Greenhouse Gas Emissions in King County

An Updated *Geographic-plus Inventory*, a *Consumption-based Inventory*, and an Ongoing Tracking Framework

Prepared for:
King County, Washington

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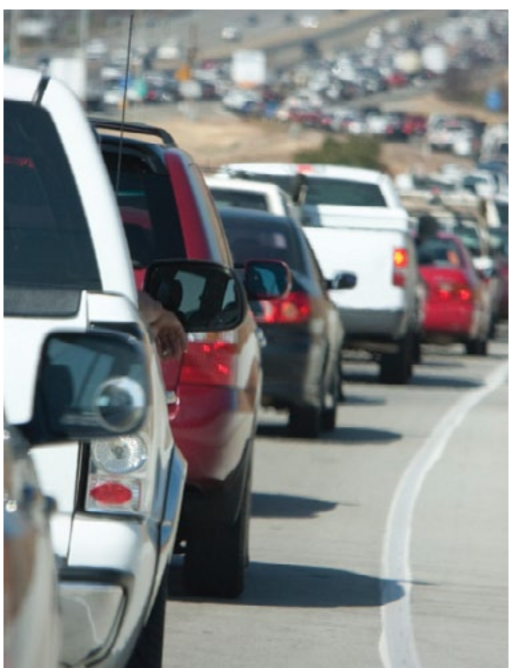

King County

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Executive Summary

There is scientific consensus, as documented by the United States National Academies and the Intergovernmental Panel on Climate Change, that human sources of greenhouse gases (GHGs) such as carbon dioxide and methane are causing unprecedented and severe changes in global and local climate systems. To avoid the most serious impacts to the environment, human health, and the economy, significant reductions in GHG emissions will be necessary. This will require bold action from local governments and communities up to national and international levels.

King County has adopted policies focused on responding to climate change, including making it one of three framework policies guiding King County's *Comprehensive Plan*. Additionally, the 2010 King County *Strategic Plan* formally adopted reducing GHG emissions and preparing for the effects of climate change as key County objectives.[1]

This report presents results from two different, but complementary, inventories of GHG emissions associated with King County, Washington.[2] The *Geographic-plus Inventory* estimates the annual GHG emissions released within King County's geographic boundary (it is called "plus" because it also includes some emissions outside the boundary, such as those associated with air travel and electricity generation). The *Consumption-based Inventory* uses a relatively new methodology to quantify the emissions associated with consumption of all goods and services by King County residents and governments (as well as certain business investments). This inventory includes emissions associated with production, transport, sale, use, and disposal of goods and services – no matter where they are produced. Emissions associated with goods and services made in King County but exported out of the region are excluded from the *Consumption-based Inventory*. This report also separately quantifies several additional sources and sinks of emissions – which don't fit neatly into either inventory – including those associated with carbon stored in forests and the emissions benefits of recycling. Finally, it develops and pilots a simplified and streamlined ongoing measurement framework to support King County in its efforts to assess key sources of GHG emissions in years between more comprehensive GHG inventories.

2008 Geographic-plus Inventory findings

- **GHG emissions rose 5 percent from 22.4 million metric tons of carbon dioxide equivalent (million MTCO$_2$e) in 2003 to 23.4 million MTCO$_2$e in 2008. On a per person basis, however, King County's GHG emissions were stable between 2003 and 2008.**
- **Per person GHG emissions of 12.4 MTCO$_2$e per King County resident are 20 percent less than the average Washington State resident (15.5 MTCO$_2$e) and about half the average U.S. resident (23.4 MTCO$_2$e).** Much of the difference in per person emissions can be attributed to abundant low-GHG emissions hydropower electricity sources and to the particular mix of industry in King County.
- **Transportation was the largest source of GHG emissions within King County**, representing 6.0 MTCO$_2$e per person. Cars and trucks were the largest source of transportation emissions at 4.7 MTCO$_2$e per person, but emissions from air travel were also significant at 1.2 MTCO$_2$e per person.
- **Heating and cooling both residential and commercial buildings was the second biggest source of emissions**, representing 4.3 MTCO$_2$e per person.

1 To learn more about King County's policies, as well as projects and programs that help the County meet their intent, visit www.kingcounty.gov/climate.

2 This includes the entire physical region from the Cascade Mountains to the Puget Sound, and the cities, towns, and unincorporated areas within, as opposed to only King County government agencies

- **Emissions from the waste sector, associated with landfill and wastewater treatment processes, represent less than 1 percent of total emissions in King County. Emissions associated with the production of goods and materials (some of which become part of the waste stream) can be significant, however**, and are part of the reason for also conducting the separate *Consumption-based Inventory*.
- **Emissions from industry, though significant, are much less than the national average**, largely due to the different mix of sectors present within King County. The difference in emissions is notable given that King County has about 30 percent more industrial activity (in dollar terms) per person than either Washington State or the United States.
- **Between 2003 and 2008 there was a 11 percent decline in per-person GHGs associated with vehicle travel by cars and light trucks.** These trends were due primarily to increasing fuel efficiency of passenger vehicles (up 5 percent) and decreased vehicle travel (down 7 percent per person). Absolute emissions associated with cars and light trucks also decreased slightly.
- **Overall, declines in per person emissions from vehicles were partially offset by increases in emissions associated with buildings and (to a lesser extent) air travel.** However, increased per person emissions from buildings are likely largely due to colder weather and associated higher heating demands in 2008 (up 11 percent) compared to 2003.

GHG emissions rose 5% from 22.4 million metric tons of carbon dioxide equivalent (million $MTCO_2e$) in 2003 to 23.4 million $MTCO_2e$ in 2008. On a per person basis, however, King County's GHG emissions were stable between 2003 and 2008.

Per person GHG emissions of 12.4 $MTCO_2e$ per King County resident are 20% less than the average Washington State resident (15.5 $MTCO_2e$) and about half the average U.S. resident (23.4 $MTCO_2e$).

2008 Consumption-based Inventory findings

- **This inventory used a cutting edge methodology to quantify – for the first time – the release of emissions associated with consumption in King County.** Consumption is defined as consumer spending, government spending, and business capital investments (and net accumulations to inventory). Emissions associated with consumption come from the production, transport, sale, use and disposal of goods (including food) and services.
- **Consumption-based GHG emissions were 55 million $MTCO_2e$ for King County, with per person emissions of 29 $MTCO_2e$.** Per person, this is more than twice as high as in the *Geographic-plus Inventory* and about four times higher than the global average.
- **From a consumption perspective, emissions associated with personal transportation are the single greatest category of emissions**, as in the *Geographic-plus Inventory*. However, consumption-based emissions associated with home energy (13 percent), food (14 percent), goods such as furniture and electronics (14 percent), and services such as health care and banking (14 percent) are nearly as large as emissions related to personal transportation (16 percent).
- **GHG emissions associated with *producing* goods and services (including materials and manufacturing) comprise more than 60 percent of all consumption-based emissions.** *Using* these goods and services (such as fueling a car or powering a refrigerator) represents more than 25 percent of consumption-based emissions. By contrast, transporting, selling, and disposing goods and services together represents less than 15 percent of consumption-based emissions.

- **The emissions *intensity* of producing different goods and services can vary dramatically.** Looking at emissions per dollar can help inform how to shift to lower-GHG consumption patterns. For example, study findings suggest that shifting spending from some GHG-intensive goods and services (such as clothing or electronics) to other categories (such as entertainment) could reduce GHGs.
- **Almost three quarters of emissions associated with consumption in King County are released outside King County, with about a quarter occurring internationally.** The distribution of emissions far beyond King County's boundaries reflects the complex international supply chains for many products.

Consumption-based GHG emissions were 55 million $MTCO_2e$ for King County, with per person emissions of 29 $MTCO_2e$. Per person, this is more than twice as high as in the Geographic-plus Inventory and about four times higher than the global average.

Almost three quarters of emissions associated with consumption in King County are released outside King County, with about a quarter occurring internationally.

Other Emissions findings

- Some key sources and sinks of emissions do not fit clearly into either the *Geographic-plus* or *Consumption-based* inventories and are quantified or discussed separately. These include emissions associated with some solid waste disposal, carbon stored in disposed waste, the emissions benefits of recycling and public transit, emission offsets retired by Seattle City Light, and biological carbon stored in forests.
- King County's high levels of recycling and composting helped avoid approximately 2.0 million $MTCO_2e$ (relative to if all that material was instead disposed) in 2008, primarily from avoiding new emissions associated with production and manufacturing of new materials. This is about 0.7 million $MTCO_2e$ better than if King County was recycling and composting at national average rates. Quantifying and tracking recycling and composting benefits separately highlights the impact these programs have in reducing emissions.
- King County forests sequester a net of approximately 0.4 million $MTCO_2e$ annually due to tree growth.

Differences between the Geographic-plus and Consumption-based inventories

The *Geographic-plus inventory* includes emissions associated with goods and services produced in King County (regardless of where they are consumed), whereas the *Consumption-based Inventory* includes emissions associated with goods and services consumed here (regardless of where they are produced). Most of the difference between the Geographic-plus and Consumption-based inventories can be attributed to the fact that in King County, we consume more emissions-intensive goods (such as vehicles and food) than we produce.

Neither the Geographic-plus nor the *Consumption-based Inventory* method is the "right" method for all contexts. The *Geographic-plus Inventory* is better suited for tracking emissions associated with buildings, both residential and commercial, as well as for local vehicle transportation. However, it fails to capture the GHG emissions impact of many of the important purchase decisions that residents and government agencies regularly make, and thus misses important opportunities to reduce emissions. In contrast, the *Consumption-based Inventory* provides insights on how other consumer choices, such as decisions related to food or products, affect global greenhouse gas emissions far beyond the region's border. At the same time, the consumption-based methodology yields a coarser estimate that is limited by uncertainties, data constraints, and lack of granularity (i.e., it has no ability to distinguish lower-emitting purchases within a given product category).

Implications and Next Steps

For local governments, including King County and King County Cities, this study demonstrates the high importance of continuing efforts to address emissions associated with vehicle travel, buildings (including electricity use), and waste management. At the same time, it shows that food, goods, and services consumed by King County residents are associated with GHG emissions, largely beyond King County's borders, that are of an equally significant scale. Additional government activities, such as information campaigns (e.g., food-waste reduction) or lead-by-example programs (e.g., environmentally preferable purchasing), can help to create a broader and deeper impact on global greenhouse gas emissions.

Because of King County's hydropower resources and consequent lower-than-average electricity emissions, many electricity-intensive goods and services (like steel) are produced with lower emissions in King County than in the nation as a whole. This may lead to an assumption that increased consumption of locally-made goods and services would lead to lower GHG emissions. However, shifting additional production of goods and services into King County would not necessarily result in reduced global GHG emissions, since additional large hydropower resources are unlikely to be developed and other low-emissions energy sources may not be developed as fast as in other regions. Still, significant GHG emissions reductions could occur by shifting production into King County if most new energy sources come from energy efficiency improvements and from additional, low-GHG emissions energy sources such as renewable solar, wind or tidal power – so that the average emissions intensity of these new energy sources remained below the intensities of other regions.

Together, the two inventories help to paint a more complete picture of King County's contributions to global climate change than either would on their own. Still, neither inventory is especially well-suited to tracking changes in emissions sources over which local government have unique and direct influence. For this reason, the report also developed a simplified and streamlined ongoing tracking framework that meets two key objectives: *measurability* and *policy influence*. The study defines a core set of emissions to be tracked annually: those associated with building energy use, local vehicle travel, and waste management. These emissions comprise the majority (70 percent) of emissions in the *Geographic-plus Inventory*. The tracking framework outlines the methodology for tracking these key sources in years between conducting more comprehensive inventories. Along with emissions for these sources, this study recommends that King County track a set of related metrics, such as per-capita building energy use and vehicle miles traveled.

For residents, this study quantifies the GHG emissions associated with residents' decisions about where they live, how they get around, and how they operate homes. Additionally, for the first time it also quantifies the impacts from decisions about purchases of goods and services, such as for food and home furnishings. Significant additional work to inform best practices about reducing emissions from these newly quantified sources – for example, by examining the intensity of diet choices and by purchasing items that last longer – will be necessary. Regardless, it is clear that significant opportunities exist for residents to address climate change through purchasing decisions.

Several next steps for this project are currently underway and will take place through mid 2012. These include further developing and communicating additional results of both the *Geographic-plus* and *Consumption-based inventories*, applying data from the *Consumption-based Inventory* to help assess environmental purchasing efforts – both for governments and to inform consumer and business choices – and conducting further research into key sources of emissions, including those associated with food.

1. Introduction And Context

There is scientific consensus, as documented by the United States National Academies and the Intergovernmental Panel on Climate Change,[3] that human sources of greenhouse gases (GHGs) such as carbon dioxide and methane are causing unprecedented and severe changes in global and local climate systems. To avoid the most serious impacts to the environment, human health and the economy, significant reductions in GHG emissions will be necessary. This will require bold action from local governments and communities up to national and international levels.

At each level, an important first step to addressing climate change is to estimate the amount of greenhouse gases released. An inventory of greenhouse gas emissions can help government, businesses, and citizens to better understand the various sources of emissions, their relative magnitude, and thus where to focus resources and actions to reduce them.

For nearly two decades, the Intergovernmental Panel on Climate Change (IPCC) has issued and refined the methods and guidance that are followed by over 160 countries in developing national GHG inventories, including the U.S. (where the Environmental Protection Agency has further tailored the IPCC approach to U.S. conditions). These methods have been adapted to state and community levels, and expanded to apply to business and local government operations.[4] While state and local governments and communities tend to use relatively similar methods to track, or inventory, greenhouse gas (GHG) emissions, there remain important variations, as well as different perspectives that are important to consider.

Accordingly, this report presents two different views on GHG emissions associated with the community in King County, Washington. One view looks at the emissions, largely released within King County, associated with residential and commercial energy consumption and industrial activity. This relatively standard method, called a *production* or *geographic* based inventory, follows the national IPCC guidance and involves estimating the annual emissions of the most important GHGs, carbon dioxide (CO_2) and several trace gases, that are released within an entity or regional boundary. For example, a geographic inventory is most appropriate for estimating emissions associated with transportation, buildings, and industry within a region's borders.

3 Sources: Committee on America's Climate Choices (2011) and IPCC (2007)

4 For example, see IPCC (1996), US EPA (2010b), and WBCSD & WRI (WBCSD and WRI 2004)

Another relatively new view looks instead at the emissions associated with all of the goods and services consumed in the region – even if those emissions were released outside of King County in the course of making products, such as computers or food. This method is called a *Consumption-based* GHG inventory or a carbon "footprint". This approach includes the emissions associated with the production of goods or services imported into the region, such as appliances from China or food from California, but may not provide as much detail on particular local sources (e.g., cement plants), especially if those sources primarily make goods for export out of the region.

Neither of these methods is necessarily the "right" method for all contexts. At the national level, the IPCC-based geographic accounting method is widely accepted for tracking country-level progress at meeting emissions goals or commitments. However, no widely accepted standard exists for measuring, or inventorying, a *community's* contribution to global GHG emissions or climate change.[5] In general, communities undertake GHG inventories following the geographic boundaries of the production-based method but depart in ways that increase the practical relevance to local circumstances. In particular, many communities now include some emissions released outside the boundary that result from activities occurring within the boundary, especially emissions associated with electricity.[6] A Consumption-based method takes this same logic further to estimate the "embodied" or "life cycle" emissions associated with the production, transport, sale, use and disposal of goods and services consumed within the community, based on the idea that consumers who benefit from these goods and services bear some responsibility for the associated emissions. For example, a consumer who purchases food is, at least in part, responsible for the emissions released to make the food, from the energy of farm and processing equipment to the emissions released from applying fertilizers.

Both the geographic and Consumption-based methods offer useful perspectives and insights. For example, a geographic method typically provides detail on emissions associated with buildings, both residential and commercial, and therefore has clear relevance for tracking the impact of building codes as well as personal and business behaviors that affect building energy consumption. On the other hand, a Consumption-based method provides insights on how other consumer choices, such as food consumption, affect global GHG emissions far beyond the region's border.

King County and other communities use GHG inventories for a number of purposes, including to identify major sources of emissions, set goals, identify trends, track progress, and communicate to the public how the community contributes to emissions. In looking at both the geographic and Consumption-based methods, as well as a variety of possible variations thereof, this effort represents an important step in comprehensively addressing GHG emissions.

Roadmap of this Report

This report presents two alternate methods of assessing GHGs associated with King County and then establishes and tests a simplified tracking framework for use in tracking emissions on an ongoing, frequent basis. Accordingly:

- Section 2 presents results from the *Geographic-plus Inventory*, and also discusses other sources that don't fit neatly in either inventory;
- Section 3 presents results from the *Consumption-based Inventory*;
- Section 4 recommends a Tracking Framework; for King County to use on an ongoing basis
- Section 5 discusses Conclusions.
- Section 6 contains several Technical Documents as appendices, which contain further details for both inventories.

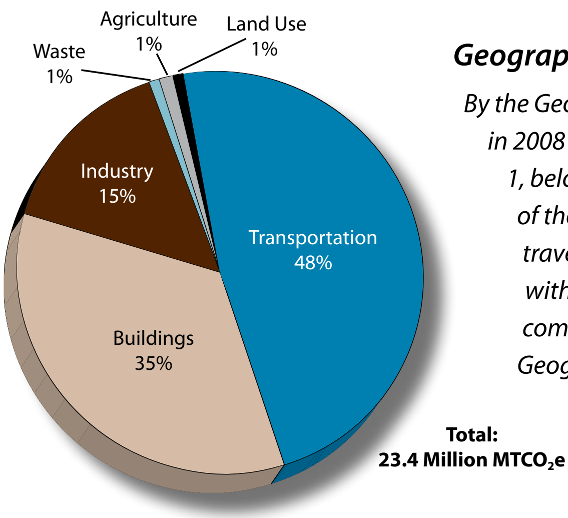
5 ICLEI – Local Governments for Sustainability has been developing a community GHG emissions protocol it intends to promote nationally.

6 In *GHG Protocol* (WBCSD and WRI 2004) terminology, these emissions are termed *Scope 2*.

2. The *Geographic-plus Inventory*

The GHG inventory described in this section documents the release of GHG emissions from cars and trucks, buildings, waste, agriculture, and other sources of emissions within King County in 2008. Because this inventory also includes some emissions that occurred outside King County's borders (notably emissions associated with electricity produced outside the county but used within it), we call it a *Geographic "Plus" Inventory*. Although some details vary, this method is in general alignment with methods used in the U.S. EPA's national GHG inventory, the Washington State GHG inventory, and standardized methods used by a number of jurisdictions nationally and internationally, including the City of Seattle.[7] (For a description of the methodology for this inventory, see Box 1, and for detailed results, see Appendix B).

Figure 1. King County 2008 GHG Emissions by Sector, Geographic-plus Methodology



Geographic-plus Inventory Results

By the Geographic-plus methodology, King County's emissions in 2008 totaled 23.4 million $MTCO_2e$. As indicated in Figure 1, below, transportation is responsible for about half of these emissions, in large part from personal vehicle travel by King County residents. Emissions associated with buildings, including homes and businesses, also comprise slightly more than one-third of King County's Geographic-plus emissions.

7 For example, see EPA (2011), Center for Climate Strategies (2007), ICLEI-USA (2003), ICLEI (2009), and UNEP et al (2010). In addition, because the *Geographic-plus Inventory* includes emissions associated with electricity use within the community, it is also consistent with the WBCSD/WRI *GHG Protocol* (WBCSD and WRI 2004).

Box 1. Methodology for the Geographic-plus GHG Inventory

The *Geographic-plus Inventory* closely follows the method used by the City of Seattle in its 2008 GHG Inventory[8], which in turn is similar to methods promoted by ICLEI – Local Governments for Sustainability for communities throughout the U.S. as well as to the State of Washington GHG Inventory.[9] In general, compiling a GHG inventory involves assembling data on activities that release emissions and the emissions intensity of those activities. For example, estimating emissions from electricity involves multiplying data on total kilowatt-hours (kwh) of electricity used with the emissions intensity (kg CO_2e per kwh) of that electricity's production, which in turn depends on what fuels were used.

Following is a summary of some of the key activity and intensity data sources used to compile King County's 2008 *Geographic-plus Inventory*. For a complete list of data sources, please see Appendix B.

