Methane commitment due to solid waste disposal.

Emissions from Contracted Construction and Operations

King county contracts out most capital construction, and a substantial fraction of roads and facilities maintenance as well. The contracted parties produce substantial direct and indirect emissions during contract execution. Ideally, the county inventory would include such emissions in the Scope 3 inventory, but doing so would require that contractors supply inventories of fossil fuel, electricity, and GHG-intensive materials use associated with each project. No mechanism for acquiring such inventories exists, so capital construction emissions are instead estimated as optional information, using a very approximate method as follows.

The Economic Input-Output Life Cycle Assessment (EIOLCA) tool maintained by the Carnegie Mellon University Green Design Initiative allows estimates of air emissions based on national average emission factors for most common industries. EIOLCA is a life-cycle assessment tool, meaning that it estimates not only direct (Scope 1) and indirect (Scope 2) GHGs and pollutants, but also upstream emissions from all the manufacturers and service providers that supply that industry, and manufacturers and service providers that supply those industries, and so forth until the original energy or materials extraction is accounted for. Such a broad scope definition is not consistent with the scopes utilized in the King County inventory. EIOLCA assigns a much larger quantity of air emissions to a construction project, than would appear in the King County inventory if the county executed the same construction project itself.

Table 28a-d show the life-cycle emissions associated with 2003 contracts over $1 million. The four tables include contracts for new roads and parking, new buildings, roads maintenance and miscellaneous maintenance, respectively.

contract	title	amount mm$	GHGs $MgCO_2e$	NO_x kg	VOCs kg	PM_{10} kg
C23031C	Eastgate Park-and-Ride Expansion	13.3	14,436	65,289	11,063	44,624
C33092C	Base Parking Garage Construction	11.2	12,223	55,279	9,367	37,782
C33035C	Redondo Heights Park & Ride	4.0	4,303	19,462	3,298	13,302
C33116C	Edgewick Bridge Replacement	3.3	3,572	16,153	2,737	11,040
	Totals	**31.8**	**34,535**	**156,184**	**26,465**	**106,749**

Table 28a – Major roads & parking construction contracts in 2003.

contract	title	amount mm$	GHGs MgCO2e	NOx kg	VOCs kg	PM10 kg
C23006C	East Base Remodel	2.9	1,726	10,138	1,952	11,989
	Totals	**2.9**	**1,726**	**10,138**	**1,952**	**11,989**

Table 28b – Major facilities construction contracts in 2003.

contract	title	amount mm$	GHGs $MgCO_2e$	NO_x kg	VOCs kg	PM_{10} kg
C33019C	S. 277th St. Reconstruction Project - Ph. III (vic. West Valley Hwy. to Frontage Road)	8.3	8,261	37,836	6,206	45,041
C33016C	NE 124th St - Phase 2B (Willows Road NE to SR 202)	8.2	8,130	37,236	6,108	44,326
C33093C	124th Ave. NE (NE 132nd Street to NE 145th Place)	3.2	3,170	14,519	2,382	17,284
C33073C	2003 South County Asphalt Concrete Pavement Overlay	2.8	2,770	12,688	2,081	15,104
C33075C	2003 North County Asphalt Concrete Pavement Overlay	2.4	2,420	11,082	1,818	13,192
	Totals	**24.9**	**24,751**	**113,361**	**18,594**	**134,947**

Table 28c – Major road maintenance contracts in 2003.

contract	title	amount mm$	GHGs $MgCO_2e$	NO_x kg	VOCs kg	PM_{10} kg
C33089C	Cedar Hills Landfill - Area 5 Stage 3 Closure & Area 6 Phase 2 Development	11.9	6,461	44,591	7,213	65,322
C23097C	South Plant - Installation of High Solids Dewatering Centrifuges	8.3	4,490	30,992	5,013	45,401
C33055C	Renton Transfer Station Roof Replacement & Safety Improvement Project	1.1	595	4,107	664	6,017
	Totals	**21.3**	**11,546**	**79,691**	**12,891**	**116,740**

Table 28d – Other major maintenance contracts in 2003.

In addition to the $80.9 million of 2003 contracts shown in Table 28a-d, $10.5 million of large contracts are unlisted because they did not fit into one of the four EIOLCA classes being used for the county analysis.

method detail

A listing **03-047** of contracts with a 2003 Notice of Selection date was generated by Jeremiah Sullivan of the Finance & Budget Office. The contract list was winnowed to include only contracts over $1 million in value, and these were each assigned one of four EIOLCA sectors, or no sector at all. The four EIOLCA sectors are as shown in the table below:

			emissions per million $ activity			
EIOLCA sector	**short title**	**full title**	**GHGs** $MgCO_2e$	**NO_x** kg	**VOCs** kg	**PM_{10}** kg
110400	new roads & parking	New highways, bridges, and other horizontal construction	1,087	4,916	833	3,360
110800	new buildings	New office, industrial and commercial buildings construction	595	3,496	673	4,134
120214	roads maintenance	Maintenance and repair of highways & streets	993	4,548	746	5,414
120300	misc. maintenance	Other repair and maintenance construction	541	3,734	604	5,470

For each contract to which one of the four EIOLCA sector numbers was assigned, the total value of the contract was multiplied by the emission factors listed to estimate total, life-cycle emissions associated with the contract. The calculations are documented in calculation file <03 contracts.xls>. The emission factors listed above were calculated on-line at <www.eiolca.net>, as documented in **03-103**, **03-104**, **03-105** and **03-106**. CACP was not utilized for estimating contract-related emissions.

county contact

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Sequestration in Solid Waste

As discussed in *CO2 from Biological Products* above, the biodegradable portion of solid waste is presumed to be derived from renewable biological sources that are constantly fixing atmospheric carbon. So the portion that fails to biodegrade in the landfill effectively sequesters atmospheric carbon underground.

waste category	**fugitive methane commitment** $MgCO_2e$	**biodegradable carbon sequestered** $MgCO_2e$
paper products	44,051	191,164
food waste	21,495	14,330
plant debris	3,289	40,626
wood/textiles	8,652	121,126
other	0	0
totals	**77,487**	**367,246**

Table 29 – Sequestration associated with waste discarded in 2003. The fugitive methane commitment from Table 32 is included for comparison purposes only.

The carbon mass trapped underground originated as CO_2 from the global carbon cycle, that was fixed in cellulose or other organic matter through photosynthesis. Hence landfill sequestration is calculated as a mass-equivalent of CO_2 extracted from the atmosphere (not as CH_4 avoided).

Table 29 details sequestration associated with the organic portions of King County's waste stream. The total of 367,246 $MgCO_2e$ may at first glance seem unreasonably large. But the county buries some 600,000 Mg of organic waste each year, of which between one quarter and one half of the mass (150,000 – 300,000 Mg) is carbon. Since the mass of a CO_2 molecule is 3.67 times the mass of C alone, that carbon represents some 550,000 to 1.1 million $MgCO_2e$. That less than 400,000 $MgCO_2e$ of this should remain buried in the well-lined Cedar Hills landfill is in fact quite reasonable, if not conservative.

method detail

Data sources and contacts are identical to those in the *Solid Waste* section of *Scope 1*, above. To generate the sequestration values reported here, the "USA sequestration only" coefficient set was chosen in the "Coefficients" tab in the lower left of the CACP record screen for the Solid Waste sector.

Energy Displacement Credits from Biogas

Both wastewater treatment plants generate digester gas in the anaerobic portion of the treatment process. Digester gas is a combustible gas composed of approximately 60% methane, 35% CO_2, and a number of trace gases.

South Plant scrubs the biogas by allowing the CO_2 and trace gases into solution in water, and returning the water to the secondary treatment system. The remaining, scrubbed, nearly pure methane is injected into the Puget Sound Energy pipeline and mixed with the natural gas supply.

	energy value sold TJ	**GHGs displaced** $MgCO_2e$
South Plant pipeline injection	295.2	14,055
West Point cogeneration	51.5	594

Table 30 – GHG displacement attributable to digester gas use at wastewater treatment facilities.

In 2003, the South Treatment Plant sold 295 TJ of methane to Puget Sound Energy. 295 TJ of methane, when burned, produces 14,055 $MgCO_2$. The injection of the methane into the Puget Sound Energy system prevents the combustion of an equal value of natural gas, which would have yielded an equal quantity of CO_2. The CO_2 generated by combusting the methane from the digester is biogenic, while CO_2 that would have been generated by combusting natural gas is anthropogenic. Hence the sale of the biogas has an associated GHG benefit of 14,055 $MgCO_2e$.

The West Point Treatment Plant does not sell digester gas to an outside customer. Instead, most of the digester gas is used to generate electricity, which is sold to the local electric utility, Seattle City Light. In 2003, 52 TJ of electricity was sold. If this electricity had been generated by SCL instead, then approximately 594 $MgCO_2e$ would have resulted. Hence, the sale of electricity to SCL has an associated GHG benefit of 594 $MgCO_2e$.

method detail

Data describing waste treatment division operations are compiled each year in a "WTD at a Glance" document, **03-030** for 2003. This was supplemented with direct input from plant managers **03-056**. The GHG emission rate from SCL electricity was retrieved from the CACP 2003 user-defined coefficients, but all other calculations are documented in <03 master.xls>.

county contacts

http://dnr-web.metrokc.gov/wtd/WTDWeb/Editor/WTDGlance.html (WTD at a Glance)

Dick Finger (West Point digester gas fates)
see *Wastewater* in *Scope 1 – Direct Emissions* above

Carol Nelson (South Plant digester gas fates)
see *Wastewater* in *Scope 1 – Direct Emissions* above

Fertilizer Displacement and Soil Carbon Sequestration Due to Biosolids

In 2003 the South Plant and West Point wastewater treatment plants produced a total 117,400 wet Mg of biosolids. Biosolids are the solid output of the anaerobic portion of the wastewater treatment process, as described in the *Wastewater* section of *Scope 1 – Direct Emissions* above. Biosolids contain almost all of the remaining organic (carbon-based) solids that entered the plants from the sewer system, but were not digested to gaseous carbon dioxide in the aerobic portion of the plant, or to gaseous methane in the anaerobic portion.

The mass of the biosolids as delivered by each plant varies from 16% to 28% solids; the remaining mass is water. The 117,400 wet Mg of biosolids produced in 2003 included approximately 24,062 dry Mg of actual solids after the mass of the water is discounted. It is this dry mass that is relevant for calculations of GHG displacement by biosolids, as only the dry mass contains the nutrients (fertilizer value) that gives biosolids their value.