Table 1. Key Data Sources for King County's *Geographic-plus Inventory*

Activity Levels	Activity Indicators	Intensity Indicators (MTCO_2e per unit)
Transportation (Road)	Vehicle-miles travelled as modeled by the Puget Sound Regional Council	National statistics on the fuel economy of cars and trucks and the carbon content of those fuels
Transportation (Air)	Fuel loaded at Sea-Tac airport provided by the Port of Seattle and estimates of the share of King County residents and employees among all passengers at Sea-Tac.	Carbon content of jet fuel per the national U.S. EPA inventory
Buildings and Industry (Electricity)	Electricity use data provided by Seattle City Light and Puget Sound Energy	Emissions intensity of electricity delivered by these two utilities as reported to the Washington State Department of Commerce
Buildings and Industry (Natural gas)	Natural gas consumption data provided by Puget Sound Energy	Carbon content of natural gas per the national U.S. EPA inventory
Waste	Landfill gas generation rates provided by the King County Solid Waste Division and Seattle Public Utilities	Landfill gas recovery rates, also provided by King County Solid Waste Division and Seattle Public Utilities
Agriculture	Acres of cropland and number of livestock animals provided by the USDA Agricultural Census	Emissions per animal or per acre from the U.S. EPA national inventory
Land Use Change	Acres of land cleared for development, estimated based in part on data in the King County Assessor's database	Average carbon stocks in King County as assessed by the University of Washington[a]

a Hutyra et al (2010)

Note that the *Geographic-plus Inventory* for King County departs from the City of Seattle's 2008 inventory in three key respects:

- **Vehicle trips:** This inventory counts emissions from all trips that occur entirely within King County, half of trips that either begin or end in the county, and no trips that both begin and end outside the county (even if they pass through the county). The rationale for this method is that it counts the trips that local policy-makers can best influence through transportation planning and incentives, such as commuting trips, while excluding the pass-through trips over which the county and its partners have little influence. Compared to a traditional, geographic approach, this "origin-destination pair" method counts 1 percent more vehicle travel overall: 3 percent less passenger vehicle travel and 39 percent more freight travel.

- **Agriculture and land clearing:** These emissions were included for King County, but were not in the City of Seattle's inventory due to the much lower incidence of these practices within Seattle city limits.

- **Air travel:** For King County, a slightly different method of allocating air travel at Sea-Tac airport was used, based on the share of residents and employees in the region, rather than a survey at Sea-Tac airport.

For the purpose of comparison, in Table 3 we adjust the City of Seattle's existing inventory to use the same methods used here for vehicle trips and air travel.

8 City of Seattle (2009)
9 See ICLEI (2003) and Center for Climate Strategies (2007)

Table 2 provides more detail on these sources of emissions.

Table 2. King County 2008 GHG Emissions by Sector, Geographic-plus Methodology (Million $MTCO_2e$)

Sector	Subsector	Total Emissions (Million $MTCO_2e$)
Transportation		**11.4**
	Road	8.9
	Marine & Rail	0.3
	Air	2.2
Buildings		**8.2**
	Residential	4.1
	Commercial	4.0
Industry		**3.5**
	Energy Use	2.3
	Process Emissions	0.4
	Fugitive Gases	0.7
Waste		**0.2**
	Landfills	0.2
	Wastewater Treatment	<0.1
Agriculture		**0.2**
	Livestock	0.2
	Fertilizer Application	<0.1
Land-use Change		**0.1**
	Residential Development	0.1
TOTAL		**23.4**

Table 3 compares King County, Washington State, and United States emissions on a per-person basis. At an estimated 12.4 $MTCO_2e$, King County's per-person emissions in the *Geographic-plus Inventory* are significantly lower than the national average of 23.3 $MTCO_2e$ per person.[10] Differences in the industry and buildings sectors account for much of the departure from the U.S. average.

Per-person King County industrial emissions are one-quarter of the U.S. average largely due to the different mix of sectors present within King County. King County has far less activity in energy-intensive sectors, such as petroleum refining, chemical manufacturing, paper production, and aluminum smelting, that dominate U.S. industrial emissions. In contrast, the County has a high concentration of manufacturing, especially the assembly of airplanes and other aerospace products, that consumes far less energy per dollar of economic output. This mix of sectors explains most of the difference in industrial emissions; King County's relatively low-GHG electricity supply explains only a

King County's per-person emissions in the Geographic-plus Inventory are significantly lower than the national average of 23.3 $MTCO_2e$ per person

10 Since inventory methods can vary, readers should take care in making comparisons to GHG inventories in other communities. In the case of the comparison shown in Table 3, the discrepancies in accounting methods are small enough to have a negligible impact on the overall comparison.

small fraction of the difference. [11] Overall, the difference in per-person industrial emissions is particularly notable given that King County has about 30 percent more industrial activity (in dollar terms) per person than either Washington State or the nation.[12]

Table 3. Comparison of Per-person 2008 King County, Seattle, Washington State, and United States Emissions by Sector, *Geographic-plus* Methodology ($MTCO_2e$ per person)[a]

Sector	Subsector	Seattle ($MTCO_2e$ / resident)	King County ($MTCO_2e$ / resident)	Washington State ($MTCO_2e$ / resident)	United States ($MTCO_2e$ / resident)
Transportation		**7.1**	**6.0**	**6.9**	**6.2**
	Road	5.2	4.7	5.1	5.1
	Marine & Rail	0.5	0.2	0.6	0.3
	Air	1.4	1.2	1.2	0.8
Buildings		**2.4**	**4.3**	**3.5**	**7.8**
	Residential	1.0	2.2	2.0	3.9
	Commercial	1.4	2.1	1.5	3.9
Industry		**1.9**	**1.8**	**3.5**	**7.4**
	Energy Use	0.6	1.2	2.6	6.3
	Process and Fugitive Emissions	1.3	0.6	1.0	1.1
Waste		**0.1**	**0.1**	**0.6**	**0.5**
	Landfills	<0.1	0.1	0.5	0.4
	Wastewater Treatment	0.1	<0.1	0.1	0.1
Agriculture		**<0.1**	**0.1**	**0.9**	**1.4**
	Livestock	<0.1	0.1	0.5	0.7
	Fertilizer Application	<0.1	<0.1	0.4	0.7
Land-use Change		**<0.1**	**<0.1**	**N/A**	**N/A**
	Residential Development	<0.1	<0.1	N/A	N/A
TOTAL		**11.6**	**12.4**	**15.5**	**23.3**

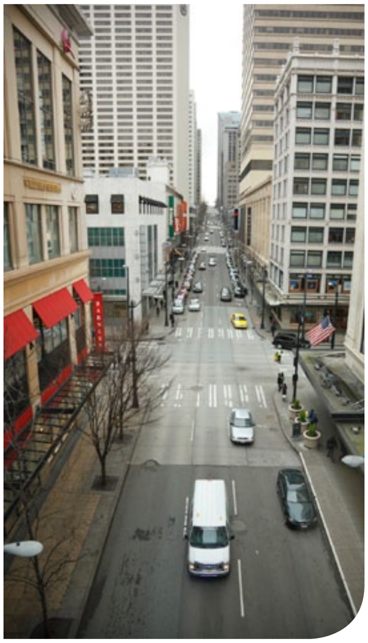
a Emissions per person for the U.S. based on SEI analysis of the U.S. inventory for 2008 (U.S. EPA 2011), with a few adjustments made to facilitate comparisons. For example, the official national inventory does not include international air travel, but these emissions were added back in for the purpose of this comparison since the King County inventory includes fuel loaded at Sea-tac airport for international flights. Emissions per person for Washington based on the state inventory (Sandlin 2010) with emission from electricity and the "RCI" sectors disaggregated by SEI into residential, commercial, and industrial energy use based on underlying EIA data from the *Electric Power Annual* and State Energy Data System. Emissions per person for Seattle based on adjusting Seattle's official inventory (City of Seattle 2009) to the *Geographic-plus* method described here and assuming that agriculture and land-use emissions were much less than 0.1 MTCO2e /resident.

11 Emissions associated with electricity use in King County average 0.22 kg CO_2e /kwh used, compared to about 0.64 kg CO_2e/kwh for the nation. If King County industry used electricity at the national average emissions intensity, emissions would increase by about 0.5 $MTCO_2e$ / person, explaining only a small portion of the difference of more than 5 $MTCO_2e$ / person industrial emissions between King County and the nation.

12 According to the 2007 Economic Census, considering manufacturing (NAICS industry codes 31-33), construction (NAICS code 23), and mining (NAICS code 21).

The other primary reason King County overall per-person emissions are lower than the U.S. average is that building operation is about half as emissions intensive in King County, a fact that can be explained primarily by King County's relatively low-GHG electricity supply. On a per-person basis, about the same amount of energy is used in King County residential buildings as in the U.S. as a whole (somewhat less energy per capita is used in commercial buildings); however, residents and businesses use a higher fraction of electricity as compared with other fuels, due in part to the region's low electricity rates, with much of this electricity provided by hydropower and natural gas.[13]

Table 3 also displays several smaller differences that may exist for a number of reasons. For example, per-person road transportation emissions are lower in King County than the national average because King County residents travel fewer passenger vehicle miles per year than the national average. This difference is likely due to at least two reasons: the fact that this *Geographic-plus Inventory* does not count long-distance vehicle trips outside the Puget Sound region (which, if included, could add 20 percent or more),[14] as well as the fact that King County is more urban than the state or country as a whole, and residents in denser areas tend to travel fewer miles per person.[15] Emissions from waste management at landfills are lower in King County than for the nation, in part because King County recovers a higher fraction of landfill gas than does the average landfill.[16] (For a deeper look at emissions associated with waste, see the next section, Other Emissions Sources.)



For a comparison of the underlying factors that explain the greatest fraction of the departure of King County's *Geographic-plus Inventory* from the U.S. average, see Table 4. Note three differences in particular between King County and the U.S., all of which were also mentioned above: King County's dramatically lower industrial energy use per economic output – five times lower (1.3 vs. 6.5 MBTU per dollar), reflecting the different mix of industries; the much lower GHG intensity in the building sector (reflecting our high fraction of low-GHG hydroelectricity), and King County's lower per-person passenger vehicle travel. Note also that King County has higher freight travel than the national average, a trend that partially offsets the impact of our lower passenger vehicle travel on total per-person road travel emissions. Truck traffic to and from the Port of Seattle could explain part, but not all, of the difference;[17] higher levels of economic activity could also explain part of the difference.

13 In 2008, King County residents used about 35 million BTU per resident, (43 percent of which was electricity) compared to 36 million BTU for the nation (11 percent electricity) per the EIA's State Energy Data System. King County businesses used about 62 million BTU per employee (60 percent electricity) compared to 75 million BTU per employee for the nation (54 percent electricity). If buildings in King County used electricity at the national average emissions intensity (see footnote12), emissions would increase by about 4 $MTCO_2e$ /person, a figure greater than the difference between the King County and U.S. per-person emissions in the building sector.

14 According to the 2009 *National Household Travel Survey* , on average, across the U.S., 19 percent of household VMT were for trips longer than 75 miles, which is a distance just beyond the extent of the "external zones" in PSRC's model (roughly Mount Vernon to the north, Olympia to the south, Snoqualmie Pass to the east, and the Hood Canal Bridge to the west) and therefore not included in our estimates. Comparable statistics for freight travel were not available, but the average distance of shipment nationally is about 200 miles, per Table 5.15 in Davis et al (2010), suggesting that more than 19 percent of freight VMT is for trips greater than 75 miles. Therefore, if (conservatively) both King County passenger and freight VMT displayed similar trends, our estimates could underestimate road travel by roughly 1/(1-0.19), or 24 percent, which would bring King County's road-transport emissions from 4.7 $MTCO_2e$ /person to greater than the national average of 5.1.

15 Kennedy et al (2009); Ewing and Cervero (2010).

16 Furthermore, waste from Seattle is long-hauled by train to a landfill in Arlington, Oregon and so is not included in Table 3. However, even if these emissions were included and waste were measured on a "waste commitment" basis (See Box 2), per-person emissions associated with waste in King County would still be about 0.1 $MTCO_2e$ per resident, because landfill gas capture at the landfill in Arlington is also relatively high and because both Seattle and King County divert from the landfill a higher fraction of food and yard waste than the national average.

17 According to an accounting of Port-related vehicle travel for the year 2005 (Starcrest Consulting Group 2007), heavy duty vehicle travel associated with the Port averaged 105,000 VMT daily in 2005, which is only about 5 percent of the total daily heavy duty VMT counted in this inventory.

Table 4. Comparison of Underlying Factors in 2008, King County, Seattle, and U.S.

Sector	Seattle	King County	United States
Transportation: Road			
Passenger 'light duty' VMT per person (miles / resident)	6,270	**6,890**	8,950
Freight 'medium and heavy duty' VMT per person(miles / resident)	1,210	**1,050**	750
Buildings			
Residential energy per person (MBTU/resident)[a]	31	**35**	36
Commercial energy per person (MBTU/employee)	67	**62**	75
Residential GHG intensity of energy (kg CO_2e/MBTU)	30	**62**	104
Commercial GHG intensity of energy (kg CO_2e/MBTU)	23	**59**	138
Industry			
Value added per resident [b]	N/A	**$15,693**	$11,919
Energy use per economic output (MBTU/thousand $ value added)	N/A	**1.3**	6.5
GHG intensity of energy (kg CO_2e/MBTU)	23	**61**	82

a In the case of mixed-use buildings, differentiating between residential and commercial energy use is challenging. This may be especially true for Seattle, which has a greater fraction of mixed use buildings than does King County or the U.S. Accordingly, some of Seattle's "Commercial" energy, as displayed here, may actually instead be for multi-family residential buildings.

b The source of these data is the 2007 Economic Census, for NAICS codes 31-33 (manufacturing), 21 (mining), and 23 (construction).

Trends in King County's *Geographic-plus Inventory* Results

To explore trends over time, we also re-calculated King County's prior, 2003 GHG inventory[18] using the same method employed here for 2008. As displayed in Table 5, we estimate emissions for 2003 to be 22.4 million $MTCO_2$e, or 12.6 $MTCO_2$e per King County resident, suggesting that, on a per-person basis, emissions have dropped very slightly between 2003 and 2008. The biggest change between 2003 and 2008 emissions was in emissions from passenger travel, which declined from 3.4 $MTCO_2$e to 3.1 $MTCO_2$e per person, or 11 percent. This is due both to an upward trend in fuel economy of passenger vehicles (up 5 percent)[19] as well as due to decreased vehicle travel (VMT) per person (down 7 percent). Declines in per-person emissions from vehicles were partially offset by increases in emissions associated with buildings and (to a lesser extent) air travel, such that the decline in overall per-person emissions is small. Increased per-person emissions from buildings are largely due to increased energy use associated with colder weather and associated increased heating demands in 2008 compared to 2003.[20]

18 King County's prior, 2003 geographic GHG inventory (Hammerschlag and Howell 2004) was largely adapted from Puget Sound Clean Air Agency's 2002 inventory for the region and used a slightly different method.

19 Fuel economy of light-duty vehicles increased from an average of 19.5 miles per gallon to 20.5 miles per gallon in 2008 per national statistics, due to retiring of older, less efficient vehicles and purchase of newer, more efficient vehicles.

20 Heating degree days (which correlate strongly with building energy use) at Sea-tac airport increased 11 percent from 4,509 in 2003 to 5,022 in 2008. If approximately 40 percent of residential and commercial energy consumption was for building heating in 2003 (based on review of Seattle City Light and Puget Sound Energy planning documents), and heating demands increased 11 percent, then emissions from buildings could be expected to increase about 0.18 $MTCO_2$e /resident (4.1 * 0.40 * 0.11), which is approximately the increase (0.2) observed.

Table 5. Trends in King County Geographic-plus GHG Emissions: 2003 and 2008 ($MTCO_2e$ per person)

Sector	Subsector	2003 ($MTCO_2e$ / resident)	2008 ($MTCO_2e$ / resident)
Transportation		**6.4**	**6.0**
	Road: Passenger[a]	3.4	3.0
	Road: Freight[b]	1.7	1.6
	Marine & Rail	0.2	0.2
	Air	1.1	1.2
Buildings		**4.1**	**4.3**
	Residential	2.1	2.2
	Commercial	2.0	2.1
Industry		**1.8**	**1.8**
	Energy Use	1.2	1.2
	Process and Fugitive Emissions	0.6	0.6
Waste		**0.1**	**0.1**
	Landfills	0.1	0.1
	Wastewater Treatment	<0.1	<0.1
Agriculture		**0.1**	**0.1**
	Livestock	0.1	0.1
	Fertilizer Application	<0.1	<0.1
Land-use Change		**0.1**	**<0.1**
	Residential Development	0.1	<0.1
TOTAL		**12.6**	**12.4**

a Includes cars, light trucks, and buses
b Includes medium and heavy duty trucks

Key findings of the Geographic-plus Inventory

The *Geographic-plus Inventory* estimates the release of GHGs within King County's borders in 2008, plus those associated with electricity use and air travel.[21] In this inventory and most inventories like it, emissions are assigned to "sectors", such as transportation, buildings, and industry. From this sector-based perspective, the following key findings emerge.

- **Transportation is the greatest source of GHG emissions within King County**, representing 6.0 $MTCO_2e$ per person. Cars and trucks are by far the largest source of transportation emissions at 4.7 $MTCO_2e$ per person, but emissions from air travel are also significant at 1.2 $MTCO_2e$ per person.

21 In addition, as described in Box 1, a nuanced method for counting emissions associated with vehicle travel is used that also departs from a strict production-based approach.

- **Buildings are also a significant source of emissions, both residential and commercial**, representing 4.3 $MTCO_2e$ per person. Emissions in the buildings sector are associated with fossil fuels (2.0 $MTCO_2e$ / person) and electricity (2.3 $MTCO_2e$ /person) used to heat and cool buildings and power appliances, electronics, and landscaping equipment. Due to King County's significant supply of low-GHG hydro-electricity, emissions from the buildings sector are much lower than the national average.

- **Emissions from industry, though significant, are much less than the national average**, a departure that can be attributed primarily to the type of industry in King County and also to the relative low-GHG electricity in our region. However, as discussed in the next section, emissions associated with manufacturing products consumed (instead of produced) in King County are much higher.

Comparing inventories between 2003 and 2008 suggest an encouraging trend: on a per-person basis, King County's GHG emissions declined slightly between 2003 and 2008, led by an 11 percent decline in per-person GHGs associated with vehicle travel by cars and light trucks.

Other Emissions Sources

In addition to the emissions sources documented in the *Geographic-plus Inventory*, an additional component of King County's GHG inventory work is to track emissions that are removed from the atmosphere (e.g., forest sequestration) or instead avoided due to waste landfilling or waste recycling. This section discusses calculations related to forest sequestration and waste management.[22]

For example, extensive forest lands in King County provide a significant emissions *sink*. Based on data provided by the U.S. Forest Service, we estimate that the 800,000 acres of forest lands in King County sequester 0.4 million $MTCO_2e$ annually (averaged over the period 1996 to 2006), on a net basis, an amount equivalent to about 2 percent of King County's emissions.[23]

For waste management, two distinct methodologies can be used to estimate emissions associated with waste disposal, including disposal in landfills, the dominant method for processing waste in King County. The *Geographic-plus Inventory* estimates waste related emissions associated with all materials currently in landfills within King County's border, no matter the year the materials were disposed. This method is sometimes called "waste-in-place" because it estimates the emissions from waste already in the landfill. Another method, called "waste commitment," counts emissions associated with all waste generated from within King County in 2008

22 Appendix C presents further details on these calculations as well as on emissions avoided due to offsets purchased by Seattle City Light.

23 This 0.4 million $MTCO_2e$ is a "net" figure that includes sequestration by trees growing on lands that remain forest and carbon loss on lands cleared of trees, including the carbon loss from residential development included in Table 2. For estimates of these two components separately, see Appendix C. USFS defines *forest land* as "land with at least 10 percent cover (or equivalent stocking) by live trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated."

(and only 2008), regardless of when or where those emissions actually occur. Table 6 presents emissions using this alternate method. Furthermore, since the *Geographic-plus Inventory* looked only at *emissions* (not sources of emissions storage or *sequestration*, either of which would be a "negative" emission), it did not quantify the long-term storage of carbon that can occur when materials such as yard waste or paper are buried in landfills. This carbon would otherwise have been released to the atmosphere had the materials not been landfilled. Table 6 also presents estimates of this long-term carbon storage.