Table 31 shows the relative dry masses of 2003 biosolids that were used for fertilizer substitution, firsthand fertilization, and compost production.

	biosolids used dry Mg	**GHGs displaced** MgCO$_2$e
fertilizer substitution	16,086	15,405
firsthand fertilization	6,725	4,928
compost production	1,251	275
totals	**24,062**	**20,609**

Table 31 – Fate of biosolids produced in 2003, and associated GHG reductions.

Biosolids used for fertilizer substitution are applied to agricultural lands that would otherwise be fertilized with commercial nitrogen and phosphorus fertilizers. The associated GHG displacement arises from a combination of two factors: first, GHG-intensive commercial fertilizer production is avoided and second, carbon in the applied biosolids is permanently stored in the soil.

Biosolids used for firsthand fertilization of forests and rangelands are applied to lands that would not otherwise receive nutrients. For this use, there is no GHG benefit from displacing commercial fertilizer, but the value of soil carbon sequestration remains, and this is the value show in Table 31. For protected forestland, firsthand fertilization may yield an additional GHG sequestration benefit due to enhanced tree growth, but the lands receiving King County biosolids are unlikely to be sufficiently protected to claim this benefit.

Biosolids used for compost production also result in permanent storage of some carbon in the soil. This carbon sink has no value if in the absence of the biosolids composting program, some other source of compost would increase soil carbon equally. Hence, the portion of GHG displacement listed above for compost production should be considered provisional.

method detail

Fates of biosolids in 2003 were compiled in <03 master.xls> from the Biosolids Program annual report **03-046** and supporting spreadsheets **03-045**. GHG displacement and sequestration factors were taken from journal articles **03-040** and **03-044**, as summarized here:

	sequestration factor MgCO$_2$e/dry Mg
commercial fertilizer displacement	0.22
soil carbon amendment	0.73
compost carbon amendment	0.22

The journal articles were co-authored by professor Sally Brown of the University of Washington, and Peggy Leonard of the King County Biosolids Program, so are the most appropriate source for the displacement factors. However, widely varying estimates of these factors exist elsewhere in the literature.

All calculations relating to biosolids are documented in <03 master.xls>; the CACP software was not used.

county contact

Peggy Leonard
see *Biosolids Application* in *Scope 1 – Direct Emissions*.

research contact

Sally Brown
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Methane Commitment Due to Solid Waste Disposal

	2003 quantity landfilled		**fugitive methane commitment**
waste category	wet tons	%	MgCO$_2$e
paper products	227,471	23.2%	44,051
food waste	195,578	20.0%	21,495
plant debris	52,789	5.4%	3,289
wood/textiles	157,655	16.1%	8,652
other	345,344	35.3%	0
totals	**978,836**	**100.0%**	**77,487**

Table 32 – Methane commitment associated with waste discarded in 2003.

The county's 2003 *methane commitment* equals all of the GHGs that will be emitted in the future, due only to the waste placed in the landfill during 2003. The methane commitment correlates poorly with actual emissions in 2003, but correlates well to the impact that consumer and government behavior during the inventory year will have on future GHG emissions. Methane commitment is useful for the purpose of setting waste handling policy.

Direct, 2003 emissions attributable to the Cedar Hills landfill are reported in *Scope 1 – Direct Emissions* above.

In 2003, King County disposed all collected waste in the Cedar Hills landfill according to the distribution shown in Table 32.

The *paper products*, *food waste* and *plant debris* categories are self-explanatory. The *wood/textiles* category includes dimensional lumber, wood from construction and demolition waste, clothes, carpet, upholstery, and diapers (which account for an incredible 2.7% of the county's total waste stream). It is assumed that plastics, glass, metals and other wastes falling in the *other* category are non-biodegradable and therefore do not cause GHG emissions.

The methane commitment is a fugitive methane commitment, that is it accounts only for methane that escapes the landfill uncombusted. Thus, the calculation presumes high quality management of the Cedar Hills landfill indefinitely, maintaining the 90% capture efficiency that is used for the Scope 1 calculations. If methane capture & destruction improve or degrade in the future, then the true methane emissions will deviate accordingly from the methane commitment calculated here.

method detail

The four waste categories listed are the four categories provided by the CACP software, that are designed to encompass all biodegradable wastes.

Total 2003 tonnage **03-008**, and a copy of the most recent waste sort **03-009** were provided by Alexander Rist. In <03-009 modified.xls>, each of the fine categories used in the waste sort was assigned to one of the four categories provided by the CACP software, or to "other." This provided gross percentages for each of the four categories, which could then be entered along with 2003 total tonnage into the Government Analysis module of the CACP software. CACP calculates methane commitment as the default value for emissions associated with solid waste.

The CACP software blends methane commitment and carbon sequestration factors in a single coefficient set labeled "USA Default." Two custom coefficient sets "USA emissions only" and "USA sequestration only" were created that zeroed the sequestration and emissions factors, respectively, of the "USA Default" set. To generate the methane commitment values reported here, the "USA emissions only" coefficient set was chosen in the "Coefficients" tab in the lower left of the CACP record screen for the Solid Waste sector. This allowed segregation of emissions reported in this section, from sequestration reported in *Sequestration in Solid Waste* below.

county contact

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Geographic Inventory

In contrast to the government inventory, the geographic inventory is not divided into scopes, since the inventory boundary is clear and singular. All of King County's geographic inventories are derived from inventories conducted by the Puget Sound Clean Air Agency (PSCAA).

GHG Emissions

Table 33 displays the 2003 geographic GHG inventory as well as historical inventories from 1999 forward.

GHG emissions in $MgCO_2e$	**1999**	**2002**	**2003 (est.)**
stationary combustion			
large stationary combustors	755,924	957,758	1,036,370
small stationary combustors	4,381,791	5,978,091	6,630,294
energy generation	234,524	172,993	156,306
mobile sources			
on-road mobile sources	12,571,127	12,038,396	11,940,632
diesel marine mobile sources	532,265	542,713	546,241
aircraft & ground support	798,764	407,210	325,301
other non-road mobile sources	1,256,424	1,432,480	1,539,439
other			
industrial process emissions	695,270	601,013	579,787
livestock & manure	177,324	69,470	50,832
landfills	--	157,157	156,748
TOTALS	**21,403,413**	**22,357,281**	**22,961,951**

Table 33 – Geographic GHG inventories of King County, 1999-2003. 2003 values are estimated from 1999-2002 growth rates, except for landfills. Landfill emissions were calculated directly at King County in 2000 and 2003; 2001 and 2002 data are geometrically interpolated from these.

Currently, PSCAA compiles and reports GHG inventories for the four counties in its domain (King, Kitsap, Pierce and Snohomish) on a triennial basis. The first contemporary inventory was conducted in 1999, and the second in 2002.[4] King County estimated the 2003 inventory from 1999-2002 growth rates.

PSCAA is not a CCP participant, and does not categorize emissions in the same sectors. As a convenient reference, a brief explanation of each inventory category used by PSCAA follows below. Full methodology descriptions appear in the PSCAA inventory report.

large stationary combustors – This group Includes all fossil fuel combustion sources required to report emissions to PSCAA each year, except energy generators. These are

4 A 1990 inventory was also conducted simultaneously to the 1999 inventory, but is not used by the county for calculating growth rates due to its lower accuracy.

defined as sources that emit 25 tons or more of CO, PM_{10}, NO_x or VOCs; or 6 tons of all hazardous air pollutants (HAPs); or 2 tons of any one HAP in a given year.

small stationary combustors – All stationary fossil fuel combustors that are not electric generators and do not qualify as large stationary combustors.

energy generation – Electricity and steam generators.

on-road mobile sources – Cars, light trucks, heavy trucks and motorcycles. Includes gasoline and diesel models.

diesel marine mobile sources – All diesel boats. The vast majority of emissions are from commercial vessels, but a few diesel recreational boats also contribute.

aircraft & ground support – It is assumed that 8% of the fuel loaded into aircraft at Sea-Tac airport is burned in the county during takeoffs and landings. For local airports serving small craft, it is assumed that all fuel loaded into aircraft is burned within the county. Emissions from ground support equipment are estimated based on Sea Tac's inventory of such equipment.

other non-road mobile sources – Includes heavy and light off-road equipment, locomotives, gasoline boats, and LPG and CNG vehicles.

industrial process emissions – CO_2 emissions from cement calcination and SF_6 emissions from electric power distribution equipment.

livestock & manure – This category includes CH_4 emissions from enteric fermentation, and CH_4 and N_2O emissions from manure mangement.

landfills – All active and legacy landfills in King County. The great majority of these emissions are accounted for in the *Solid Waste* sector under *Scope 1* in the government inventory.

method detail

Kwame Agyei of PSCAA provided the 2002 inventory document **02-001**. The values reported for King County in this report were mapped onto the categories that were used in PSCAA's 1999 report. This mapping was necessary in order to calculate category-by-category growth rates for the purpose of estimating the 2003 inventory. The mapping is numerically documented in <02 master.xls>, and systematically documented here:

category from Table 33	1999 category nomenclature per <02-003>		2002 category nomenclature per <02-001>
large stationary combustors	other point sources	C.1	point sources
small stationary combustors	other stat area burn	C.2	area sources
energy generation	power utilities	C.3	electric generators
on-road mobile sources	onroad gasoline	B.1	on-road vehicles: gasoline
	onroad diesel	B.1	on-road vehicles: diesel
diesel marine mobile sources	diesel marine	B.2	marine vessels and boats: diesel
aircraft & ground support	aircraft & GSE/APU	B.3	aircraft & ground support
other non-road mobile sources	other nonrd diesel	B.4	locomotives
		B.5	miscellaneous non-road: diesel
	nonroad gasoline	B.2	marine vessels and boats: gasoline
		B.5	miscellaneous non-road: 4-st gas
		B.5	miscellaneous non-road: 2-st gas
	nonroad LPG	B.5	miscellaneous non-road: LPG
	nonroad CNG	B.5	miscellaneous non-road: CNG
industrial process emissions	cement calcination	D.1	cement production
	elect distrib SF_6	D.3	other processes: SF_6
livestock & manure	livestock	E.2	livestock & manure
landfills	landfills	E.4	landfills
non-IPCC compliant categories	power purchases	C.4	indirect from electricity
	resid wood burning	E.6	residential wood combustion
	open burning	E.1	open burning
new categories as of 2002		C.5	fugitive pipeline methane
		D.3	other processes: Nucor Steel, dolomite, semiconductors, inorganics, other organics, petrochemicals
		E.3	soil cultivation
		E.5	water/sewage

The PSCAA categories power purchases (C.4), residential wood burning (E.6) and open burning (E.1) are not IPCC-compliant and were not included in the geographic inventory reported here. Power purchases are not included in IPCC geographic inventories because this would lead to double-counting of GHG sources in the location where the power was generated. Residential wood burning and open burning are not included in IPCC geographic inventories because the fuel source is biological so the associated CO_2 emissions are not characterized as anthropogenic.