Table 6. King County 2008 Waste Management Emissions (Million MTCO_2e), "Waste Commitment" Perspective

	Emissions (+) or Carbon Storage (-),
Transportation to and Processing at Landfills	0.04
Fugitive Landfill Emissions Commitment	0.18
Subtotal	**0.22**
Carbon storage in landfill	-0.44
Net total	**-0.22**

As Table 6 indicates, carbon storage in landfills is greater than the emissions released from landfills, meaning that landfills are a net emissions sink. This finding would seem to suggest that landfilling materials is beneficial from a GHG perspective, at least for some slow-to-decay organic materials, such as wood products.[24] However, looking only at the emissions or storage associated with material disposal ignores the alternate potential uses of those materials. In particular, in many cases, landfilled materials may instead be reused, recycled or composted, activities which may bring significant emissions benefits. For example, recycling paper may both reduce energy use at a paper mill and also allow for increased carbon sequestration in trees that are no longer harvested to make paper.

Accordingly, this report quantifies emissions implications of recycling and composting programs in King County. Estimating the avoided emissions that can result from recycling programs (or any other source of avoided emissions) can be challenging, as doing so involves assessing emissions reductions relative to what otherwise would have happened, or to "business as usual." Table 7, below, shows estimates of the benefits of recycling relative to if all the material was instead disposed as well as a more conservative (and arguably more realistic) approach where benefits are estimated relative to national average or "common practice" recycling rates.

Table 7. Emissions Associated with Recycling Programs in King County (Million MTCO_2e), 2008

	Emissions Relative to 100 percent Disposal	Emissions Relative to National Average Recycling Rates
Avoided Transportation to Landfills	-0.04	-0.01
Avoided Landfill Emissions Commitment	-0.23	-0.08
Foregone Carbon Storage	0.82	0.21
Recycling Process and Avoided Manufacturing	-2.44	-0.75
Composting Process and Avoided Manufacturing	-0.08	-0.03
Totals	**-1.96**	**-0.66**

24 All calculations of emission releases and carbon storage were conducted using the EPA's WARM model and associated documentation (US EPA 2010a)

3. The *Consumption-based Inventory*

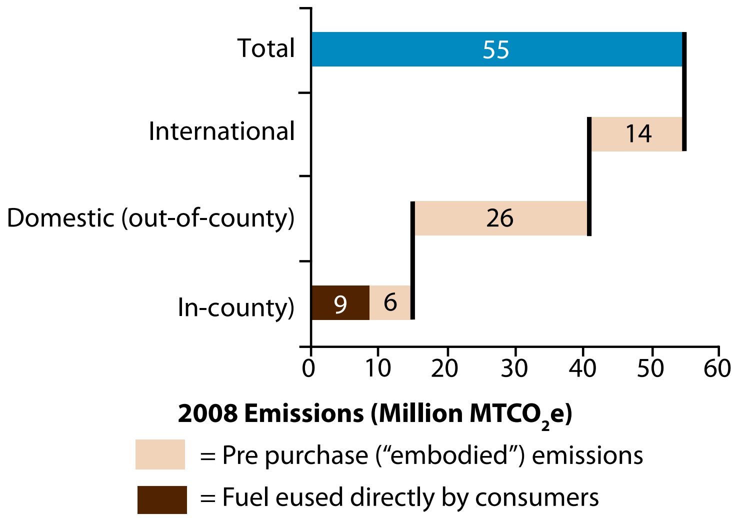
This section describes King County's *Consumption-based* GHG inventory. The key difference of this method from the *Geographic-plus* method is that here we count the emissions associated with producing all products and services consumed in King County, regardless of whether they are produced locally, nationally, or internationally. Likewise, this method excludes the emissions released within King County to make products (such as software or cement) for sale outside King County. (For a description of the methodology for this inventory, see Box 3, and for detailed results, see Appendix D).

Consumption-based Inventory Results

Overall, the emissions "footprint" of King County's consumption (an estimated 55 million $MTCO_2e$) is significantly greater than the emissions released within King County using the largely production-based approach in the *Geographic-plus Inventory* described in the previous section (23 million $MTCO_2e$).

Of these 55 million $MTCO_2e$, nearly three-quarters (40 million $MTCO_2e$) were released outside King County, with a significant quantity (14 million $MTCO_2e$) released in other countries. Figure 2 shows where emissions associated with King County consumption were released. When viewed from the consumption perspective, most emissions are "embodied" in goods and services rather than being released directly by the consumer via the burning of fossil fuels.

Figure 2. Consumption-based GHG Emissions by Geography of Release



The distribution of emissions far beyond King County's boundaries reflects the complex international supply chains for many products. For example, a King County resident's purchase of a car assembled in Tennessee would be associated with some emissions in the U.S. at the assembly plant, as well as emissions at factories in other countries where component parts are fabricated, materials such as steel are produced, or raw materials such as iron are extracted. Emissions from producing materials and components such as these – as well as finished products – are each described in our analysis according to the geography in which they were released.

Figure 2 shows that most emissions associated with consumption in King County are released outside the county. Most goods (and many services) are imported and emissions to *produce* these goods and services are significant.

Figure 3 displays Consumption-based emissions according to where in the economic "life cycle" the emissions are released. The life-cycle phases are defined as follows:

1. **Producer:** manufacturing, growing, raising, or otherwise producing a good, material, or service, including any supplies or materials needed;

2. **Pre-purchase transportation:** transporting supplies or materials to a manufacturer or other producer, transporting a good from producer to wholesaler or retailer;

3. **Retail/Wholesale:** operating wholesale and retail establishments;

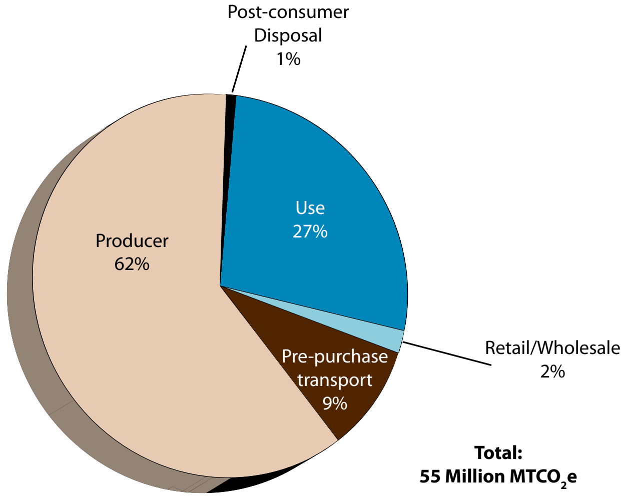
4. **Use:** using a good, such as a personal vehicle, home heating system;

5. **Post-consumer disposal:** disposing of post-consumer wastes in landfills.

For example, emissions associated with the "producer" phase of food arise from energy consumption to make fertilizers, direct emissions of nitrous oxide when fertilizers oxidize in the soil, fossil fuels burned by agricultural equipment, methane from cows digesting their feed, and natural gas burned to power equipment at food processing plants.

As the figure indicates, 34 million $MTCO_2e$ or over 60 percent of King County's Consumption-based emissions are associated with *producing* goods and services, more than a quarter (15 million $MTCO_2e$) are associated with *using* them (e.g., driving a car or using an appliance), and relatively small shares are associated with transporting, selling, and disposing them.[25]

Figure 3. King County 2008 *Consumption-Based* GHG Emissions by Life-cycle Phase



Producing goods, food, and services contributes more than half of the GHG emissions associated with consumption in King County. This underscores the importance of purchasing habits on emissions. Simply by buying products, King County residents, governments, and businesses are contributing to climate change through the emissions released to make these products. This conclusion suggests an opportunity to look at what goods and services require more emissions to produce, so that consumers, governments, or others purchasing goods and services can focus on decisions that are likely to have the greatest benefit. Table 8 shows these embodied emissions, along with use and disposal phase emissions, by product and service category. (In Table 8, emissions in the *producer*, *pre-purchase transport*, and *retail/wholesale* life-cycle phases are consolidated as *embodied*, since they occur before or in direct association with the purchase of the good or service.)[26]

In addition to the overall emissions in each product and service category, it is also useful to examine emissions *intensity* per dollar of spending, also included in Table 8. These metrics normalize the *embodied* (pre-purchase)

25 Note that results in Figure 3 and subsequent tables and figures are based on consumption that occurred in 2008. Goods purchased in 2008 (and for which *Producer* emissions are shown in Figure 3) are not always the same goods *used* in 2008 (and for which *Use* emissions are shown in Figure 3). For example, cars used in 2008 were made in many prior years, and cars purchased in 2008 will be used for many years into the future.

26 The individual contributions of *pre-purchase transport* and *retail/wholesale* by product and service category are not shown because the model cannot accurately parse all the emissions in these two life-cycle phases to individual product or service categories. Instead, emissions from transporting goods from producer to wholesale and retail distributors are included as other transport, and emissions from wholesale and retail establishments are included as other: wholesale and retail. About half of the pre-purchase transportation emissions arise from transporting intermediate products, such as fertilizers transported from factory to farm. These emissions are included in the consolidated "pre-purchase emissions" life-cycle phase for each product. Only the transportation emissions from producer to retailer cannot be assigned to individual product or service categories in our model.

emissions in each subcategory by the cost of purchasing each good or service.[27] Emissions intensity is more useful than total emissions when assessing alternative consumption choices because it gives an indication of the emission impacts of a given unit of spending. For example, the emissions associated with an average computer purchase (e.g. $1,000 for a new computer) is less than an average purchase of *Other transport - air* (e.g. a cross-country airline trip costing $1,000).[28]

Furthermore, Table 8 indicates that the most emissions-intensive (on a per-dollar basis) category of consumption is food. Looking at the sub-categories of food suggests opportunities to reduce the GHG intensity of food consumption. For example, our analysis suggests that, on average, red meat and dairy are more emissions intensive than poultry and eggs, which in turn are more intensive than grains, fruits, and vegetables.

Box 3. Methodology for the Consumption-Based GHG Inventory

This method estimates GHG emissions by multiplying consumption (in dollar terms) with the emissions intensity (CO_2-equivalent per dollar) of that consumption. Below the data and process for estimating these two key components is described.

- **Consumption ($).** Consumption ("final demand" in economic terminology) is measured by total consumer, government and business investment spending for finished goods and services in an economy. Consumption estimates for King County (scaled from national totals) come from the IMPLAN economic modeling software. IMPLAN is a widely used input-output model based on data from the U.S. Commerce Department's Bureau of Economic Analysis, the U.S. Bureau of Labor Statistics, the U.S. Census Bureau, and other sources. Consumption data is processed in IMPLAN's "input-output" tables, which allow for expenditures in one sector of the economy to be tracked to all other sectors. [29] For example, using input-output analysis it is possible to estimate what fraction of the cost of an average automobile is retained by the manufacturer, what fraction the manufacturer spends on steel, and what fraction the steel mill spends on iron ore versus electricity and other inputs.[30] The IMPLAN model tracks consumption data in 440 sectors of the economy.
- **Emissions intensity (CO_2e /$).** Emissions intensities for each of these sectors have been developed based on existing GHG inventories (e.g., the U.S. EPA's national inventory and King County's *Geographic-plus Inventory* described in the previous section). For each sector of the economy, the numerator of the emissions coefficient is based on these inventories, while the denominator in terms of $ of economic activity is derived from data in IMPLAN. Lastly, since an increasing fraction of goods and materials consumed in the U.S. are produced internationally, adjustments are made to emissions intensities for imported goods, based on a global input-output model originally developed at the Center for International Climate and Environmental Research (CICERO).[31]

Finally, a few adjustments and additions to this framework were made where better local data are available. In particular, data from Seattle City Light and Puget Sound Energy characterizes emissions from building energy use, data from the Puget Sound Regional Council to characterize vehicle travel, and data from King County Solid Waste Division and Seattle Public Utilities to characterize waste management (as in the *Geographic-plus Inventory*).[32]

The end product is an integrated model of the GHG impacts of King County's consumption, the Consumption-based Emissions Inventory (CBEI) model, which relates consumption (in dollar terms) to GHG emissions in terms of $MTCO_2$e.[33] A previous version of the CBEI model was developed with funding and input from the Oregon Department of Environmental Quality,[34] and the model has also been applied to the City and County of San Francisco and the State of California. Like any model, CBEI is subject to uncertainty. For example, model results are based on commodity sector averages, but there is potential for significant variability between similar products (brands) and/or producers. CBEI results do not characterize the emissions or emissions intensity of any individual product (brand) or producer.

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27 Emissions associated with *use* and *disposal* are not included in the emissions intensity metrics since decisions on when and to what extent to use and dispose products are distinct from decisions to purchase them, and because use and disposal usually also involve separate purchases – such as energy to power a car or appliance. For example, at a producer (wholesale) price of $2.50 per gallon, the emissions intensity of purchasing and burning a gallon of gasoline would be 3.5 kg CO_2 per $ (considering combustion emissions only).

28 The figures in this table are based on the "producer dollars" of final demand without taking into account the markups (margins) applied by wholesale and retail establishments.

29 Besides IMPLAN, other sources of input-output data in the U.S. include the Bureau of Economic Analysis' RIMS II (simpler than IMPLAN) and the commercially available REMI (more complex).

30 Data are not available for individual products or manufacturers, just in aggregate for many detailed sectors of the economy

31 Peters and Hertwich (2008). Thanksto Glen Peters for sharing his model results with us.

32 However, unlike in the geographic plus methodology, emissions for building energy use or vehicle travel as reported in the Consumption-based methodology (for example, in Table 8) also include the upstream emissions of producing the fuels combusted (e.g., natural gas, gasoline) in these activities.

33 Model citation: Stanton et al (2011).

34 Thank you to David Allaway at Oregon DEQ for his extensive collaboration with us on the prior iteration of CBEI.

Table 8. King County 2008 GHG Emissions by Product or Service Category, Consumption-Based Methodology (Million $MTCO_2e$, unless otherwise specified) [a]

Category	Subcategory	Total Emissions	Embodied (pre-purchase) Emissions	Use Emissions	Disposal Emissions	Embodied Emissions Intensity ($kgCO_2e/\$$)[b]
Personal Transportation		**9.0**	**1.5**	**7.5**	**<0.1**	**0.52**
	Cars and trucks	9.0	1.4	7.5	<0.1	0.54
	Public transportation	<0.1	<0.1	*	<0.1	0.26
Home Energy and Appliances		**7.1**	**0.3**	**6.8**	**<0.1**	**0.66**
	Heating and cooling appliances	4.6	<0.1	4.5	<0.1	0.59
	Lighting	1.1	<0.1	1.1	<0.1	0.73
	Food-related appliances	0.8	0.1	0.7	<0.1	0.69
	Other appliances	0.6	0.1	0.5	<0.1	0.63
Food		**7.7**	**7.6**	*****	**0.1**	**0.78**
	Red meat	1.3	1.3	*	<0.1	2.25
	Dairy	0.8	0.8	*	<0.1	1.71
	Beverages	0.8	0.8	*	<0.1	0.63
	Grains, baked goods	0.8	0.8	*	<0.1	0.79
	Fruit and vegetables	0.6	0.6	*	<0.1	0.98
	Poultry and eggs	0.5	0.5	*	<0.1	1.42
	Frozen food	0.2	0.2	*	<0.1	1.02
	Other food	0.9	0.9	*	<0.1	0.75
	Restaurants	1.8	1.8	*	0.1	0.42
Other Goods		**7.6**	**6.8**	**0.6**	**0.0**	**0.26**
	Furnishings and supplies	3.5	3.4	*	<0.1	0.18
	Computers	1.5	1.3	0.1	<0.1	0.25
	Clothing	1.3	1.3	*	<0.1	1.07
	Other electronics	1.0	0.6	0.4	<0.1	0.64
	Lawn and garden	0.3	0.2	0.1	0.1	0.95
Services		**7.9**	**7.9**	*****	**0.0**	**0.19**
	Healthcare	3.1	3.1	*	<0.1	0.19
	Finance, insurance, real estate, legal	1.4	1.4	*	<0.1	0.12
	Entertainment	1.3	1.3	*	<0.1	0.29
	Education	0.9	0.9	*	<0.1	0.29
	Other services	1.2	1.1	*	<0.1	0.19
Construction		**4.2**	**4.2**	*****	**0.1**	**0.36**
	Non-residential	2.6	2.5	*	0.1	0.34
	Residential	1.7	1.7	*	<0.1	0.40
Other[c]		**11.4**	**11.4**	**<0.1**	**<0.1**	**0.21**
	Retail and wholesale	2.6	2.6	*	<0.1	0.16
	Other transport – truck	1.2	1.2	*	<0.1	1.55
	Other transport – air	1.0	1.0	*	<0.1	1.19
	Other transport – water, rail, other	0.6	0.6	*	<0.1	0.32
	Other	6.0	6.0	<0.1	<0.1	0.26
Total		**55.0**	**39.6**	**15.0**	**0.4**	**0.38**

*Use phase emissions for these categories are zero by definition, though in some cases emissions may be associated with the use of products but instead assigned to another category. For example, emissions associated with using a clothes-washing machine are included under the use phase of "other appliances", and emissions associated with food preparation are assigned to "food-related appliances".

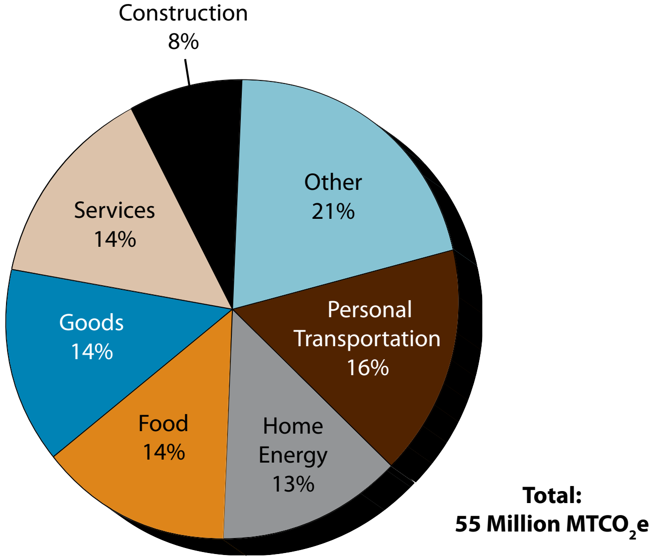
a The Consumption-based methodology includes "final demand" and associated emissions from government spending and business capital investment in addition to consumer spending. For most categories, consumer (household) demand is responsible for 85 percent or more of the emissions. Categories where government or investment demand represent more than 15 percent of the total emissions are *lighting* (government demand represents about one-quarter), *furnishings and supplies* (investment demand, e.g. for office equipment, represents about half), *computers* (investment demand represents about two-thirds and government demand about one-tenth), *other electronics* (investment and government demand together represent about one-quarter), all construction (mostly investment demand, including for residential construction, probably due to mixed use, multi-family housing, or spec housing owned, at least initially, by investors), and *Other: other*, where most are associated with investment in a variety of types of equipment (including significant emissions in the aircraft category, likely due to aerospace products that were made, but not sold, in 2008, and therefore represented a net, if temporary, accumulation to inventory).

b Excluding *use* and *disposal* phase emissions.

c All of the *Retail* and *wholesale* and most of the *Other transport* categories are in support of goods (and, to a lesser extent, services). However, because our model cannot determine the fraction devoted to individual subcategories, we report them here as stand-alone items. Future iterations of our model may be able to assign these emissions to individual subcategories of goods or services. The *Other* emissions are primarily from different types of equipment, machinery, and other long-lived capital stock purchased by business and industry. The biggest single contributor is airplanes - for example, purchases of airplanes by Horizon Air and Alaska Air, both based in King County.

Figure 4 shows the relative emissions in each of the categories displayed in Table 8. As seen in this figure, emissions associated with personal transportation are the greatest single category (except for the catch-all *other*), as in the *Geographic-plus Inventory*, and emissions associated with other main categories – home energy, food, goods, and services – are all of a similar magnitude.