New categories that IPCC added in the 2002 inventory are also not included, because there was insufficient data available to create a projection to 2003. The new categories will be included in the 2005 inventory and onward, when sufficient PSCAA data will allow the calculation of growth rates and associated projections.

Values for the landfills (E.4) category are replaced with values calculated for the government inventory above. This is possible because the government inventory takes responsibility for all landfills in the county. The landfill emissions values calculated for the government inventory are more precise than those estimated by PSCAA. Furthermore, PSCAA debits the county for fugitive CO_2 from the landfill, which is also not IPCC-compliant.

PSCAA contact

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GHG Sequestration

	stock	accumulation	
	MgC	MgC	$MgCO_2e$
forest industry	13,081,010	-108,793	-398,627
misc. private	9,702,925	9,175	33,619
state	8,285,548	-10,283	-37,679
other public	9,738,032	203,862	746,969
forest service	14,780,568	131,537	481,965
totals	**55,588,084**	**225,498**	**826,247**

Table 34 – 2003 forest carbon stock and accumulation in geographic King County. Stock is the total biomass in the forests; accumulation is the incremental increase in biomass during the inventory year.

King County encompasses some 1.4 million acres, of which about 800,000 are forestland. Forestland absorbs CO_2 as the trees and other vegetation grow, locking up the associated carbon in the forest biomass. The county's 800,000 acres currently support about 56 million metric tons of biomass carbon.

Each year, some lands experience net growth, and others a net decline in biomass. Growth means that additional CO_2 is being converted to trees and vegetation, while decline means harvest or decay is removing carbon from the forest for a most likely fate of becoming CO_2 again. In 2003, King County's forest land probably experienced a net increase in carbon storage of approximately 230,000 metric tons, or an equivalent GHG sequestration of about 830,000 $MgCO_2e$. These estimates are derived from projections made in a 2002 study; they are not measured values.

Each year King County also experiences substantial sequestration in the large Cedar Hills landfill. In 2003 approximately 367,246 $MgCO_2e$ were sequestered in the form of biomass-derived materials that are not expected to decay to landfill gas or leachate. See section *Optional Information* in the government inventory for a more detailed description of landfill sequestration.

method detail

County-wide sequestration in forestland is inventoried in **03-076**, which includes an estimate for 2000 values and a projection for 2005 values. In <03-076 modified.xls>, geometric growth rates are calculated separately for the five land ownership categories. These growth rates were used to interpolate the stock and accumulation for the intermediate year 2003.

county contact

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Criteria Pollutant Emissions

PSCAA's 2002 King County criteria air pollutant inventories are summarized in Table 35. PSCAA does not conduct a complete inventory of criteria pollutants every year, so King County reports the most recent year for which a complete inventory occurred.

all values in Mg	NO_x	VOCs	$PM_{2.5}$
on-road vehicles	52,952	38,182	930
non-road vehicles	19,807	11,184	1,230
large stationary sources	4,572	1,700	174
other	4,326	32,261	5,956
totals	**81,658**	**83,327**	**8,291**

Table 35 – King County geographic inventories of NO_x, VOCs and $PM_{2.5}$.

PSCAA inventories $PM_{2.5}$ rather than PM_{10} emissions; the particulate matter emissions would have greater values if PSCAA was inventorying the more widely defined PM_{10}.

NO_x emissions are predominantly due to vehicles, as they are in the government inventory.

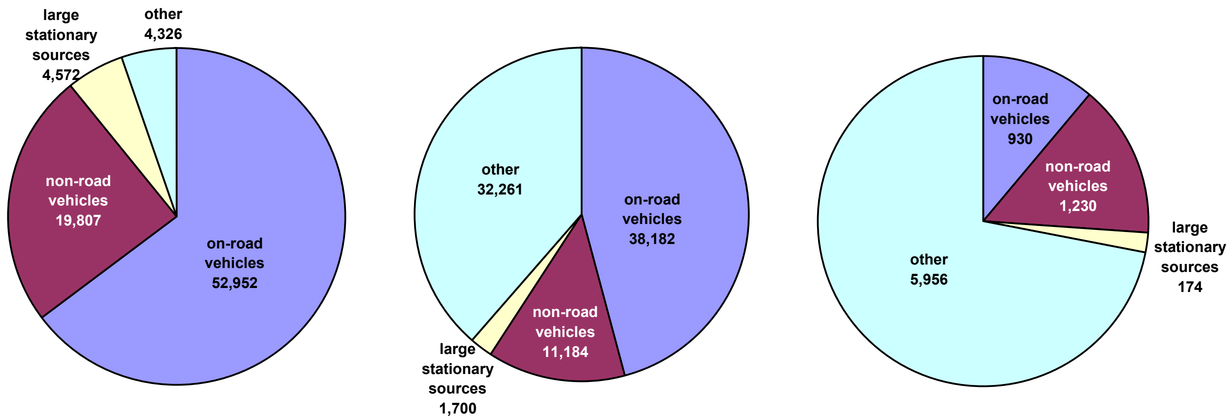
Though VOCs are also caused substantially by vehicles, the "other" category is another significant contributor. The largest VOC sources included within this category are indoor, residential wood burning and volatile substances such as paint and cleaning products.