Figure 4. King County 2008 GHG Emissions by Category of Consumption, Consumption-based Methodology

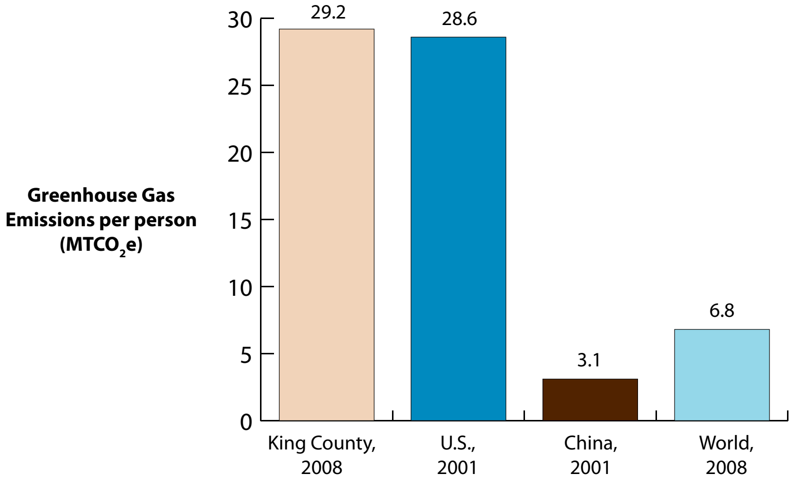


Comparison with Other World Regions

At 55 million $MTCO_2e$, emissions associated with King County's consumption in 2008 amount to 29 $MTCO_2e$ per King County resident. As displayed in Figure 5, this is roughly equivalent to the U.S. average, as lower emissions from King County's low-GHG electricity supply are offset by higher levels of consumption of goods and services. King County's per-person Consumption-based emissions are many times higher than either the global average or the average for the world's current leader in absolute emissions, China, differences that are also due to higher levels of wealth and corresponding consumption in King County.[35]

35 China's per-person Consumption-based emissions have risen since 2001. A recent analysis (Peters et al. 2011) found that China's per-person emissions of CO_2 only (not counting CH4, N_2O, or other non-CO_2 gases) exceeded 4 $MTCO_2e$ per person in 2008. However, the only comparable analysis known to us that includes key non-CO_2 gases is the one cited here for 2001.

Figure 5. Comparison of Consumption-based GHGs per Person[a]



a Sources: King County (this study); U.S. and China (Hertwich and Peters 2009). A *Consumption-based Inventory* for the world is no different than on a production basis. In 2008, global emissions were about 44,000 MTCO2e, with a population of about 6.5 billion, or 6.8 $MTCO_2e$ per person (World Resources Institute 2011).

While per-person King County emissions in the *Geographic-plus Inventory* are much lower than for the U.S. as a whole (Table 3), it is striking that per-person emissions are roughly equal to the U.S. average in the *Consumption-based Inventory*. Per-person emissions from personal vehicle travel and residential energy (emission sources that are in both Consumption-based and Geographic-plus inventories) are much lower in King County, but emissions associated with food, other goods, and services are higher than the U.S. average. Indeed, based on economic modeling estimates,[36] per-person expenditures in King County (considering expenditures from households, governments, and business investment) are roughly 50 percent higher than the U.S. average. Evidently, our region's significant wealth – for example, per-person income of $40,000 in King County compared to $28,000 nationally in 2008[37] – led to above-average consumption of goods and services. Although King County's relative wealth may lead to higher emissions in the short term, it may also give us a practical advantage in the long term, as the region possesses resources that can help to innovate and finance the global transition to a low-carbon economy.

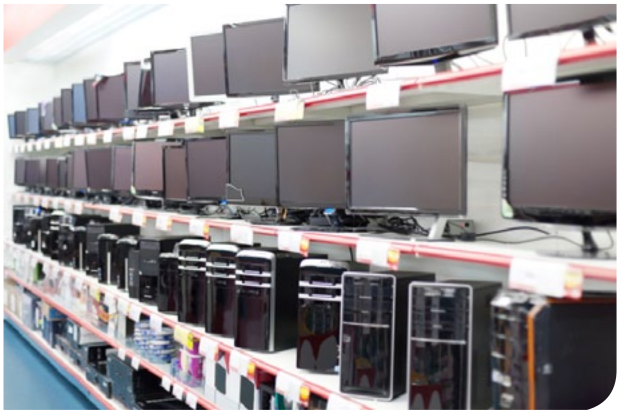
Although comparing modeled expenditures between King County and the nation helps explain why the consumption-based emissions of the two regions may be similar despite differences in electricity supply, doing so also shines a light on a limitation of the *Consumption-based Inventory* methodology. In particular, the King County expenditure figures in our model are based in part on national household expenditure data scaled to King County, not on actual survey data of purchasing behaviors within King County. Unfortunately, very few such local data exist. Second, since emissions are assumed to scale directly with expenditures within each of the 400-plus categories of consumption analyzed, our analysis cannot take into account differences in product quality, prices, or differences between similar products made with different materials or production practices (such as shade

36 IMPLAN estimates expenditures (final demand) for King County based on a variety of methods. For consumer expenditures (the biggest share), IMPLAN scales national data to the county level based on the number of households and household income for each of the nine income categories in the national Consumer Expenditure Survey. (We know of no direct measurement or data that tracks expenditure of King County residents by product category). For federal government expenditures, IMPLAN uses an actual database of federal expenditures by county. For state and local expenditures, IMPLAN uses a state-level survey and distributes to the County level based on corresponding government employment levels. For capital investment, IMPLAN uses national survey data by industry sector scaled to the county level based on relative employment level in each industry (MIG Inc. 2004)..

37 Per table B19301 in the U.S. Census Bureau's American Community Survey (ACS) for 2008. Respective totals for 2010 are $36,000 and $26,000, respectively, per table B19301 of the ACS for 2010.

grown versus conventionally grown coffee). As a result, if King County consumers are systematically buying goods with higher prices but not higher emissions, then actual emissions could be lower than our model estimates.[38] Both of these limitations remain important areas for further research and analysis in the rapidly evolving field of consumption-based inventories.

Key Findings and Discussion of *Consumption-based Inventory*



The *Consumption-based Inventory* estimates the release of all emissions associated with consumption in King County in 2008, where consumption is defined as consumer spending, government spending, and business capital investments (and net accumulations to inventory). In this inventory, emissions are assigned to categories of consumption, such as different types of goods or services. In many cases, these categories include emissions from multiple sectors used in the *Geographic-plus Inventory*. For example, emissions associated with the consumption of food include some emissions from each of the six sectors listed in the *Geographic-plus Inventory* (Table 2).

Our key findings from the Consumption-based GHG inventory are:

- **The emissions "footprint" of King County's consumption is about 29 $MTCO_2e$ per person**, similar to the U.S. average. This total is more than twice as high as the *Geographic-plus Inventory* and about four times higher than the global average.
- **From a consumption perspective, King County's emissions associated with personal transportation are the single greatest category of emissions**, as in the *Geographic-plus Inventory*.
- **Emissions "embodied" (those that occur pre-purchase) in goods, food, and services together comprise about 40 percent of Consumption-based emissions**, suggesting that the embodied emissions associated with common purchases are a significant contributor to global GHG emissions.
- **Producing and using goods releases far more GHG emissions than transporting or disposing them**. Across all categories of consumption, more than half of King County's Consumption-based emissions are associated with producing what we purchase, and more than a quarter are associated with using these items (e.g., driving a car or using an appliance). This finding suggests that efforts to assess low-GHG consumption behaviors would benefit by focusing on the relative emissions associated with producing different alternatives.
- **The consumption perspective highlights emissions rarely included in most community-scale GHG inventories.** For example, the emissions associated with the full life-cycle of food consumed in King County are more than 50 times higher

From a consumption perspective, King County's emissions associated with personal transportation are the single greatest category of emissions.

Producing and using goods releases far more GHG emissions than transporting or disposing them.

38 For a summary of how higher incomes can translate to higher expenditures but not necessarily higher GHG emissions, see Girod and de Haan (2010).

than the emissions associated with agriculture within King County borders, as measured in the *Geographic-plus Inventory*. In addition, the emissions associated with the production of goods (including vehicles) and buildings is more than three times the emissions associated with in-county manufacturing, or industry.

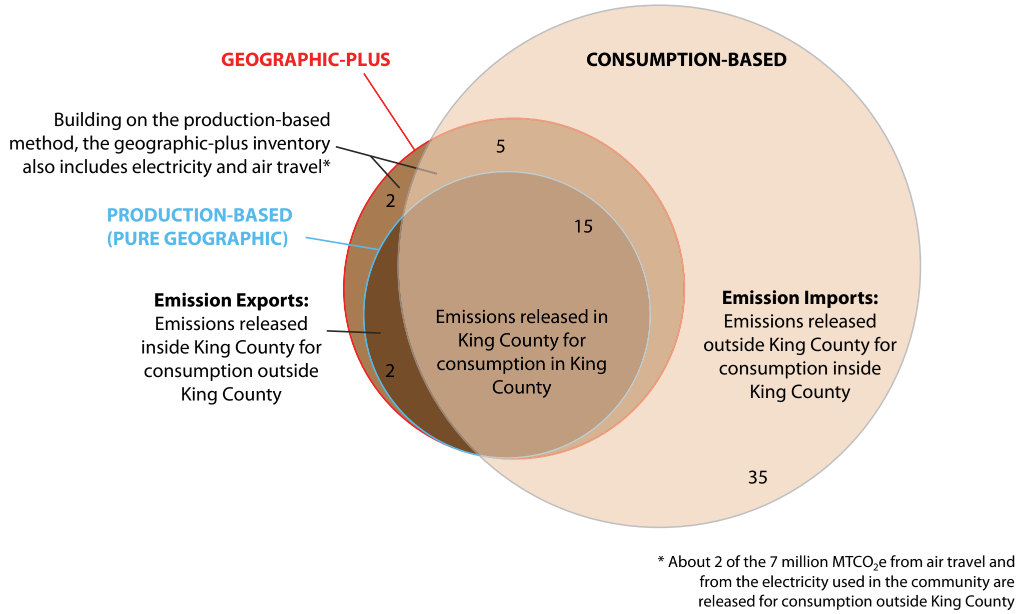
- **The emissions *intensity* of producing different goods and services can vary dramatically.** Looking at emissions per dollar can help inform how to shift to lower-GHG consumption patterns. The emissions intensity of consumption varies by more than a factor of ten, from over 2 kg CO_2e per dollar (e.g., red meat) to less than 0.2 kg CO_2e per dollar (e.g., financial services or healthcare), and also varies substantially within categories (e.g., the emissions intensity of food choices varies by a factor of up to three).

The *Consumption-based Inventory* offers a fundamentally different view of a community's emissions than a traditional production, or geographic, inventory.

To help understand the differences, Figure 6 compares the *Consumption-based Inventory* to the *Geographic-plus Inventory*, as well as to a pure production, or geographic, inventory for King County. In this figure (a modified Venn diagram), circles are sized in approximate proportion to emissions. The *Geographic-plus Inventory* departs from a pure production-based inventory by including about 7 million $MTCO_2e$ emissions associated with producing electricity used within King County (but produced outside the county) and emissions associated with air travel by King County residents and employees.[39] The *Consumption-based Inventory* departs even more substantially from a production-based inventory, in counting the emissions embodied in all goods, food, and services imported into the region (about 40 million $MTCO_2e$). But as described previously, the *Consumption-based Inventory* excludes emissions associated with in-county production for consumption elsewhere (about 2 million $MTCO_2e$). About 15 million $MTCO_2e$ are in all three inventories – these represent emissions released in King County to produce goods and services consumed in the county, as well as fuel consumed directly by final consumers (e.g., natural gas for home heating or gasoline for personal transportation).

Figure 6. Comparison of King County GHG Inventories

(Numbers indicate approximate 2008 emissions, in million $MTCO_2e$, in each portion of the diagram; Areas are approximately proportional to emissions)



39 A method for counting emissions from vehicle trips that excludes pass-through trips but includes a share of emissions associated with vehicle trips that cross the King County border is also implemented. Although this method adds about as many emissions as it subtracts (1 million $MTCO_2e$ in either case), it counts trips over which King County has a greater influence. Accordingly, using this method will facilitate tracking progress over time.

Compared to the *Geographic-plus Inventory*, the *Consumption-based Inventory* relies more heavily on less certain economic data sources. Furthermore, uncertainty in the *Consumption-based Inventory* is greater for individual product or service categories than it is for the total emissions estimate. Statistically robust local survey data on consumption behaviors would help increase accuracy of Consumption-based emissions estimates. Similar opportunities exist to improve the accuracy of the *Geographic-plus Inventory*. For example, further research into local vehicle licensing data could help improve the accuracy of the *Geographic-plus Inventory* with respect to the average fuel economy of freight and passenger vehicles (which is currently based on national average statistics). For further discussion of uncertainty, please see the two complete inventories in the appendices.

Local Production, Lower Emissions?

The finding that significant emissions are associated with the net import of goods and services into King County is not necessarily surprising, given that many of the items consumed in King County (e.g., vehicles, appliances, home furniture, clothing, and many types of food) are not produced in significant quantities within the region. If more of these items were made in King County, more emissions would be released locally, but would global emissions increase or decrease? This question defies easy answer.[40]

One popular notion is that significant emissions are associated with transporting food and goods and so buying "local" can reduce GHGs. Clearly, if more goods were made locally, their transport distances from production to consumer would indeed be lower. Yet as Figure 3 indicates, *pre-purchase transportation* represents only about 10 percent of all emissions associated with consumption. Furthermore, only about half of these emissions – or 2 million $MTCO_2e$ – are associated with transporting goods and food from producer to wholesale and retail channels.[41] Even if local production significantly lowered these emissions, the effect on overall Consumption-based emissions would be small and could be counteracted in part by any increases in transportation requirements of intermediate goods, such as fertilizers or fabric used, say, in local agriculture or clothing production.

Emissions associated with transporting food and goods are (on average) relatively minor, but as indicated in Figure 3, emissions from *producing* these items are more significant, and so therefore deserve closer scrutiny when evaluating alternative production locations. One way to evaluate alternative locations would be to compare the emissions *intensity* (emissions per unit) of production in King County compared to other parts of the country or the world. If emissions intensity of producing goods is lower in King County, then increasing local production would help reduce King County's Consumption-based emissions as well as global GHG emissions. For example, the Ash Grove cement plant in Seattle has released emissions at the rate of

40 For one, because of the definition of a *Consumption-based GHG inventory*, producing more goods, food, and services locally would have no effect at all on emissions associated with King County's consumption unless those items were also consumed here. However, for the sake of argument, let's assume that by shifting production to King County we mean shifting production of goods, services, and food that are indeed consumed in King County.

41 An in-depth analysis of the transportation requirements of food production found that transportation from farm or production facility to the retail store represented only about one-quarter of total transportation requirements of producing food. In that study, all transportation demand represented 11 percent of the total GHGs associated with food (C Weber and Matthews 2008).

0.88 $MTCO_2e$ per ton of cement clinker produced, slightly less than the national average of 0.93.[42] Accordingly, increasing production at Ash Grove, while increasing emissions in King County's *Geographic Plus Inventory*, could decrease global emissions, if were to displace an equivalent amount of cement production at other facilities with higher emission rates. Similarly, the Nucor Steel plant has released emissions at the rate of 0.2 $MTCO_2e$ per ton of steel, less than the global average for a similar (electric arc furnace using scrap feedstock) facility of about 0.4 $MTCO_2e$ per ton of steel.[43]

Differences in the material or energy efficiency of production practices, the GHG-intensity of the fuel or energy supply, and GHG recovery practices (if applicable) can all directly affect the emissions released to produce an otherwise equivalent product – whether cement, steel, food, clothing, or furniture. To assess whether increasing local production would decrease global GHGs, all of these factors would need to be assessed. King County would seem to have one clear advantage: relatively low-GHG electricity. However, even this benefit is not assured. A key reason that King County's electricity supply is low-GHG is the hydroelectric resources owned and operated by Seattle City Light and Puget Sound Energy, and to a lesser extent owned by and purchased from the Bonneville Power Authority. However, the region's hydroelectric resources are largely tapped. Therefore, if and as production of goods and services in King County grows, the *marginal* (added) sources of electricity used to support this growth could be significantly more carbon-intensive than hydroelectricity.

Indeed, plans by Puget Sound Energy show this to be the case; over the next 20 years, less than half of PSE's planned new electricity-generation capacity will be low-GHG renewables: about the same ratio as the national average.[44] As a result, adding future production in King County may not have the same GHG benefits (relative to the U.S. average) as in the past. An exception could be goods produced using electricity provided by Seattle City Light, since SCL plans to expand its wind, geothermal, and other renewable electricity sources to meet any growth in demand.[45]

Overall, if SCL stays on its plan and PSE increases its commitment to renewable energy (such as solar, wind, or tidal power), then King County could retain its advantage is low-GHG energy compared to the U.S. average. If that proves true, then locating new production in King County (and increasing consumption of locally-made products) could bring significant GHG benefits.

This example highlights the challenges in assessing whether increasing the purchase of King County-made goods would lead to a reduction in emissions associated with consumption (and accompanying net, global emissions benefit) and points to the need to consider the marginal sources of production and energy both serving King County and alternative regions.[46] Better estimates of the emissions consequences of shifting consumption patterns (among origins of production or, for that matter, product categories) would benefit from further research, and in particular, a deeper understanding of, and accounting for, marginal sources of energy (and production practices) for specific product types.

42 Data sources: Ash Grove: Puget Sound Clean Air Agency measurements in 2006; U.S: Cement Sustainability Initiative database (www.wbcsdcement.org/GNR-2009/index.html) for 2009. Methods may not be comparable, and additional research would be needed to confirm this difference.

43 Data sources: Nucor Steel: Puget Sound Clean Air Agency measurements in 2006; World: IEA (2008).

44 According to analysis of data from PSE (2011) and the U.S. Energy Information Administration (U.S. EIA 2011), the average emissions intensity of new electricity-generation capacity will be about 0.4 $MTCO_2e$ per MW (generated) for both PSE and the national average over the next twenty years.

45 Source: Seattle City Light (2010)

46 Similarly, the CBEI results are not sufficient, alone, to suggest that increasing the purchase of one category of goods or services at the expense of another would, by necessity, reduce global emissions.

4. Recommended Tracking Framework for King County

Greenhouse gas inventories – including the *Geographic-plus* and *Consumption-based* inventories presented in Sections 2 and 3 – provide broad insights into King County's contributions to global GHG emissions. However, inventories, by themselves, are not necessarily the best tools to track the progress of communities towards emission reduction goals. To the extent inventories rely on downscaling of state or national data for certain emissions sources, techniques we used in portions of both inventories, they cannot effectively reflect the outcome of actions local communities take to reduce these emissions. Inventories also include some emission sources over which local communities have little influence, or for which changes in reported local GHG emissions are not reflective of impacts on global GHG emissions, such as was the case when the LaFarge cement plant closed its kiln in Seattle at the end of 2010. Furthermore, inventories can be costly and time-consuming, and as a result, very few local communities conduct them annually. And yet, tracking progress on an ongoing basis can provide important indicators to increase community awareness and to inform decision-makers. In this section, we discuss, recommend, and apply a framework for tracking the most relevant King County emissions on an ongoing basis, as a tool to complement more comprehensive, but less frequent emissions inventories. To help clarify the distinction, we define a community *inventory* and *tracking framework* as follows.

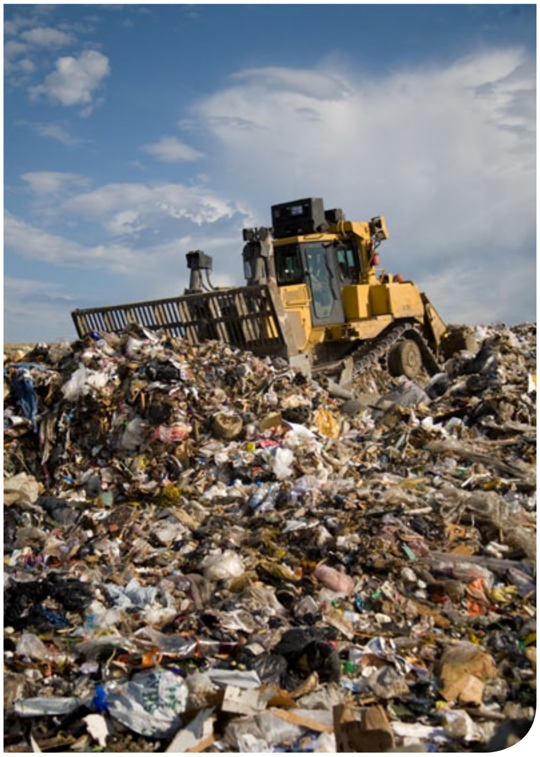
- A GHG *inventory* is a comprehensive accounting of a community's sources of, or contributions to, greenhouse gases.
- A GHG *tracking framework* is a focused and more continuous accounting of a community's most relevant emissions sources and emissions drivers (such as population and economic activity), expressed in the form of metrics designed to assess progress in efforts to reduce emissions.

The key distinction of a *tracking framework* from an inventory is in its greater focus on detecting changes in emissions and (where possible) the underlying drivers of that change that are associated with actions at a local scale. Though subtle, the distinction is important. Because of its focus on detecting changes, a *tracking framework* must therefore place greater emphasis on emissions sources that a community can influence and for which change can be measured. Accordingly, tracking framework may place less (or different) emphasis on emissions sources that cannot as readily be influenced or measured, even if those sources are significant. (Box 4 describes the method for assembling the recommended tracking framework, including the criteria considered).

Recommended Scopes

To support assembly of the tracking framework (and as described in Box 4), each of the emissions sources in either the *Geographic-plus* or *Consumption-based* emissions inventories were assessed (or, in one case, as from supplemental calculations[47]).

As indicated in Figure 7, some emissions sources are both more *measurable* and solidly within the direct *influence* of local governments. Together, these emissions sources combine the greatest capability for government influence with greatest ability for measuring and tracking emissions. In particular,



- Local vehicle travel, for which local governments write land use codes and conduct transportation planning that substantially determine patterns of vehicle travel;
- Residential and commercial buildings, for which local governments substantially influence building energy consumption through building codes and incentives (or, in some cases, mandates) for energy retrofits; and
- Waste, where local governments contract or directly operate management infrastructure such as refuse collection programs, recycling and composting facilities, and landfills.

These emission sources can be estimated and regularly updated with readily available local data on building energy (energy utilities), vehicle transportation (PSRC), and waste (waste management utilities). They comprise the majority (~70 percent) of emissions in the *Geographic-plus Inventory*. It is recommended that these sources form the "core" of King County's tracking framework and be tracked on an annual basis.

47 For emissions associated with "waste", we combine the assessment of waste commitment emissions and carbon storage (both as documented in Box 2), since these two outcomes of waste disposal are largely inseparable from each other. The result is that waste emissions are near zero.

Box 4. Criteria for Developing the GHG Tracking Framework

The recommended GHG tracking framework was developed by assessing emissions sources and possible tracking methods against a set of criteria, as listed in Table 9. These criteria were developed in partnership with the King County, City of Seattle, and Puget Sound Clean Air Agency staff that formed this project's Steering Committee. The criteria were also informed by an ongoing, parallel effort to develop a GHG accounting and reporting protocol for U.S. communities.[48] As indicated in the table, we place a particular emphasis on *policy influence* and *measurability & consistency*. These two criteria are used to assess the suitability of different emissions sources for the tracking framework and make key decisions about the framework's structure. (For a detailed assessment of emissions sources against the first two criteria, see Appendix A.) We use the additional criteria as screens that the overall framework must meet.

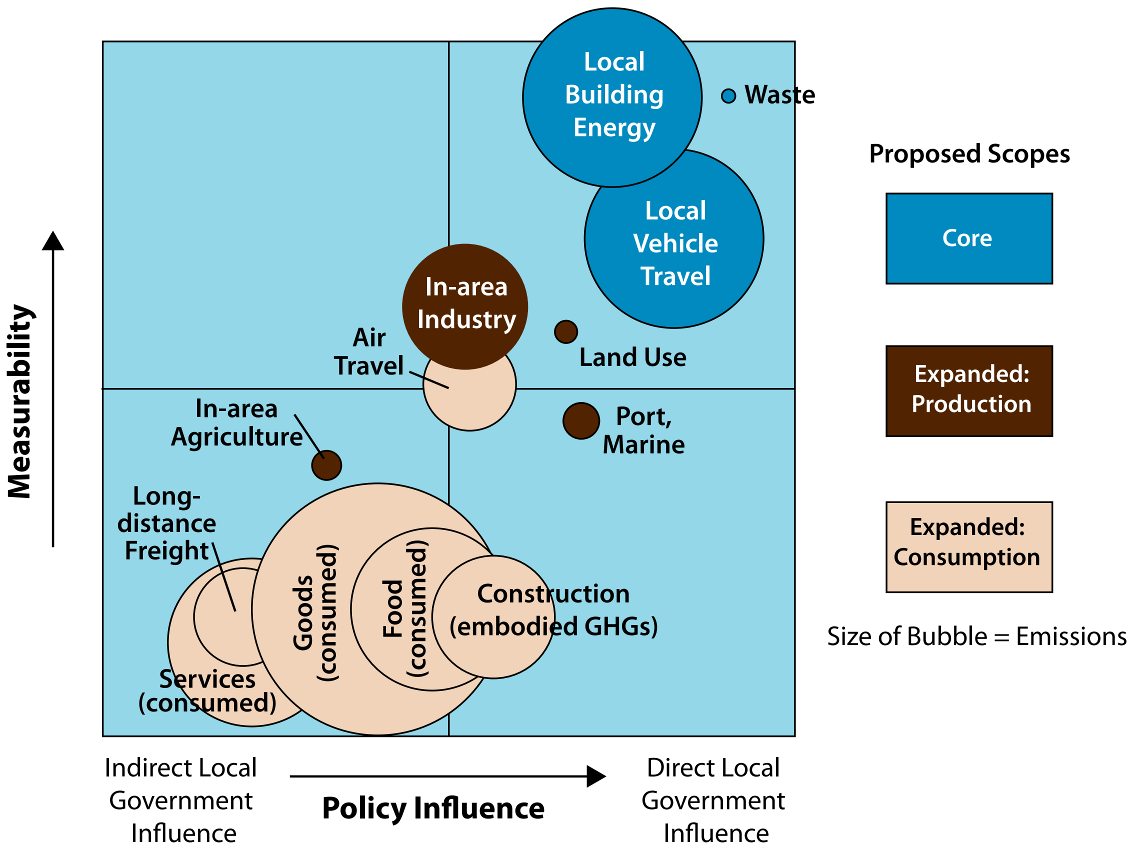
Table 9. Criteria Used to Assess Emissions Sources and Develop GHG Tracking Framework

Criterion	Purpose
Policy Influence	Emphasize sources for which community actions can have a measureable impact on global GHG emissions through policy levers available directly to local governments or indirectly through partnerships or programs with business or the community.
Measurability & Consistency	Ensure that data for a given source are readily available at reasonable cost, so that progress can be assessed using similar estimates over time. Design methods with an eye to potential changes in data availability, data structure, and reporting over time, taking into account the level of resource expenditure (i.e., cost-effectiveness) of the method.
Transparency and Simplicity	Enable the communication of metrics in a clear, credible, and understandable manner to the public and decision-makers.
Accuracy	Ensure that uncertainties are minimized to the extent possible, that quantification avoids any systematic bias (over or under-estimation), that minimizes overlaps among emissions sources (double-counting), and that provides a reliable basis for decision-making.
Completeness	Ensure emissions sources that are both relevant and significant are included.
Balance	Aim to reflect not only the emissions impacts of policies that can reduce emissions – whether those emissions occur within or outside the geographical boundary – but also of policies and actions by government, businesses, or households that could increase global emissions.

Feedback on the draft framework was gathered in two meetings in May 2011, one with the Project Steering Committee and another with a cross-section of King County staff.

48 That effort, coordinated by ICLEI-Local Governments for Sustainability, "aims to develop common conventions and standardized approaches, including an easily implemented set of guidelines, to assist local governments with quantifying and reporting GHG emissions associated with the communities they serve and represent" (ICLEI - USA 2011). King County and Seattle staff who served as members of this project's steering committee also served on the steering committee for the ICLEI effort, and in turn helped develop the criteria in Table 9 and develop that protocol, including by sharing drafts of this recommended King County tracking framework.

Figure 7. Assessment of GHG Emissions Sources and Recommended Scopes



In addition to the "core", it is also recommended that King County regularly assess two additional scopes, one devoted to consumption-based emissions and one devoted to additional emissions associated with in-county production. Together, the three scopes are:

- **Core**, a tracking of key emissions associated with buildings, transportation, and waste in King County. The Core scope is designed to be trackable on an annual basis, as it can be readily and cost-effectively updated for the fraction of a cost of a full GHG inventory using readily available data from Puget Sound Energy, Seattle City Light, transportation agencies, and waste management utilities, among other sources. If and as data quality improves, along with policy levers for reducing emissions, other emissions sources could be included in the Core scope.
- **Expanded: Production**, a tracking of emissions sources that are (largely) associated with the production (and through transportation) of goods and food in King County, regardless of where these products are consumed. For the most part, these sources should be tracked on an intensity basis (MTCO2e per tonne or $ value of product) to provide more focus on measures under local control (such as production practices and energy sources, as opposed to regional, national, or international demand for the products made.) Most data already exist to perform this tracking, but they are scattered across a disparate array of sources.
- **Expanded: Consumption**, a tracking of emissions associated with consumption, regardless of where goods, food, or services are produced. Like the *Consumption-based Inventory* presented in this report, this scope focuses on the embodied (pre-purchase) emissions associated with goods, food, and services. Unlike the *Consumption-based Inventory*, it focuses only on these embodied emissions and does not include emissions associated with use and disposal of these items, because emissions associated with these life-cycle phases are already addressed

in the core scope.[49] However, while an estimate of consumption-based emissions is provided in this report, our model is not able to track local changes to most of these emissions sources over time. Further research is needed to develop trackable, local data sources.

While the two "expanded" scopes could be tracked on an annual basis, given data and resource constraints, it is recommended that they be tracked on a less frequent, though regular basis, perhaps every three to five years. This timing could coincide with the preparation of full GHG inventories, where communities choose to conduct them. Table 10 summarizes key attributes of the three scopes.

Table 10. Summary of Proposed Scopes

Scope	Updating Frequency	Data Sources and Issues	Coverage
Core	Annual	• Readily available energy (Puget Sound Energy, Seattle City Light) and transport (PSRC) data • Opportunity to increase measurability in some key areas (e.g., to use Department of Licensing data for a better assessment of vehicle efficiency)	About 70 percent of the *Geographic-plus Inventory*
Expanded: Production	Regular (e.g., every 3 to 5 years or when inventory updated)	• Many disparate data sources, e.g., Puget Sound Clean Air Agency, Port of Seattle, U.S. Forest Service, others.	Up to 30 percent of the *Geographic-plus Inventory*
Expanded: Consumption	Regular (e.g., every 3 to 5 years or when inventory updated)	• No adequate data sources are known to exist for most types of consumption. Further research needed to develop regular, trackable data sources of consumption data, whether on an economic (e.g., dollar-value) or physical (e.g., weight) of items purchased.	Up to 70 percent of the Consumption Inventory

A key feature of the core scope is the relative availability of data sources needed. Still, opportunities exist to improve data access in this core scope. For example, regular sector and community-level reporting of energy use by utilities would facilitate tracking of the core metrics and greatly assist communities within King County in adopting this method. And Department of Licensing data on vehicle registration could be used to develop locally specific (rather than national) metrics on fuel economy of vehicles.

In the other two scopes, data needs are greater. In particular, for in-area industry, data are distributed across the Puget Sound Clean Air Agency (which has information on regulated pollutants, including some data that enables ready calculation of some GHGs for some facilities); state-level data sources (e.g., on industrial oil consumption); and in a few cases, such as use of tires for fuel at cement kilns, are only available directly from companies and may be subject to confidentiality concerns. For tracking consumption-based emissions, no publicly available data sources were found that track local purchasing of particular commodities in King County. More research and development are needed before a robust tracking framework for consumption-based GHGs can be implemented.[50] The next section, which is devoted to tracking metrics, further explores data needs.

49 A full *Consumption-based Inventory*, if conducted on a regular basis, could still include these *use* and *disposal* emissions.

50 Possible candidates include the IMPLAN-provided data used to conduct the Consumption-based inventory presented in this report as well as the federal government's Consumer Expenditure Survey (CEX). The CEX does have a rolling, two-year-average report on the Seattle "Metropolitan Statistical Area" (MSA), which the census bureau defines as all of King / Pierce / Snohomish counties. Given that large area and the relatively small sample sizes in the survey, CEX data is also unlikely to be fit for the job of tracking changes in King County consumption behaviors.

Tracking Metrics

For each of the three recommended scopes, the recommended tracking framework includes a set of metrics to enable ongoing monitoring of community GHG emissions and underlying drivers of those emissions. Tracking metrics vary by scope:

- The Core scope features tracking of GHGs (both in total and per person) in the transport, buildings, and waste sectors, including an overall metric that can be used to assess progress across all core sectors.
- The Expanded Production scope features a set of intensity metrics for local industrial production. Emissions from industry are normalized per output to remove the effect of larger economic trends in demand (largely outside King County) for these products. The Expanded Production scope also includes metrics associated with in-county agriculture, land use, port activity, and waste disposal at in-county landfills. Existing data sources would need to be upgraded to allow ready tracking of the Expanded Production scope.
- Metrics associated with the Expanded Consumption scope, such as consumption of various goods and services (per ton or dollar) per resident, will require further research to develop and update. Given the considerably better data availability (and high emissions intensity) relative to many other categories of consumption, air travel may be a good category for initial research. Food (given high overlap with public health efforts and high emissions intensity) may also be a good starting point, as could particularly emissions-intensive construction materials.

Table 11 lists recommended metrics across all scopes.

Table 11. Metrics for the GHG Tracking Framework

Emissions Source	Key Policy Levers	Overall Metric	Activity Metric	Intensity Metric
Core				
Transportation: Road (Vehicle Travel)	• Land use planning • Road & transit infrastructure • Parking and road pricing • Trip reduction programs	GHGs (total and per person)	VMT (total and per person)	GHGs / VMT
Buildings: Residential & Commercial (excluding mobile equipment)	• Building codes • Electricity supply	GHGs (total and per person)	Energy use, in BTU (total, per capita, and per-person-HDD)	GHGs / BTU
Waste	• Waste infrastructure • Landfill operation / contracts	GHGs (total and perperson, including carbon storage)	Tons disposed (total and per person)	GHGs / Ton
Total (Sum of Above)	--	**GHGs (total and per person)**	--	--
Expanded: Production				
"Heavy" Industry	• Electricity supply • Material / energy exchanges	None	None	GHGs / tonne
Other Industry	• Electricity supply	None	None	GHGs / unit of output (e.g., $)
Agriculture	• Incentives for anaerobic digesters	None	None	GHG / animal

Emissions Source	Key Policy Levers	Overall Metric	Activity Metric	Intensity Metric
Expanded: Production Continued				
Port of Seattle	• Port regulations and incentives regarding fuels and shore power	None	None	GHG / ton throughput
Land-Use Change	• Land use planning • Building permitting	GHGs (total)	Acres in forest cover, acres cleared	GHGs / acre
In-region Landfills	• Landfill operation / landfill gas collection	GHGs (total) GHGs avoided due to energy generation	Energy generated at landfill (MBTU)	None
Expanded: Consumption				
Food, Goods, Services	• Education: diet / waste • Government procurement	GHGs (total and per person)	Consumption per resident (kg or $) by product	Embodied GHGs / kg or GHGs/$
Construction	• Building codes • Promotion of voluntary standards	GHGs (total and per person)	Material consumption, by type (tons)	Embodied GHGs / ton
Recycling & Composting[a]	• Waste infrastructure • Recycling & composting operation / contracts	GHGs (total and per person) from avoided manufacturing assessed relative to national average recycling practices	Tons recycled and composted relative to national average (total and per person)	GHGs / Ton[b]
Air travel	• Alternative infrastructure (video-conference, high-speed rail)	GHGs (total and per person)	Passenger-miles or trips (total and per person)	GHGs / mile or GHGs/trip

a Recycling and composting are assessed separately and not included in the summed total of the Core scope.

b Based on the EPA's WARM model

Piloting the Framework

The goal of the tracking framework is to monitor changes in key emissions sources, as well as in underlying drivers of those changes. It is recommended that King County update metrics associated with the "core" scope annually, with others updated on a less frequent, but regular, basis, perhaps every three to five years. To test the framework and establish a baseline of tracking metrics, Table 12 applies the recommended framework to King County's Core emissions for the years 2003 and 2008. For additional details on data sources used to assemble these metrics, see Table 16 in Appendix A.

Table 12. Baseline Core GHG Tracking Metrics for King County: 2003 and 2008

(Parentheses indicate emissions avoided, sequestered, or stored)

Emissions Source		2003	2008	% Change
Core				
Transportation: Road				
	Emissions (Million $MTCO_2e$)	9.2	8.9	(4%)
	Emissions per person ($MTCO_2e$ /resident)	5.2	4.7	(9%)
	Passenger emissions per person ($MTCO_2e$ /resident)	3.4	3.1	(11%)
	Freight emissions per person ($MTCO_2e$/resident)	1.7	1.7	(5%)
	Passenger VMT per person - (thousand miles/resident)	7.4	6.9	(7%)
	Freight VMT per person (thousand miles/resident)	1.1	1.1	(7%)
	Passenger emissions per mile ($kgCO_2e$/VMT)	0.46	0.44	(5%)
	Freight emissions per mile ($kgCO_2e$/VMT)	1.53	1.57	2%
Buildings: Residential & Commercial				
	Emissions (Million $MTCO_2e$)	7.0	7.8	12%
	Emissions per person ($MTCO_2e$ /resident)	3.9	4.1	5%
	Residential emissions per person ($MTCO_2e$ /resident)	2.1	2.2	3%
	Commercial emissions per person ($MTCO_2e$ /resident)	1.8	1.9	7%
	Residential energy per person (MBTU[a]/resident)	33.5	34.8	4%
	Commercial energy per person (MBTU/employee)	59.3	61.9	4%
	Heating Degree Days (HDD)	4,509	5,022	11%
	Cooling Degree Days (CDD)	277	195	(30%)
	Residential GHG intensity of energy (kg CO_2e/MBTU)	62.64	62.3	0%
	Commercial GHG intensity of energy (kg CO_2e/MBTU)	58.9	59.0	0%
Waste: Landfills (CH4 Commitment Basis)				
	Emissions (million $MTCO_2e$)	(0.25)	(0.22)	12%
	Emissions per person ($MTCO_2e$ /resident)	(0.14)	(0.12)	17%
	Residential waste disposed per person (tons / resident)	0.39	0.34	(13%)
	Nonresidential waste disposed per person (tons / employee)	0.80	0.68	(15%)
Total Core Emissions				
	Total Emissions (Million $MTCO_2e$)	15.9	16.4	3%
	Population (million residents)	1.77	1.88	6%
	Employment (million commercial employees)	0.93	1.01	9%
	Emissions per person ($MTCO_2e$ /resident)	9.0	8.7	(3%)

a MBTU = million BTU, also sometimes referred to as mmBTU. This metric includes all fuels and electricity in terms of final energy content. In other words, electricity is converted to BTUs based on the energy content of electricity delivered (3414 BTU/kWh) rather than the energy content of fuels and resources used to produce electricity ("primary energy").

The metrics shown in Table 12 reiterate some recent trends (between 2003 and 2008) noted earlier in this report. Looking at the underlying drivers also helps illuminate the following:

- In road transportation, almost all recent trends have led to lower emissions per person: lower passenger and freight VMT per person, as well as lower emissions intensity (due to increasing fuel economy) of passenger travel. The emissions intensity of freight travel, however, has increased modestly. This change – based on national statistics, is not well understood but has been thought to be due to a trend towards more powerful engines as well as due to implementation of energy-consuming devices to control other air pollutants (NOx and particulates).51 Further research (perhaps using Department of Licensing data) could help better define the fuel economy of local vehicles.

- In buildings, key metrics have held relatively constant, considering the difference in weather between 2003 and 2008. Both residential and commercial energy per person increased, but these can largely be explained by the colder weather in 2008.[52]
- In waste management, carbon storage in landfills decreased very slightly (fewer emissions were stored as carbon-rich materials such as wood or paper), but this trend was due to decreasing waste disposal per capita. Many of these materials were diverted to recycling (which is tracked as part of the *Expanded: Consumption scope*, discussed next), a process that can avoid significant emissions.

Overall, emissions in the Core scope increased from 15.9 million $MTCO_2e$ to 16.4 million MTCO2e between 2003 and 2008, an increase of 3 percent that due in large part to growth in population (6 percent) and commercial employment (9 percent), as well as colder weather in 2008. On a per-person basis, however, emissions decreased from 9.0 to 8.7 $MTCO_2e$, a decline of 3 percent. Of course, 2008 was the beginning of the global economic recession (as well as a year with particularly high gasoline prices), a fact that could help explain the downward trend in per-person emissions, particularly for vehicle travel. However, per-person vehicle miles travelled declined in King County each year between 2004 and 2009, suggesting that the drop is longer term and not unique to the beginning of the recession in 2008.[53] As King County begins to climb out of the recession, future updates of these tracking metrics may provide additional insights into the relationship between the economy and GHG emissions.

For preliminary baseline tracking metrics for the expanded consumption and production scopes for 2003 and 2008, see Appendix A.

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51 For discussion of these trends, see www.fra.dot.gov/Downloads/Comparative_Evaluation_Rail_Truck_Fuel_Efficiency.pdf.