Vehicles contribute very little to the $PM_{2.5}$ inventory. Again indoor, residential wood burning is a primary source, though dust from roads and land clearing are equally important sources.

The details of emissions falling under the "other" category for all of the criteria pollutants are summarized in Table 36. All of the emissions are visually summarized in Figure 7.

all values in Mg	NO_x	VOCs	$PM_{2.5}$
open burning			
wildfires & forest mgmt.	30	60	103
structure burns	2	18	16
agricultural burns	11	72	77
fossil fuel combustion			
industrial	1,112	17	74
commercial	1,109	31	112
residential	1,564	86	130
other combustion			
commercial cooking		111	767
commercial incineration	4	1	3
indoor wood burning	233	7,365	1,586
land clearing	247	250	957
fugitive dust			
paved roads			554
unpaved roads			647
construction			927
volatile substances			
architectural coatings		2,492	
indoor surface coatings		4,367	
decreasing & cleaning		7,255	
consumer products		6,081	
solvent storage & distribution		4,054	
landfills	13	1	2
totals	**4,326**	**32,261**	**5,956**

Table 36 – Detail of the "other" category in the geographic inventory of criteria air pollutants.



NO_x
81,658 Mg total

VOCs
83,327 Mg total

$PM_{2.5}$
8,291 Mg total

Figure 7 – Criteria air pollutant emissions in the geographic inventory.

Appendix A:
Standard factors used in GHG calculations

molecular mass ratios			
CO_2/C	3.664	[unitless]	
CO_2/CH_4	2.743	[unitless]	
100-year global warming potentials (from Second Assessment Report)			
CO_2	1	[unitless]	
CH_4	21	[unitless]	
N_2O	310	[unitless]	
higher heating values of fuels			
gasoline	36.1	MJ/L	
diesel	39.1	MJ/L	
natural gas	0.0391	MJ/L	at 1 atmosphere, 15 degC
propane	25.2	MJ/L	
carbon content of fuels			
gasoline	18.3	g/MJ	
diesel	18.9	g/MJ	
natural gas	13.0	g/MJ	
propane	16.1	g/MJ	
energy equivalents			
gallon gasoline equivalent	137	MJ	
kWh	3.60	MJ	
mmBtu	1,054	MJ	
therm	105	MJ	

Appendix B:
2000-to-2003 government inventory category crosswalk

	2003 inventory	
2000 inventory nomenclature	**Scope**	**Sector**
Direct Emissions		
Municipal Solid Waste		
Cedar Hills Landfill	Scope 1	Solid Waste
Closed Landfills	Scope 1	Solid Waste
Mobile Sources		
Metro Buses	Scope 1	Vehicle Fleet
County Fleet - (gas and diesel)	Scope 1	Vehicle Fleet
	Scope 3	Other
Lawn and Garden	Scope 1	Other
Miscellaneous Fuel Use	*not inventoried*	
Employee Auto Use for County Business	Scope 3	Other
Municipal Wastewater Treatment		
Renton Treatment Plant	Scope 1	Wastewater
West Point Treatment Plant	Scope 1	Wastewater
Vashon Treatment Plant	Scope 1	Wastewater
Biosolids	Scope 1	Other
Area Sources (Evaporative Emissions)		
Paint (Interior/Exterior)	Scope 1	Other
Traffic Paint	Scope 1	Other
Cleaners	Scope 1	Other
Auto Products and Misc. Solvents	Scope 1	Other
Road Paving/Repair materials	Scope 1	Other
Pesticides	Scope 1	Other
On-site Energy		
Propane	Scope 1	Buildings
Natural Gas	Scope 1	Buildings Wastewater
Indirect Emissions		
Electricity (Seattle City Light)	Scope 2	Buildings Vehicle Fleet Wastewater/Solid Waste Other
Electricity (Puget Sound Energy)	Scope 2	Buildings Wastewater/Solid Waste Other
Steam (Seattle Steam)	Scope 2	Buildings
Mobile Sources		
Employee Commute	Scope 3	Employee Commute
Lawn and Garden	*not inventoried*	
Heavy Equipment	Optional Info	
Municipal Solid Waste		
Employee Waste	*not inventoried*	
Area Sources		
Road Paving/Repair materials	Optional Info	
Pesticides	*not inventoried*	
Cleaners	*not inventoried*	
Paint	*not inventoried*	
New items not in the 2000 inventory		
balance of gas purchases	Scope 1	Other
streetlights	Scope 2	Streetlights
balance of electricity purchases	Scope 2	Other
large construction contracts	Optional Info	
methane commitment from solid waste	Optional Info	
biosolids offsets & sequestration	Optional Info	
sequestration in solid waste	Optional Info	

Appendix C:
Relationships to waste management GHG measures

The King County Solid Waste Division (SWD) participates in the EPA *WasteWise* program, which provides the county with annual estimates of GHG reductions achieved with recycling and reduction programs. The numbers reported by *WasteWise* are calculated with a model known as *WARM*. *WARM* is available to the public free of charge, and is sometimes used by waste managers to calculate GHG reductions associated with recycling and reduction programs directly.

The CACP software tool used to calculate the county's government inventory is based on emission factors provided by the EPA, but does not easily reconcile with GHG reductions reported by *WasteWise* or *WARM*. The reasons for the discrepancies are described here.

Waste-in-Place vs. Methane Commitment

There are two, fundamental methods of accounting GHGs attributable to landfills: waste-in-place and methane commitment.