52 For example, considering that energy for heating is about half of residential energy consumption and one-third of commercial energy consumption in the Seattle area (Lazarus, Erickson, and Chandler 2011), then the 11 percent increase in heating demands (as measured by HDD) between 2003 and 2008 would translate into approximately a 6 percent (0.5*0.11) and 4 percent (0.33*0.11) increase in per person energy consumption, respectively, similar to the 4 percent observed in both sectors.

53 Based on data for 2000 through 2009 for King County from the Highway Performance Management System (HPMS). In 2010, the Washington Department of Transportation changed its method for HPMS data, so results for 2010 are not comparable.

5. Conclusions

GHGs are accumulating in the atmosphere at levels that could dangerously disrupt the global climate system. Deep reductions in GHG emissions will require bold actions at all levels, from nations to communities. While the Intergovernmental Panel on Climate Change has set clear standards for nations to inventory emissions, as yet, no widely accepted standard exists for measuring, or inventorying, a community's contribution to global GHG emissions. Like many communities, King County has used methods designed for application largely at the national level. However, when applied at the community level, these methods are lacking. Recognizing these limitations, King County is now grappling with the question of what GHG emissions to measure and how to track them on a regular basis.

In this study, conducted for King County and its partners at the City of Seattle and Puget Sound Clean Air Agency, two very different GHG inventories for King County are compiled. The *Geographic-plus Inventory*, documents releases of GHG release of GHG emissions from cars and trucks, buildings, waste, agriculture, and other sources of emissions within King County in 2008. This method is in general alignment with methods used in the U.S. EPA's national GHG inventory, the Washington State GHG inventory, and standardized methods used by a number of jurisdictions nationally and internationally. This method relies in large part on regular and well-known data sources, including utility billing data and, state-collected fuel mix reports for electric utilities, vehicle travel models from the Puget Sound Regional Council, and national fuel economy statistics.

The other, *Consumption-based Inventory*, estimates emissions associated with producing, using, and disposing all products and services consumed in King County in 2008, regardless of whether emissions are released locally, nationally, or internationally. This method relies largely on economic data (some of which is scaled to King County from national totals) to estimate the "embodied" emissions associated with all products and services consumed in King County.

Together, the two inventories provide a comprehensive picture of King County's contributions to global GHG emissions. Not surprisingly, both inventories point to local vehicle travel and building energy use as major sources of emissions in King County. Each inventory also offers other, unique insights. For example, the *Geographic-plus Inventory* shows that emissions from the buildings sector are half the national average on a per-person basis, due almost wholly to King County's significant supply of low-GHG hydroelectricity. The *Geographic-plus Inventory* also shows that emissions associated with producing goods in King County (e.g., from industry) are much less (on a per-person or per dollar basis) than the national average. Yet emissions associated with producing goods consumed in King County are significant: as the *Consumption-based Inventory* shows, embodied emissions associated with goods, food, and services consumed in King County are greater than the entire *Geographic-plus Inventory* and are largely released outside King County. The *Consumption-based Inventory* also shows that the full emissions footprint of King County's consumption is several times higher than the global average.

Neither the Geographic-plus nor the *Consumption-based Inventory* method is the "right" method for all contexts, however. In particular, neither inventory is especially well-suited to tracking changes in emissions sources over which local governments have unique and direct influence. For this reason, a new recommended greenhouse gas emissions tracking framework was developed for King County, in close consultation with the project's Steering Committee, additional King County staff, and other analysts.

The recommended framework focuses on three distinct "scopes" of emissions. This framework features annual tracking of a "core" scope of emissions sources that can be more easily measured and over which local governments (King County included) have relatively direct and unique policy influence. These emissions sources consist of local building energy use, vehicle travel, and waste disposal. This scope can be tracked annually using data that are, for the most part, readily available from local utilities and planning agencies. In the near term, this scope should be the primary focus of King County's GHG tracking efforts. Other scopes, however, are also important to consider: an Expanded Production scope that focuses on in-county industrial production activities and an Expanded Consumption scope that focuses on in-county consumption emissions that are not already included in the *Geographic-plus Inventory*. Each of these two expanded scopes will require additional research and data development to fully implement. For each of the three scopes, the overall tracking framework provides a set of metrics that government, businesses, and households can use to assess changes in emission levels and underlying drivers of those changes.

The three scopes are defined largely by assessing the relative policy influence and measurability of emission sources, assessments that are inherently qualitative and subject to local conditions. Other communities interested in tracking performance in reducing GHG emissions may also consider this approach and adapt the tracking framework to their local circumstances. Such communities should also look to other approaches to exploring the roles of communities in global GHG emissions, such as the GHG accounting and reporting protocol for local communities under development by ICLEI – Local Governments for Sustainability, which is using similar concepts and criteria as our assessment, including reference to consumption-based GHG accounting.[54]

The results of this study suggest a number of opportunities to address climate change through actions at the government and community levels. In particular, key findings pertaining to each group include the following:

- **For local governments**, this study demonstrates the high relevance of government policies addressing GHG emissions associated with vehicle travel, building energy use (including electricity use), and waste management. At the same time, it shows the production of food, goods, and services consumed by King County residents results in GHG emissions, largely beyond King County's borders, that are of an equally significant scale. Government efforts focused on "sustainable consumption" can also affect these emissions, and the results in this report

54 Members of this project's team, including staff from SEI, King County, and City of Seattle are also involved in the ICLEI effort.

can help serve as a screening tool to identify product or service categories that are, by virtue of their embodied GHG emissions impacts, good candidates for further research, policy development, information campaigns, or government purchasing strategies.

- **For residents**, our analysis can help identify categories of decisions with significant implications for global GHG emissions. For example, emissions associated with personal vehicles and home energy use are significant and are directly affected by decisions on where to live, how to get around, and how you operate your home. Emissions associated with regular purchases goods and services, such as for food and home furnishings, are also significant, and can be affected by (for example) examining the emissions intensity of food choices and by purchasing items that last longer, among other actions.

The study's findings can also pertain to businesses, though business purchasing was not a specific focus of the research.

King County's initiative to compare inventory methods and embark on a new, more relevant tracking framework represents an important contribution toward community-level action on climate change. Such efforts are especially timely, and can help to spur and complement renewed national and international momentum on climate policy. As a long-time leader on local climate action, King County may well help to shape broader dialogues on appropriate community-scale responses to the climate crisis.

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Appendix A: *Further details on Recommended Tracking Framework*

Appendix B: *Geographic-plus Inventory*

Appendix C: *Supplemental Emissions*

Appendix D: *Consumption-based Inventory*

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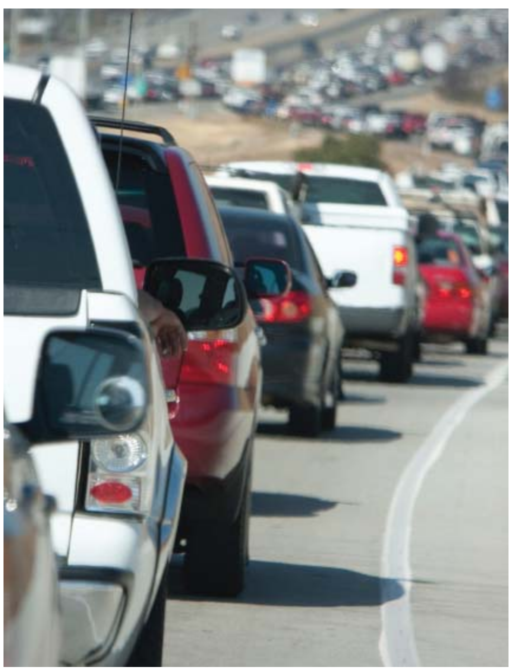
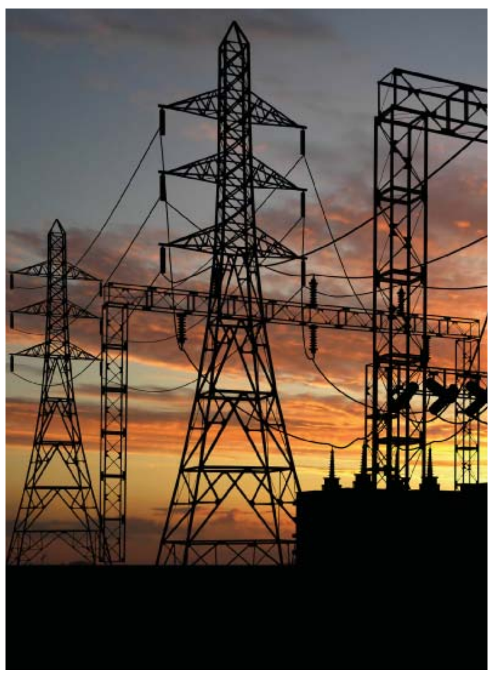
Greenhouse Gas Emissions in King County

Appendix A: Further Details on Recommended Tracking Framework





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Further Details on Recommended Tracking Framework

This Appendix provides additional details on several topics related to the recommended tracking framework:

- Assessment of emissions sources for inclusion in tracking framework;
- Emissions sources not included in the tracking framework;
- Treatment of pre-combustion emissions from fuel production and delivery;
- Data sources used to support the tracking framework;
- Preliminary Tracking Metrics for *Expanded:Production* and *Expanded:Consumption* Scopes.

Assessment of Emissions Sources for Inclusion in Tracking Framework

Table 1 presents further details on our assessment of emissions sources, as discussed in Box 4 in the main report text.

Table 1. Assessment of Policy Influence and Measurability for GHG Emissions Sources

Key to Ratings:	Policy Influence	Measurability
●	Direct & unique	High
⭘	Mixed	Medium
○	Indirect &/or diffuse	Low

Sector	Subsector	Policy Influence (Levers)	Measurability (Data Sources)
Emissions Sources from *Geographic-plus Inventory*			
Transportation			
	Road	● Land use planning ● Road & transit infrastructure ● Parking and road pricing ● Trip reduction programs	● WSDOT vehicle counts (VMT) ⭘ PSRC models (VMT) ⭘ Dept. of Licensing (efficiency) ⭘ Fuel sales
	Marine & Rail	⭘ Port regulation	⭘ Port of Seattle inventory
	Air	⭘ Internet infrastructure to support video conferencing	● Port of Seattle fuel data ○ Passenger attribution to KC
Buildings			
	Res'l / Comm'l	● Building codes ● Energy supply	● Utility billing data (BTU, MWh) ⭘ Fuel mix reports (tCO_2/MWh)
Industry			
	Energy / Process	● Electricity supply ○ Material / energy exchanges	● Utility billing data (BTU, MWh) ⭘ PSCAA data ⭘ Company-provided data
	Fugitive	⭘ Regulation on some (e.g. HFC)	○ Scaled national data (HFC, SF6)
Waste			
	Landfills	● Waste infrastructure ● Landfill operation / contracts	● Utility data (tons) ⭘ Gas capture (CH_4/ton)
	Wastewater	● Wastewater infrastructure	⭘ Gas generation / capture
Agriculture			
	Livestock	⭘ Incentives for digesters	⭘ USDA animal counts
	Fertilizer Application	○ Outreach	○ Scaled national data (N_2O)
Land-use			
	Res'l Development	● Land use planning ● Building permitting	● KC Assessor (permit data) ● Satellite/field data (clearing)
***Consumption--based Inventory* Sources**			
Personal Transportation		(See *Transportation*, above)	
Home Operation		(See *Buildings: Residential*, above)	
Food		○ Education: diet / waste ⭘ Government procurement	○ IMPLAN or CEX data & I-O ($) ⭘ GHG Inventories & I-O (CO_2e/$)
Goods		○ Consumer education ⭘ Government procurement	○ IMPLAN or CEX data & I-O ($) ⭘ GHG Inventories & I-O (CO_2e/$)
Services[1]		○ Business education ⭘ Government procurement	○ IMPLAN or CEX data & I-O ($) ⭘ GHG Inventories & I-O (CO_2e/$)
Construction[2]		⭘ Building and land use codes ⭘ "Green building" incentives	○ IMPLAN or Census[3] data & I-O ($) ⭘ GHG Inventories & I-O (CO_2e/$) ● Process LCAs ($CO_2$e/ton)
Other			
	Retail and wholesale	(Can be considered a subset of *Buildings: Commercial*, above, though limited ability to disaggregate into types of goods consumed.)	
	Other transport (long-distance freight)	⭘ Road-to-rail infrastructure ○ Systems for local production	○ IMPLAN, CEX, or Census & I-O ($) ⭘ GHG Inventories & I-O (CO_2e/$)

[1] Policy levers available to Buildings: Commercial could also reduce the embodied emissions of services to the extent that commercial building energy in King County is a significant fraction of these emissions. However, emissions associated with in-county operations of commercial buildings, at 4.0 $MTCO_2$e (Table 2 of the main report) and not all of which are associated with in-county consumption, are less than half the entire embodied emissions associated with services consumed in King County, 9.7 $MTCO_2$e (Table 8 of the main report, including restaurants). This suggests that in-county buildings represent at most about 40% of the embodied emissions associated with services.

[2] The assessment of *Construction* here pertains to the embodied emissions in construction materials and therefore receives different ratings than the assessment for *Buildings*, which pertains to building energy use.

[3] Purchasing data for some materials not generally purchased directly by consumers (e.g., cement and other construction materials) is available from the Economic Census instead of the Consumer Expenditure Survey (CEX).

Emissions Sources Not Included in the Tracking Framework

The tracking framework focuses on a Core scope of emissions in the transportation, buildings, and waste sectors for which data are readily available. For the two additional scopes, *Expanded Production* and *Expanded Consumption*, the focus is on sectors or categories of emissions that, taken together, meet the criteria discussed in Table 9 in Box 4 of the main report. The tracking framework does not yet cover all sources included in the *Geographic-plus Inventory*, however. After considering data limitations and the relative magnitude of emissions, the sources in Table 2 in the recommended tracking framework are not included at this time. More work is needed to include these sources, which together comprise less than 10% of the *Geographic-plus Inventory*.

Table 2. Emissions Sources in the *Geographic-plus Inventory* Not Yet Included in the Tracking Framework

Sector	Source	Total Emissions, 2008 (Million $MTCO_2e$)	Reason Not Included in Tracking Framework at This Time
Transportation			
	Ferries	0.04	▪ Very small (<0.5%) share of *Geographic-plus Inventory*
	Cruise Ships	0.05	▪ Very small (<0.5%) share of *Geographic-plus Inventory*
	Marine pleasure craft	0.01	▪ Very small (<0.5%) share of *Geographic-plus Inventory*
	King County International Airport (Boeing Field)	0.13	▪ Small (<2%) share of *Geographic-plus Inventory* ▪ Little opportunity for local government policy influence ▪ Emissions largely associated with industrial activity (e.g., Boeing) satisfying demand outside King County
Buildings			
	Residential: lawn equipment	0.05	▪ Very small (<0.5%) share of *Geographic-plus Inventory* ▪ No locally specific data sources known
	Commercial: lawn and other mobile equipment	0.41	▪ Small (<2%) share of *Geographic-plus Inventory* ▪ No locally specific data sources known
Industry			
	Fugitive Gases (ODS substitutes and SF_6)	0.73	▪ No locally specific data sources known
	Industrial Equipment	0.78	▪ No locally specific data sources known
Waste			
	Wastewater Treatment	<0.01	▪ Very small (<0.5%) share of *Geographic-plus Inventory*
Agriculture			
	Fertilizer Application	<0.01	▪ Very small (<0.5%) share of *Geographic-plus Inventory* ▪ No locally specific data sources known
	Total *Geographic-plus* Sources Not Included at This Time:	**2.20**	

Each of these sources can continue to be assessed in the context of a regular GHG inventory (and each is currently included in the *Geographic-plus Inventory*).[4]

Treatment of Pre-combustion Emissions from Fuel Production and Delivery

The Core scope of the recommended tracking framework includes emissions associated with burning fuels for transportation and buildings in King County, regardless of whether those fuels are burned directly (e.g., in a vehicle or home) or instead indirectly to produce electricity used in vehicles and buildings.

[4] In addition, as described in the main body of this report, it is not recommended that emissions associated with the *use* and *disposal* phases of the Consumption-based inventory be included in the Expanded: Consumption tracking framework. These emissions are (for the most part) included within the Core scope.

Other emissions can also be associated with fuel use: emissions associated with producing and transporting the fuels themselves. For example, fossil fuels require extraction and processing equipment that in turn require energy and associated emissions. Producing biofuels, too, requires equipment for feedstock growth, harvest, and processing, and may require clearing of land to plant biofuel crops. Furthermore, even if land is not directly cleared to grow biofuel crops, growing these crops may induce land to be cleared elsewhere to make up for lost production of the prior crop. For example, if corn in the Midwestern U.S. is directed to biofuel production instead of to food (or feed) uses, other land may be cleared (even if in another part of the world) to make up for (all or a portion of) the corn diverted away from food production. This phenomenon is sometimes called indirect land use change and can comprise a substantial portion of the emissions associated with biofuel production.[5] Since most GHG inventories (including the US EPA's national inventory) count biofuel combustion as zero emissions, including pre-combustion emissions may have a greater impact on biofuel emissions accounting than for fossil fuels and therefore more significantly affect the relative emissions between biofuels and fossil fuels than among different types of fossil fuels.

There is no well-established method of assessing the pre-combustion emissions associated with fuel production and delivery in a community's GHG inventory. One approach could be to estimate and include these emissions by developing corresponding emission factors (or multipliers) for each fuel used in the community.[6] However, one drawback of this approach is that it would introduce new uncertainties into otherwise well-established emission factors for fossil fuels and would rely on regular, detailed assessments of the processes used to produce the variety of fuels used.

An alternate approach could be to focus the assessment on biofuels (leaving treatment of fossil fuels unchanged), given the potential for biofuel emissions to be more substantially impacted by accounting for pre-combustion activities. For example, emissions from biofuels could be counted as a fraction of the standard, combustion emissions for a comparable petroleum-based fuel. The fraction could be determined as the ratio of the full life-cycle emissions of the two comparable fuels based on the best available life-cycle studies of the fuels. For example, the US EPA (2010) finds that life-cycle emissions of sugarcane-derived ethanol are about 40% of life-cycle emissions for gasoline per unit of energy. Accordingly, emissions from sugarcane-derived ethanol could be counted as 40% of the standard combustion (*tailpipe*) emissions for gasoline. While this method would slightly underestimate the full emissions associated with biofuels it would maintain consistency in accounting for petroleum fuels with most other GHG inventories, including the *Geographic-plus Inventory* calculated here. The benefits and drawbacks of the two approaches are summarized in Table 3.

[5] For a review of the issue, see Fargione, Plevin, and Hill (2010). For assessments of emissions associated with indirect land use change, see US EPA (2010) or CARB (2009).
[6] As of June 2011, such a method is being considered by ICLEI for their U.S. community GHG protocol.

Table 3. Benefits and Drawbacks of Alternate Methods of Accounting for Pre-Combustion Emissions from Fuel Production and Delivery

Approach	Benefits	Drawbacks	Additional Notes
Count (absolute) pre-combustion emissions associated with all fuels	▪ Most complete accounting for global emissions impacts of fuel use	▪ Introduces uncertainty into otherwise well-established practice of fossil fuel emissions accounting ▪ Could introduce annual variation into emissions estimates that may be unrelated to policy actions taken in the community and therefore reduce ability to track progress	▪ Because it is more complete, this method would better support assessment of the life-cycle emissions tradeoffs of replacing existing energy-using products with more efficient models[7]
Count emissions of biofuels as a ratio of their petroleum fuel equivalents	▪ Maintains simplicity and consistency with existing fossil fuel emissions accounting and most other GHG inventories ▪ Confines uncertainties associated with pre-combustion emissions to biofuel emissions	▪ Introduces a known inaccuracy, as it would report an underestimate of the full life-cycle emissions associated with the alternative fuel	▪ Could be adapted to assess alternative fossil fuels (e.g., liquid fuels derived from tar sands or coal) as a ratio of their "standard" petroleum fuel equivalents

Currently, liquid biofuels represent a very small fraction of fuels used in King County. However, the region has been cited has having the highest per-capita use of biodiesel in the country,[8] which (combined with federal incentives for biofuels) suggests that biofuel use may increase. Accordingly, accurately accounting for biofuel emissions will be increasingly important.