The waste-in-place method estimates landfill emissions during a specific interval of time. Waste decays slowly, emitting methane at the highest rate during its first year in the landfill but continuing to emit smaller amounts of methane for 30 years or more. The waste-in-place method accounts for this by summing the contributions from all the waste placed in prior years, to estimate the emissions during an inventory year. The waste-in-place method is used in Scope 1 of the government inventory to estimate the emissions from Cedar Hills and from the closed landfills during calendar year 2003.

The methane commitment method estimates the total contribution a given quantity of waste will make to a landfill's emissions, over all time. Even though the methane commitment method does not estimate real emissions at a specific point in time, it does appropriately quantify what the presence or absence of the waste will do to the climate over the long run. For this reason waste managers typically prefer the methane commitment method, because it most accurately describes the effects that 3R (reduce, reuse, recycle) programs will have on GHG emissions.

Differences between CACP Software and *WARM*

The CACP software used to calculate the county's inventory provides separate mechanisms for applying the waste-in-place and methane commitment methods. The waste-in-place method is used to generate the actual emissions in the inventory year, reported in Scope 1. Separately, an estimate of future GHG emissions due to the year's waste disposal is reported in Optional Information, using the methane commitment method. The emission factors used by the CACP software to make these calculations were provided by the U.S. EPA, which also stewards *WARM*.

WARM (*WAste Reduction Model*) uses the methane commitment method. However, rather than estimating an absolute methane commitment from a certain quantity of solid waste, *WARM* estimates a differential methane commitment due to a change in waste management. *WARM* requires the user to input a "baseline" waste management scenario and an "alternative" scenario, and then reports the differential methane commitment between the two. The model also estimates differential changes in upstream emissions from the change in management scenario. Changes in upstream emissions are due to reductions in materials extraction, fabrication and transportation when objects are reduced or recycled instead of discarded.

Even though the CACP software and *WARM* both use EPA coefficients, they do not produce comparable results. The CACP-calculated methane commitment reported in Optional Information is absolute rather than differential. It is the gross commitment due to all the waste discarded in the inventory year. It does not include the upstream emissions that *WARM*'s differential analysis does, because these are of dubious meaning in an absolute analysis. For this reason, a differential methane commitment calculated by subtracting adjacent years of the King County inventory still will not agree with a *WARM* analysis of the same two years.

Of course, the waste-in-place emissions reported in Scope 1 of the inventory bear almost no relationship to a *WARM* analysis at all. Differential waste-in-place emissions calculated by subtracting adjacent years of the King County Scope 1 inventory mostly reflect growth or reduction in the total mass of buried organic waste that is contributing to methane reduction. Such a differential is only weakly related to a differential methane commitment.

Relationship to WasteWise

The EPA's *WasteWise* public assistance program supplies participants with annual estimates of GHG reductions achieved through 3R programs. The EPA contracts the environmental consulting firm ERG to operate *WARM* on behalf of *WasteWise* participants. *WasteWise* participants are not asked to provide details regarding the waste management facilities they use, other than identifying them as either composting, combustion or landfill facilities. As a result, ERG assumes national average treatment. Where a participant identifies landfilling as a fate, only 49% of the resulting methane is presumed to be generated in a landfill that combusts it.[5]

However Cedar Hills landfill is a fully lined and capped facility with an active gas collection system that likely capture more than 90% of the generated methane. Within two years Cedar Hills will also boast a landfill gas-fired electric generator rather than a flare. The GHG benefit of a reduction in waste destined for the Cedar Hills landfill is much smaller than the GHG benefit of a reduction in waste destined for the national average of landfills. Hence, the GHG reduction estimates we receive from *WasteWise* are overestimates of the actual reduction achieved.

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5 Email from Ronald Vance, ERG representing U.S. EPA, to R. Hammerschlag, King County, 6/30/04.

Appendix D:
Explanation of the nitrification-denitrification process

The chemical and biological processes through which nitrogen (N) atoms in biological waste are taken up in gaseous nitrous oxide (N_2O) molecules are multiform and complex. For a full explanation, please refer to a wastewater treatment textbook such as Metcalf & Eddy's *Wastewater Engineering – Treatment and Reuse*. What follows is a highly simplified description of only the most common process used deliberately in some wastewater treatment plants. For clarity, the simplified chemical equations below disregard charge states of the molecules (which in most cases are actually ions), and omit intermediate products.

King County does not attempt to cause nitrification and denitrification in its wastewater treatment plants; in fact the county specifically avoids it. However, some wastewater treatment plants deliberately induce the process because a low-nitrogen plant effluent is required, for instance in a region where eutrophication is a significant environmental issue. By inducing the process, such a wastewater treatment plant converts the biomass nitrogen into gaseous compounds (NO, N_2 and N_2O) that volatize and leave the process as an air emission rather than in the plant effluent.

The most common mechanism for generation of N_2O from N in biomass is nitrification followed by denitrification. Most biomass nitrogen is assimilated in the form of ammonia, NH_3. The first process, nitrification, converts the ammonia into nitrate and nitrite, NO_2 and NO_3 respectively. Nitrification is itself a two-step process. The first step produces nitrate:

$$NH_3 \rightarrow NH_2OH \rightarrow NO_2$$

and the second nitrite:

$$NO_2 \rightarrow NO_3.$$

Separate species of bacteria are responsible for the two steps. Most nitrifying organisms are aerobic autotrophs, meaning that they require the presence of oxygen, but do not consume biomass (do not require organic food). Since autotrophs do not eat, they get their energy instead through solar radiation or through energy embodied in chemical bonds in their environment. So the nitrification process does not consume significant biomass.