In the current *Geographic-plus Inventory* and Core tracking framework, we count biofuel GHG emissions as zero by default, following the practice of the US EPA's national inventory. National GHG inventories officially count biofuels as zero carbon, following IPCC guidance. This is largely reasonable since the national inventories also count net changes to biomass carbon stocks (e.g., in forests). If, as the result of land use change or wood harvesting, biofuel production results in changes to biological carbon stocks, then national inventories, in principle, should already capture these changes. Counting biofuel GHG emissions as zero makes less sense for community-scale inventories than it does for national inventories, since community-scale inventories generally cannot capture net changes in biomass carbon stocks where biomass energy is produced.[9]

Therefore, for future accounting of biofuels, pursuing one of the two methods discussed above is recommended. Once data sources are established to estimate the fraction of biofuel use in King County, this method could be introduced so that King County's tracking framework by default neither overcounts the climate benefit of biofuels nor includes a perverse incentive to use biofuels (or, for that matter, alternative fossil fuels) that may not provide net GHG benefits.

Lastly, similar questions may need to be addressed for solid biomass used for electricity and heat production, especially in the case of woody biomass fuels. Either the absolute or the ratio approach discussed above could also be adapted to consideration of solid biomass (or other alternative fuel sources) used in electricity or heat production.

[7] For example, accurate assessments of the embodied emissions in a vehicle, building, or appliance relative to the emissions associated with *using* that product would need to consider not only the combustion emissions but also the pre-combustion emissions associated with the fuel used.
[8] http://www.harvestcleanenergy.org/biofuel/index.html
[9] For more on this, see Searchinger et al. (2009).

Further Details on Data Sources for Core Metrics

Table 4 lists particular data sources used to assemble the Core tracking metrics in Table 12 of the main report. For further details on many of these data sources, see Appendix B.

Table 4. Data Sources Used for Core Tracking Framework

Emissions Source	Activity Data	Intensity Data	Issues or Challenges
Core			
Transportation: Road			
Passenger (Light duty vehicles)	▪ PSRC (VMT model results) ▪ WA DOT (HPMS VMT data for scaling across years)	▪ Federal Bureau of Transportation Statistics (BTS)	▪ Using national intensity data does not capture changes in local vehicle or fuel mix, suggesting opportunity for data development ▪ WA DOT's HPMS method changed in 2010, so a means to compare pre-2010 data will need to be developed
Passenger (Bus)	▪ King County Metro and Federal Transit Administration's National Transit Database	▪ King County Metro	▪ Existing King County Metro and Sound Transit data not easily organized in the origin-destination pair approach used for other vehicle travel ▪ Improvements in PSRC models may enable bus VMT to be assessed together with other vehicles, as above
Medium / heavy duty vehicles	▪ PSRC (VMT model results) ▪ WA DOT (HPMS VMT data for scaling across years)	▪ US DOT Federal Highway Administration's Highway Statistics	▪ Same as above for passenger vehicles
Buildings: Residential & Commercial			
Natural gas	▪ PSE (sales in therms)	▪ US EPA (GHGs per therm)	Unclear how natural gas purchased direct from wholesalers and only delivered by PSE (e.g., to Seattle Steam) is counted in PSE statistics
Electricity	▪ PSE and SCL (sales in kwh)	▪ Washington Department of Commerce (GHGs per kwh delivered)	
Oil	▪ Federal Energy Information Administration (EIA) State Energy Data System (SEDS) ▪ Census Bureau, for scaling factors (employment, # homes with oil heat)	▪ US EPA (GHGs per BTU of oil)	▪ Scaling of state totals is insufficient method, particularly for commercial oil use, suggesting opportunity for data development (e.g., with local heating oil suppliers) ▪ Future of EIA SEDS data is in question given federal budget.
Steam	▪ PSCAA data (natural gas consumption at Seattle Steam and University of Washington steam plants)	▪ US EPA (GHGs per therm)	▪ May require collaboration with Seattle Steam in the future, given recent switch to biomass as partial feedstock and development of emissions factor for their biomass use
Waste: Landfills			
King County's waste (currently Cedar Hills)	▪ King County Solid Waste Division	▪ US EPA (WARM tool) and King County Solid Waste Division (Landfill gas capture rate)	
Seattle's waste (currently Arlington)	▪ Seattle Public Utilities	▪ US EPA (WARM tool)	▪ Landfill gas capture rate at Arlington landfill is unknown. EPA WARM's (prior) 75% default used. May want to update to WARM version 11 default (90%).

Preliminary Tracking Metrics for *Expanded: Production* and *Expanded: Consumption* Scopes

Table 5 provides preliminary baseline tracking metrics for the expanded scopes for 2003 and 2008. Although data for these scopes are limited, we assemble preliminary, example metrics here to demonstrate possible metrics and to provide comparison between sources. Ultimately, developing a robust tracking framework for many of these sources (especially those in italics) may require focusing instead on specific emissions sources where policy influence is more direct or unique and/or where data availability is greater, such as the production metrics of land use or in-region landfills or the consumption metric of air travel.[10] Regardless, improved data collection systems are needed to enable tracking of these metrics over time and could be the subject of additional research.

[10] For a source-by-source assessment of policy influence (levers) and measurability (data sources), see Table 1.

Table 5. Preliminary Baseline Expanded GHG Tracking Metrics for King County: 2003 and 2008
(Parentheses indicate emissions avoided, sequestered, or stored)

Emissions Source		2003	2008
Expanded: Production[11]			
Cement	$MTCO_2e$ /tonne clinker produced	n/a	*0.99*
Steel	$MTCO_2e$ /tonne steel produced	n/a	*0.20*
Glass	$MTCO_2e$ /tonne glass produced	n/a	*0.36*
Other Industry	Emissions per value added (kg CO_2e / $)	n/a	*0.06*
Agriculture	$MTCO_2e$ / tonne of animal	*7.9*	*7.7*
Port of Seattle	$MTCO_2e$ / ton throughput	0.012	0.011
Land Use[12]			
	Emissions (Million $MTCO_2e$)	n/a	(0.4)
	Total Forest Cover (Acres)	n/a	860,000
	Annual Change in Forest Cover (Acres)	n/a	(4,400)
In-region Landfills[13]			
	Emissions (Million $MTCO_2e$)	0.21	0.21
	Energy generated at landfill (MBTU)	0	0
	Emissions avoided due to energy generation	0	0
Expanded: Consumption			
Embodied Emissions in Goods, Food, and Services[14]			
	Emissions (Million $MTCO_2e$)	n/a	*24.0*
	Emissions per person ($MTCO_2e$ /resident)	n/a	*12.8*
Embodied Emissions in Construction			
	Residential (Million $MTCO_2e$)	n/a	*2.5*
	Non-residential (Million $MTCO_2e$)	n/a	*1.7*
	Residential per person ($MTCO_2e$ /resident)	n/a	*1.3*
	Non-residential per person ($MTCO_2e$ /resident)	n/a	*0.9*
Recycling and Composting[15]			
	Diversion (recycling + composting) rate (%)	36%	48%
	Recycling relative to national average (t / resident)	0.09	0.15
	Composting relative to national average (t /resident)	0.05	0.07
	Avoided emissions due to recycling (Million $MTCO_2e$)	(0.5)	(0.8)
	Avoided emissions due to recycling ($MTCO_2e$ /resident)	(0.3)	(0.4)
	Emissions storage due to composting (Million $MTCO_2e$)	(0.01)	(0.02)
	Emissions storage due to composting ($MTCO_2e$ /resident)	(0.20)	(0.20)
Air travel			
	Emissions (Million $MTCO_2e$)	1.7	2.0
	Emissions per person ($MTCO_2e$ /resident)	1.0	1.1

[11] The estimates here of cement, steel, and glass emissions intensity rely on measurements made in 2006 by the Puget Sound Clean Air Agency (PSCAA). Better and more complete reporting of fuel use for these sectors (beyond what currently tracked by PSCAA) would be needed to update these metrics on a regular basis. Emissions intensity of "other industry" is approximate, based on value added in 2007 (2008 data not available) and includes value added by cement, steel, and glass in the denominator due to insufficient data to exclude these sectors.

[12] Metrics for emissions and annual change in forest cover reported here for 2008 are based on average rates of change between 1996 and 2006 as reported by the USFS and discussed in Appendix C. The metric of total forest cover is the USFS estimate for 2006.

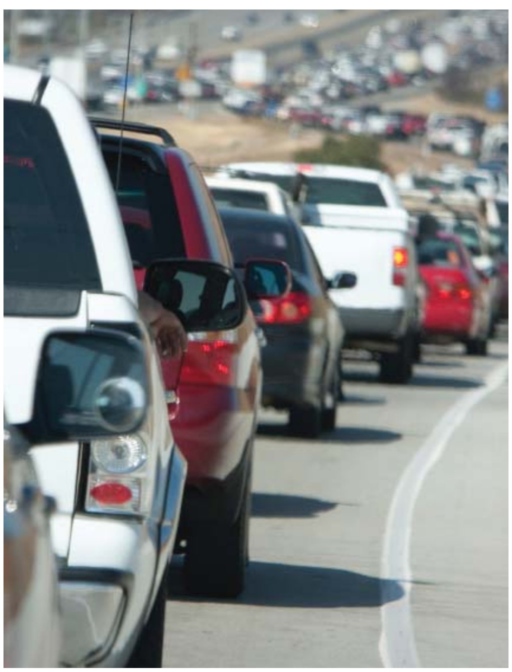
[13] Since 2008, King County Solid Waste Division has since installed a landfill gas processing facility to generate electricity from methane collected at the Cedar Hills landfill, so future updates to metrics for energy generation at landfills and associated emissions benefits will be non-zero.

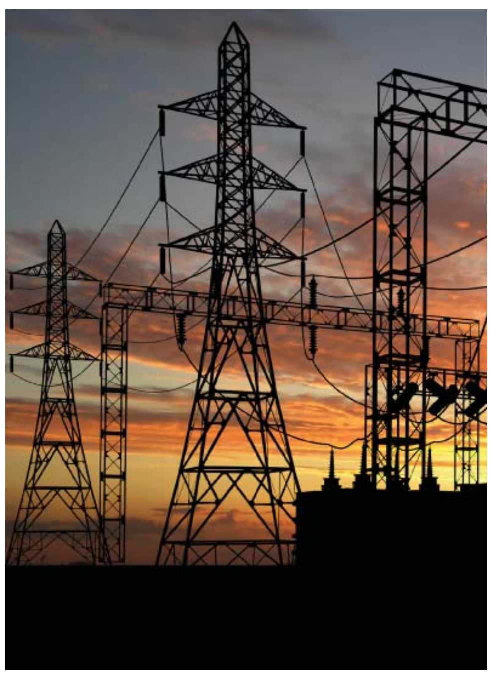
[14] The metric listed here includes embodied emissions in cars and trucks, home appliances, food, other goods, and services as in Table 8 of the main report. Ultimately, developing tracking metrics such as consumption of different types of food, goods, or services is recommended (ideally as measured by a functional unit, such as a kg of food), as called for in Table 11 of the main report.

[15] The assessment of recycling benefits is focused on the avoided manufacturing emissions due to use of recycled feedstock, not on avoided landfilling or transportation emissions (if any), any change in those emissions will be picked up in the Core tracking framework.

Greenhouse Gas Emissions in King County

Appendix B: Geographic-plus Inventory





King County

SEI STOCKHOLM ENVIRONMENT INSTITUTE

2008 King County Community Greenhouse Gas Emissions Inventory: "Geographic Plus" Methodology

December 8, 2011

http://www.kingcounty.gov/climate

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Stockholm Environment Institute – U.S. Center
for the King County Department of Natural Resources and Parks

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Introduction and Methodology

This document presents one of two companion greenhouse gas (GHG) emissions inventories for King County, Washington. The inventory described in this report estimates the release of GHG emissions from cars and trucks, buildings, waste, agriculture, and other sources of emissions within King County in 2008. Because this inventory also includes some emissions that occurred outside King County's borders (notably emissions associated with electricity produced outside the County but used within it), it is called a "geographic plus" inventory.

This inventory is accompanied by the 2008 King County Community Greenhouse Gas Emissions Inventory – Consumption Methodology. That inventory estimates all emissions associated with consumption of goods and services in King County (including all citizen and government spending), no matter where the emissions occur.

King County and its partners are using the results of these inventories in identifying significant sources of GHG emissions, developing emissions reduction programs and policies, and to assess progress towards community emissions reduction goals. For more information on what the results of the inventories mean and how they fit together, see *Greenhouse Gas Emissions in King County: An Updated Geographic Inventory, a Consumption-based Inventory, and an Ongoing Tracking Framework*, , to which this report is considered an appendix.

To enable comparisons over time, the geographic plus inventory estimates greenhouse gas emissions for both 2003 and 2008 using the same methodology.[1] Results are first presented overall, for all sectors studied, followed by sector-by-sector discussions of results and methodology. Appendices document the sources cited throughout this report and additional data used.[2] For more information about the methodology and data, contact climatechange@kingcounty.gov.

The Seattle office of Stockholm Environment Institute–U.S. compiled this GHG inventory in autumn, 2010 (with minor revisions in 2011) under contract to King County.

Overview of King County Emissions

Total Emissions

Transportation, buildings, industrial, and other activities together released approximately 23.4 million metric tons of greenhouse gases (in terms of carbon dioxide equivalent) in 2008.[3] This represents an increase of 1.0 million metric tons, or 5%, since 2003. As indicated in Figure 1 and Table 1, below, transportation is responsible for half these emissions.

---

[1] King County's prior community GHG inventory, conducted in 2004 for the year 2003, was based largely on the Puget Sound Clean Air Agency's regional GHG inventory and used a different method. In this inventory, we estimate 2003 emissions using the same methodology as for 2008 to enable comparisons over time. While the 2003 inventory was instrumental in initial stages of King County climate action planning and implementation of climate solutions, emissions methodologies have evolved and the previous inventory is out of date.

[2] Note that this report and inventory follows many (but not all) of the conventions used in the City of Seattle's 2008 Greenhouse Gas Inventory report, available at http://www.seattle.gov/archive/climate/, including data and some of the descriptive text. We thank the City of Seattle Office of Sustainability and Environment, especially Jill Simmons and Hillary Papendick, for making their files and documents available to us and for conducting those Seattle-specific calculations that we reuse here.

[3] In this report, greenhouse gases are reported in metric tons of carbon dioxide equivalent, or $MgCO_2e$. Gases other than carbon dioxide (CO_2), such as methane (CH_4) and nitrous oxide (N_2O), are converted to their CO_2-equivalent global warming potentials using standard factors from the Intergovernmental Panel on Climate Change.

Figure 1. King County Community Greenhouse Gas Emissions by Sector ("Geographic plus" methodology)

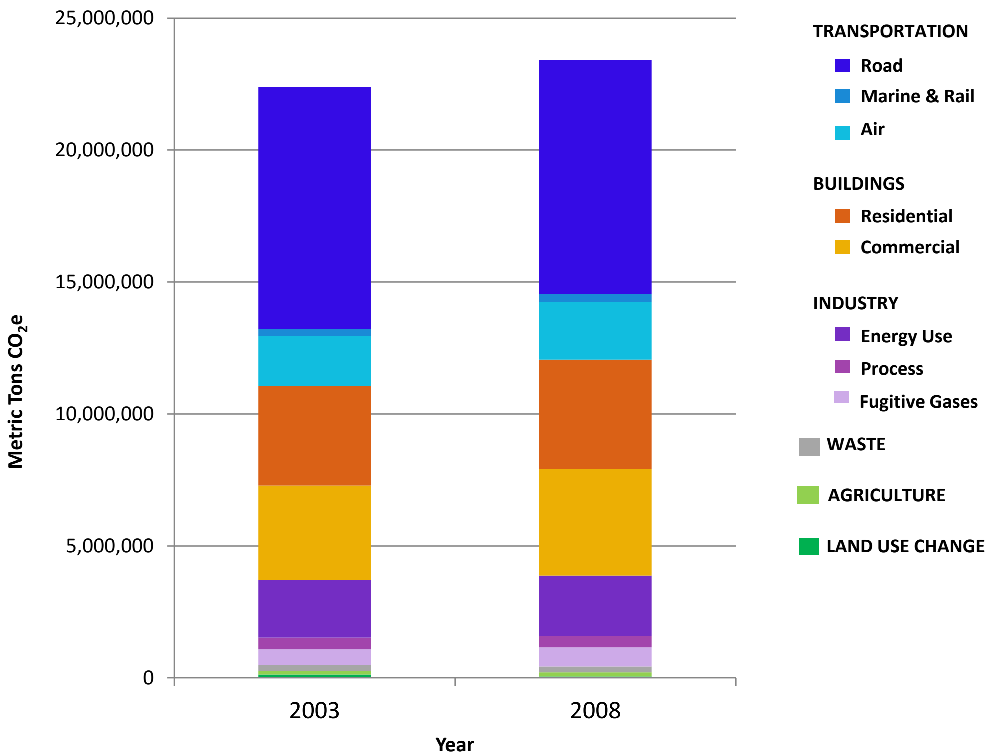

Table 1. King County Greenhouse Gas Emissions by Sector (Metric Tons CO_2e)

GHG Emissions by Sector	2003	2008
TRANSPORTATION	**11,330,000**	**11,354,000**
Road	**9,169,000**	**8,868,000**
Cars & Light Duty Trucks	*5,964,000*	*5,633,000*
Trucks	*3,077,000*	*3,115,000*
Buses & Vanpool	*128,000*	*119,000*
Marine & Rail	**266,000**	**309,000**
Ship & Boat Traffic	*167,000*	*200,000*
WA State Ferries	*51,000*	*39,000*
Rail	*49,000*	*70,000*
Air	**1,895,000**	**2,177,000**
Sea-Tac Airport	*1,757,000*	*2,043,000*
King County Airport	*138,000*	*134,000*
BUILDINGS	**7,342,000**	**8,180,000**
Residential	**3,763,000**	**4,136,000**
Electricity	*1,867,000*	*2,057,000*
Natural Gas	*1,565,000*	*1,815,000*
Petroleum (Heating)	*284,000*	*215,000*
Petroleum (Yard Equipment)	*46,000*	*49,000*
Commercial	**3,580,000**	**4,044,000**
Electricity	*2,001,000*	*2,278,000*
Natural Gas (Commercial Equipment)	*36,000*	*39,000*
Natural Gas (Heat and Other)	*832,000*	*952,000*
Petroleum (Commercial Equipment)	*341,000*	*370,000*
Petroleum (Heat and Other)	*209,000*	*227,000*
Steam	*160,000*	*177,000*
INDUSTRY	**3,225,000**	**3,451,000**
Energy Use	**2,181,000**	**2,284,000**
Electricity	*535,000*	*504,000*
Natural Gas (Industrial Equipment)	*49,000*	*52,000*
Natural Gas (Heat and Other)	*523,000*	*511,000*
Petroleum (Industrial Equipment)	*686,000*	*729,000*
Petroleum (Heat and Other)	*85,000*	*134,000*
Coal	*286,000*	*338,000*
Tire	*17,000*	*17,000*
Process	**451,000**	**435,000**
Cement (Calcination)	*411,000*	*395,000*
Steel	*3,000*	*3,000*
Glass	*37,000*	*37,000*
Fugitive Gases	**593,000**	**732,000**
ODS Substitutes	*542,000*	*676,000*
Switchgear Insulation	*51,000*	*56,000*
WASTE	**218,000**	**217,000**
Landfills	*214,000*	*213,000*
Wastewater Treatment	*4,000*	*4,000*
AGRICULTURE	**145,000**	**158,000**
Enteric Emissions from Livestock	*52,000*	*57,000*
Manure Management	*85,000*	*94,000*
Soil Management	*7,000*	*6,000*
LAND USE CHANGE	**123,000**	**53,000**
Residential Development	*123,000*	*53,000*
TOTAL EMISSIONS	**22,382,000**	**23,412,000**

Per Capita Emissions

King County's emissions increased an estimated 5% between 2003 and 2008, during a time when population increased 6%. On a per-capita basis, therefore, King County's emissions are remaining relatively constant.[4] As indicated in Table 2, increases in per-capita emissions from buildings and industry were offset by decreases in per-capita transportation emissions.

Table 2. Per Capita King County Greenhouse Gas Emissions by Sector (Metric Tons CO_2e)

Per Capita GHG Emissions by Sector	2003	2008
TRANSPORTATION	**6.4**	**6.0**
Road	5.2	4.7
Marine & Rail	0.2	0.2
Air	1.1	1.2
BUILDINGS	**4.1**	**4.3**
Residential	2.1	2.2
Commercial	2.0	2.1
INDUSTRY	**1.8**	**1.8**
Energy Use	1.2	1.2
Process	0.3	0.2
Fugitive Gases	0.3	0.4
WASTE	**0.1**	**0.1**
AGRICULTURE	**0.1**	**0.1**
LAND USE CHANGE	**0.1**	**<0.1**
TOTAL EMISSIONS	**12.6**	**12.4**

Readers should take care in making comparisons to GHG inventories in other communities. Since there is no widely accepted standard method for conducting GHG inventories of community emissions, methods can vary across communities, making direct comparisons difficult.