Denitrification reduces nitrate and nitrite to the gaseous compounds nitric oxide (NO), nitrous oxide (N_2O) and nitrogen gas (N_2):

$$NO_3 \rightarrow NO_2 \rightarrow NO \rightarrow N_2O \rightarrow N_2.$$

Most denitrifying organisms are anaerobic heterotrophs, meaning that they require the absence of oxygen, and consume biomass.

Since the nitrification-denitrification sequence requires aerobic conditions followed by anaerobic ones, it tends only to occur in dynamic environments. N_2O emissions are low over dry soils because conditions remain largely aerobic, while in wet climates intermittent, heavy rainfall can create the cycling, aerobic and anaerobic conditions that induce the nitrification-denitrification cycle.

Appendix E:
Excel macro code to process CACP output

The CACP report output includes numerous underutilized rows and splits out data by fuel type, a detail that is rarely utilized in the inventory document. The macros appearing on the following pages simplify the output so that it can be more easily imported into spreadsheets and tables. The macros are most easily used by opening the Excel workbook <CACP cleanup macros.xls> simultaneously with the CACP report workbook. The <CACP cleanup macros.xls> worksheets will not be visible because the workbook is defined to use a hidden window, but entries for the simplifyGHGOutput and simplifyCAPOutput macros will be visible under Tools --> Macro --> Macros.

<CACP cleanup macros.xls> should be in directory //Clean Air Initiative/CACP software/. If it cannot be found the macros can be recreated by cutting and pasting the code on the following two pages into a CACP report workbook. You will need to open a new macro in the VBA (Visual Basic for Applications) editor and paste in the code there. If you do not know how to work with the VBA editor, ask a Technology Unit employee for assistance.

To create a CACP report workbook, use the CACP Report menu item to bring up the “Government Analysis Report Options” dialogue box. Select “Detailed Report,” and select “Group First by Location,” then click Preview. On the preview menu bar, click the diskette icon to save a file, and choose “Excel spreadsheet (*.XLS)” under “File type.” Choose a filename and save. This will create a CACP report workbook that is ready to be cleaned up with one of the macros. Use the simplifyGHGOutput macro if you created a GHG report; use the simplifyCAPOutput macro if you created a criteria air pollutants report.

```
Option Explicit
Option Base 1

Sub simplifyGHGOutput()

Dim row As Integer
Dim sh As Range
Set sh = ActiveWorkbook.ActiveSheet.Cells

' Fix the mislabeled column header

Range("F5").Formula = "Equiv CO2"

' Delete unnecessary header rows

Rows("1:4").Delete
Rows("2:2").Delete    ' Row 2 used to be row 6

' Format columns
' Includes removing "Subtotal " from beginnings of group-level
'    subtotals, since the fuel-level detail is about to be
'    deleted anyway

Columns("A:C").ColumnWidth = 2
Columns("D").ColumnWidth = 40
Columns("D").Replace What:="Subtotal ", Replacement:=""
Columns("E:L").NumberFormat = "#,##0"

' Remove unused columns

Columns("G:I").Delete
Columns("H:J").Delete

' Loop through the rows and delete the fuel-specific line items.
' This is an uncontrolled loop; the subroutine will terminate
'    when it finds the "Total" line at the bottom of the
'    CACP rport.

row = 4
Do
   Do While ( _
         sh(row, 1) = vbNullString _
         And sh(row, 2) = vbNullString _
         And sh(row, 3) = vbNullString _
         And ((sh(row, 4) = vbNullString _
               And sh(row, 6) <> vbNullString) _
            Or (sh(row, 4) <> vbNullString _
               And sh(row, 6) = vbNullString)))
      sh(row, 1).Activate
      ActiveCell.EntireRow.Delete
   Loop
   If (sh(row, 1) = "Total") Then Exit Sub
   row = row + 1
Loop

End Sub
```

```
Sub simplifyCAPOutput()

Dim row As Integer
Dim sh As Range
Set sh = ActiveWorkbook.ActiveSheet.Cells

' Delete unnecessary header rows

Rows("1:4").Delete

' Format columns
' Includes removing "Subtotal " from beginnings of group-level
'    subtotals, since the fuel-level detail is about to be
'    deleted anyway

Columns("A:C").ColumnWidth = 2
Columns("D").ColumnWidth = 40
Columns("D").Replace What:="Subtotal ", Replacement:=""
Columns("E:L").NumberFormat = "#,##0"

' Remove unused columns

Columns("G:I").Delete
Columns("H:H").Delete

' Loop through the rows and delete the fuel-specific line items.
' This is an uncontrolled loop; the subroutine will terminate
'    when it finds the "Total" line at the bottom of the
'    CACP rport.

row = 4
Do
   Do While ( _
         sh(row, 1) = vbNullString _
         And sh(row, 2) = vbNullString _
         And sh(row, 3) = vbNullString _
         And ((sh(row, 4) = vbNullString _
               And sh(row, 6) <> vbNullString) _
            Or (sh(row, 4) <> vbNullString _
               And sh(row, 6) = vbNullString)))
      sh(row, 1).Activate
      ActiveCell.EntireRow.Delete
   Loop
   If (sh(row, 1) = "Total") Then Exit Sub
   row = row + 1
Loop

End Sub
```