[4] In subsequent sections of this report, readers may notice that some sources of emissions are estimated from one year to another by scaling results from one year to another based on population or employment trends. The total share of this emissions inventory estimated by using such scaling factors is about 10% in both years. For these emissions sources (e.g., pleasure-craft emissions, which are part of *marine* emissions), per-capita emissions are held constant *by definition* and would not warrant a conclusion such as that made in the text here. But because these sources represent such a small share of overall emissions, the conclusion that King County's per-capita emissions are holding relatively constant is not likely to be affected.

Despite these challenges, it is clear that at an estimated 12.4 metric tons CO_2e, King County's per capita emissions in this inventory are lower than the national average of 23.3 metric tons CO_2e per person.[5] Two primary factors help explain this departure. One is that major sources of production (e.g., factories, particularly for emissions-intensive sectors such as petroleum refining or chemical manufacturing, as well farms) are less prevalent in King County (relative to population) than in the nation as a whole. The other is that low-carbon electricity (e.g., hydroelectricity) is a higher fraction of the electricity provided by utilities operating in King County, especially Seattle City Light.

For additional discussion of comparison of both King County's "geographic plus" and consumption-based emissions to national or global totals, please see the *Greenhouse Gas Emissions in King County* document, to which this report is an appendix.

[5] Source: U.S. EPA. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2008, http://www.epa.gov/climatechange/emissions/usinventoryreport.html, after making some minor adjustments to facilitate comparisons. For example, the official national inventory does not include international air travel, but these emissions were added back in for the purpose of this comparison since the King County inventory includes fuel loaded at Sea-tac airport for international flights.

Transportation Sector

The transportation sector includes road, marine, rail, and air travel. This sector is the largest source of greenhouse gas emissions within King County, comprising approximately half of the county's total emissions. While total transportation emissions increased slightly from 2003 to 2008, per-capita transportation emissions decreased slightly.

Road Transportation

Road transportation includes the emissions from passenger, commercial, and transit vehicles. Emissions from road transportation dominate King County's transportation-sector emissions, accounting for 7% of the sector's emissions, and 38% of all emissions in King County. The Puget Sound Regional Council (PSRC) modeled and provided an estimate of vehicle miles traveled (VMT) on streets and highways, on which emissions from commercial trucks, cars and light trucks, and van pools were based. Emissions from buses were calculated based on fuel use data provided by King County Metro.

The attribution of emissions from road transport to King County is not straightforward, as many vehicle trips by King County residents and employees are not completely contained within the county, and other vehicles pass through the county without stopping within its borders. This inventory employs a method that counts emissions from all trips that occur entirely within King County, half of trips that either begin or end in the county, and no trips that both begin and end outside the county (even if they pass through the county).[6] For example, this "origin-destination pair" method counts half of commuting trips by residents who live in King County and commute out-of-county, but excludes truck or personal trips traveling through the county on I-5. The rationale for this method is that it attempts to count the trips that local policy-makers can best influence through transportation planning and incentives, such as commuting trips, while excluding trips over which the county and its partners have little influence.[7]

[6] A number of jurisdictions throughout the country use this methodology. For further discussion of this method, see: Ramaswami, Anu, Tim Hillman, Bruce Janson, Mark Reiner, and Gregg Thomas. 2008. A Demand-Centered, Hybrid Life-Cycle Methodology for City-Scale Greenhouse Gas Inventories. *Environmental Science & Technology* 42, no. 17: 6455-6461. doi:10.1021/es702992q.

[7] The method counts half of the emissions associated with trips that either begin or end in the county in order to recognize the shared responsibility with the other half of the originating or destination pair, as well as to avoid double counting of trips if other, neighboring jurisdictions were to use the same method. This method of counting VMT (and, in turn, emissions) yields a result that is largely similar (~1 % different) to the VMT occurring within the geographic bounds of King County. While this small difference might suggest that the difference between the two methods is trivial, King County should, in theory, have a greater chance of supporting community reduction in the VMT measured in this origin-destination pair method than in a strict geographic method. Also, significant differences exist for certain vehicle types. For example, the VMT for medium and heavy trucks attributed to King County in this method versus a strictly geographic approach are 26% and 50% higher, respectively, suggesting that

Table 3 presents emissions from road transportation. Road emissions decreased slightly between 2003 and 2008, driven largely by improvements in fuel economy in cars and light trucks that outpaced a slight decline in efficiency of trucks.[8]

Table 3. Road Transportation Emissions (Metric Tons CO_2e)

	2003	2008
Cars & Light Duty Trucks	5,964,000	5,633,000
Trucks	3,077,000	3,115,000
Buses & Vanpool	128,000	119,000
Totals	**9,169,000**	**8,868,000**

the method may do a better job of capturing the emissions associated with transporting goods consumed in King County.

[8]This inventory uses national average fuel economy figures. Some jurisdictions (e.g., New York City) use local vehicle registration data to estimate a local fuel economy, but defining a local coefficient was beyond the scope of this project. An average rate for King County could be calculated by matching EPA combined fuel economy values by vehicle type with Department of Licensing registration data. Though time-consuming to develop, this value would be useful in tracking improvements in vehicle efficiencies in King County over time. Total vehicle miles travelled (VMT) declined slightly (1%) between 2003 and 2008, per the Highway Performance Monitoring System (see *Source Notes* box). Lower VMT in 2008 may partly be explained by high gas prices, as the summer of 2008 saw the highest gas prices of the decade.

Source Notes

Road transportation emissions were predominately calculated from daily average vehicle miles traveled (VMT) modeling results for calendar year 2006, provided by PSRC **(KC08-11-2_TripsVMT-KC)**, for cars and light trucks, Metro VanPool, and trucks (medium and heavy duty). To estimate VMT for years 2003 and 2008, PSRC's modeled VMT results were scaled by a ratio of 2008 and 2003 (to 2006) VMT from the Highway Performance Monitoring System (HPMS), which records yearly data on average daily VMT by county. VMT results were also scaled by 95% to correct for the fact that the PSRC-provided figures were based on weekday-only traffic, which is higher than average traffic, including weekends **(KC08-11-9_VMTcorr)**.

The table below categorizes total average weekday VMT from all vehicles traveling entirely in, starting in, or ending in King County in 2006. The shaded area depicts the VMT that are counted according to the origin-destination pair method (and totaling 44,330,479 miles): 100% of trips contained within King County, 50% of trips with an origin or destination in King County, and 0% of trips that both start and end outside King County.

Origin \ *Destination*	King County	Outside King County
King County	32,298,529	11,726,485
Outside King County	12,337,415	

Finally, in order to calculate emissions, annual VMT were multiplied by emissions factors derived from national average fuel efficiencies (miles per gallon) and fuel-specific (gasoline or diesel) carbon contents.

Emissions from bus travel were calculated through fuel use data provided by King County Metro and the National Transit Database (NTD). King County Metro bus fuel use was provided by King County Metro **(KC08-11-3_KCM-Motorbus)**, and annual revenue miles were collected from the NTD **(KC08-11-5_NTD-KCMetro08** and **KC08-11-6_NTD-KCMetro03)**. Sound Transit fuel use for 2008 was also downloaded from NTD **(KC08-11-4_NTD-T17EnergyCons)**. Calculation steps and data sources are listed in **KC08-00-1_MasterSpreadsheet_053111 'Trans- Road'.**

Key Drivers and Uncertainties

The principal drivers of road transport emissions are how much people drive (vehicle miles travelled, or VMT) and how efficiently their vehicles consume fuel (miles per gallon, or mpg). Uncertainty exists in each of these factors. VMT is modeled, not measured, and each model has its strengths and weaknesses. For example, the Puget Sound Regional Council's current trip-based model allows for sophisticated calculations of trips according to origins and destinations, but a "trip" in their model ends with each stop, limiting the ability to track travel activity with multiple stops, e.g., a commuting trip that starts in the City of Snohomish and stops in Everett for gas before continuing to Seattle would be considered two separate trips in

PSRC's model, one before the gas-station stop and one after[9]. Furthermore, emission rates from fuel consumption are based on national averages, rather than King County-specific rates.

Marine & Rail Transportation

Marine and rail transportation comprise a small share (1%) of total emissions in King County. Emissions from marine transportation were calculated based on estimates of fuel used by boat traffic in the waters in and around King County. Specifically, boat traffic includes pleasure craft, Washington State Ferries, cruise ships, cargo vessels, and other commercial boat traffic, such as tug boats. Emissions that occur near shore (maneuvering) and on-shore (hoteling) are included as well, based on estimates conducted by the Port of Seattle. Freight rail transportation includes emissions from locomotive use at the Port of Seattle, as well as the movement of Port of Seattle-related cargo in the county. Through rail (e.g., a train from Portland to British Columbia that passes through but does not originate or end in King County) is therefore not included in this inventory. Furthermore, passenger rail (i.e., Amtrak and Sounder commuter trains) is not considered due to lack of available data and the minor contribution to overall emissions in the county. Emissions from marine and rail transportation are presented in Table 4.

Table 4. Marine & Rail Transportation Emissions (Metric Tons CO_2e)

	2003	2008
Ship & Boat Traffic	167,000	200,000
WA State Ferries	51,000	39,000
Freight Rail	49,000	70,000
Totals	**266,000**	**309,000**

[9] This limits the ability of the VMT method employed here to fully capture the VMT associated with commuting trips. Transportation models continue to evolve and improve over time, and the models available to PSRC a few years from now will likely be better able to assess the origins and destinations of travel trips.

Source Notes

Ship & Boat Traffic (Cruise and other): 2008 and 2003 emissions were calculated from 2005 ship and boat emissions reported in the *Puget Sound Maritime Air Emissions Inventory* **(KC08-12-1_PS05MaritimeInv)**. Maneuvering emissions were scaled by tonnage for freight and by number of calls for cruise ships. Hoteling emissions were scaled by number of calls for freight and by number of calls (minus calls where the ship was connected to electrified shore power) for cruise ships **(C08-12-2_POS-Tonnage)**. King County pleasure craft fuel use was estimated by the Puget Sound Clean Air Agency using EPA's NONROAD2008 model. PSCAA provided these estimates (reformatted and summarized in **KC08-41-1_NONROAD-EquipCalcs**). 2003 emissions were estimated by scaling 2008 emissions by King County population.

WA State Ferries: Emissions from Washington State Ferries were calculated from fuel consumed by ferries on routes servicing King County. Seattle route data, previously used in the 2008 Seattle inventory and provided by WSDOT **(08-12-0)**, was updated in 2010 by WSDOT to include an additional route outside of Seattle but within King County **(KC08-12-3_FerryRoutes)**. Routes were then matched with fuel usage data **(08-12-1 CY2008 fuel)**. The Fauntleroy-Vashon-Southworth route was weighted by a fraction reflecting distance of each leg and county limits **(KC08-12-4_FVS-weight)**. 2003 emissions were approximated by multiplying 2005 Seattle emissions by the ratio of King County to Seattle ferry emissions from 2008.

Rail: Freight rail emissions were calculated based on the 2005 emissions presented in the Puget SoundMaritime Air Emissions Inventory **(KC08-12-1_PS05MaritimeInv)**. Emissions for other years of interest were scaled by the change in cargo throughput, using annual container tonnage as a proxy **(KC08-12-2_POS-Tonnage)**.

Calculation steps and data sources for marine and rail transportation are listed in **KC08-00-1_MasterSpreadsheet_053111 'Trans- Marine Traffic'** and **'Trans-Rail'**, respectively.

Key Drivers and Uncertainties

A key driver of maritime and freight rail emissions is the level of trade activity at the Port. Greenhouse gas emissions associated with the Port of Seattle have fluctuated significantly in recent years, as a function of cargo tonnage.

Generally speaking, emissions from marine sources are highly uncertain, and as such, few greenhouse gas inventories consider them. While the marine and rail emissions are included in this inventory, it is important to note that this subsector is very small compared to other sources in the county. Pleasure craft emissions, in particular, are likely underestimated.

Pleasure craft emissions were estimated with the EPA's NONROAD2008 model for King County in calendar year 2008. To scale down from the state to the county level, NONROAD allocates recreational boat population and activity using county-level water surface data from the U.S. Census Bureau, adjusting for typical variation in boat type by distance from shore. However, this method does not reflect factors such as proximity of water to high population areas or recreational quality of the body of water **(KC08-12-5_GeogAllocNONROAD)**. Both of these elements are pertinent to the King County area, and therefore it is likely that the NONROAD model underestimates emissions from this source.[10]

The rail calculation method assumes that freight emissions scale directly with freight throughput at the Port. Other factors could affect this relationship, such as alterations in operations (e.g., transporting varying loads), or equipment retrofits or rebuilds (e.g., introducing hybrid locomotives). These factors are accounted for, to some extent, in the Port inventory. However, as comprehensive port inventories are currently not calculated on an annual basis, using the most recent inventory figures available (2005) and scaling based on throughput at the Port of Seattle was the methodology used for this estimate, using tonnage data available for 2003 and 2008. Accordingly, this estimate assumes that freight rail emissions scale directly with tonnage entering the port.

Air Transportation

Emissions from air transportation include a share of emissions associated with passenger travel at Seattle-Tacoma International Airport, as well as take-off and landing emissions at King County Airport in Seattle. Together, these sources represent 9% of King County's total emissions. Emissions attributed to King County Airport are those associated with landing and take-offs at (not the full flights in and out of) the airport and are primarily associated with Boeing activities.[11] By contrast, emissions attributed to King County from Sea-Tac airport are the estimated share of all the emissions from trips in and out of Sea-Tac that are associated with residential and business activities in King County. King County's share of Sea-Tac traffic (47%) is determined by the relative share of King County's population (representing personal travel) and employment (representing business travel) in the region, based on Census Bureau and Washington Employment Security Department sources. Emissions from air transport are shown in Table 5.

Table 5. Air Transportation Emissions (Metric Tons CO_2e)

	2003	2008
Sea-Tac Airport	1,757,000	2,043,000
King County Airport	138,000	134,000
Totals	**1,895,000**	**2,177,000**

[10] In the future, another possible data source for estimating activity (and, by extension, emissions) from pleasure craft could be boat registration statistics.
[11] There is no commonly accepted method for attributing air travel emissions. Counting the landing and take-off emissions at King County airport is consistent with prior treatment in King County's 2003 inventory, Puget Sound Clean Air Agency's 2005 inventory, and the City of Seattle's 2008 inventory. Emissions from SeaTac, the region's major passenger airport, are counted differently to reflect King County's share of the emissions from the entire flight (not just the landing and take-off cycles).

Source Notes

Sea-Tac International Airport: The fraction of emissions attributable to King County was estimated with a composite of population and employment in the county, and origin within the region **(KC08-14-1_SeaTacRatio)**. Both domestic and international flights were included, though only passenger flights were considered in these calculations (i.e., no cargo-only flights were included). The Port of Seattle provided total jet fuel consumed at Sea-Tac Airport **(08-14-13)**.

King County International Airport: 2008 emissions from King County International Airport were calculated from fuel used by jets during landing and take-off. KCIA provided fuel use data (**08-14-5)** and PSCAA provided the landing and take-off fraction (51%) of fuel burned **(05-047)**.

Calculation steps and data sources are listed in **KC08-00-1_MasterSpreadsheet_053111 'Trans- Air Traffic'.**

Key Drivers and Uncertainties

The main drivers of passenger air transport emissions are personal vacation preferences and business cycles. A choice to take a trip to a far-off destination or the decision to fly instead of taking an alternative mode of transportation (such as a train, bus, or car) impact the number of flights out of Sea-Tac. Similarly, a decision to take a work-related trip, as opposed to telecommuting or taking an alternative transportation mode, contributes to the number of flights. While planes solely transporting cargo were not considered in these calculations, it is worth noting that some cargo is loaded on most passenger flights. Therefore, one could argue that a portion of the fuel used in Sea-Tac flights could be ascribed to the consumption of goods. Emissions from King County International Airport are largely impacted by Boeing operations.

From the standpoint of policy relevance, emissions associated with air travel are somewhat difficult to influence. While the population and employment allocation method is implemented in this methodology, these factors are policy insensitive, and therefore future progress in air travel emissions could be measured through surveys tracking the impact of particular programs.

Buildings Sector

Building emissions account for 35% of greenhouse gas emissions in King County, and include the energy consumed by King County's residential and commercial buildings for lighting, appliances, heat, hot water, and building equipment. Emissions include those associated with electricity consumption (i.e., from generation of electricity by SCL and PSE). Residential and commercial buildings contribute approximately equally. Emissions in 2008 were higher than in 2003 in every category but petroleum for heating in homes, as residences switched residential heating fuels from oil to natural gas.

Residential Buildings

Residential building emissions are from single-family homes, apartment buildings, and other residential buildings in King County. The vast majority of building emissions are generated by the energy used for home heating, appliances, and hot water, though the emissions reported here also include fuel used for landscaping equipment like lawnmowers. Emissions from residential buildings are shown in Table 6.

Table 6. Residential Building Emissions (Metric Tons CO_2e)

	2003	2008
Electricity	1,867,000	2,057,000
Natural Gas	1,565,000	1,815,000
Petroleum (Heating)	284,000	215,000
Petroleum (Yard Equipment)	46,000	49,000
Totals	**3,763,000**	**4,136,000**

Emissions from electricity production are associated primarily with electricity sold by Puget Sound Energy, as the other electric utility operating in King County, Seattle City Light, relies almost exclusively on low-carbon hydroelectricity.[12]

[12] For discussion of Seattle's City Light's purchases of greenhouse gas offsets, see the *Supplemental Emissions Calculations* report.

Source Notes

Electricity: Seattle City Light provided SCL-serviced (Seattle and some King County) residential building electricity consumption using total kWh and a breakdown of residential and non-residential electricity usage **(KC08-60-1_SCLkWh95-08)**. PSE provided the remaining King County residential electricity consumption **(KC08-61-1_PSE08** and **KC08-61-2_PSE03)**. Utility emission rates for King County were calculated by multiplying fuel mix percentages by fuel-specific emissions factors **(KC08-63-1_FuelMixPSE-SCL)**. Utility emissions for Seattle City Light were as reported in their GHG inventory **(08-60-2).**

Natural Gas: PSE provided 2008 and 2003 natural gas use by King County residences **(KC08-61-1_PSE08** and **KC08-61-2_PSE03)**.

Petroleum (Heating): King County residential oil use was estimated from 2008 Washington State home oil use, which is reported by the U.S. Energy Information Administration **(KC08-21-0_EIA_DistFuel-WA)**, according to the ratio of King County homes with oil heat to Washington State homes with oil heat. The number of King County homes with oil heat was obtained from the 2008 American Community Survey (ACS) **(KC08-20-1_ACS08HeatFuel)**.

Petroleum (Yard Equipment): King County yard equipment fuel use was estimated by the Puget Sound Clean Air Agency using EPA's NONROAD2008 model. PSCAA provided these estimates (reformatted and summarized in **KC08-41-1_NONROAD-EquipCalcs**).

Calculation steps and data sources for electricity, natural gas and petroleum (heating) and petroleum (yard equipment) are listed in **KC08-00-1_MasterSpreadsheet_053111 'Electricity', 'Res- Heat & Hot Water',** and

Key Drivers and Uncertainties

The main cause of residential GHG emissions is personal energy use at home. Heat, hot water, lighting, and use of appliances drive emissions in this subsector.

While natural gas data was available for King County, heating oil, on the other hand, was not available at this scale. Heating oil was taken from Energy Information Administration (EIA) data on a state level, which was then scaled by the ratio of houses with oil heat in King County to those in Washington State. This approximation assumes that the amount of fuel used per Washington household is typical of King County. Uncertainties in the residential buildings sector are believed to be lower than for most other sectors, since data for the major sources of GHG emissions (natural gas and electricity) were provided by sales data from the utilities PSE and SCL.

Commercial Buildings

Commercial building emissions are from the energy consumed by businesses, office buildings, and institutional facilities (such as government buildings and schools). Like residential building emissions, the majority of these emissions are generated by lighting, space heating, and hot water. Many downtown Seattle buildings are heated by steam generated by Seattle Steam

Company, and the emissions associated with steam heat are reported on a separate line. Commercial buildings also include emissions from small equipment associated with commercial operations. Greenhouse gas emissions from commercial buildings are shown in Table 7.

Table 7. Commercial Building Emissions (Metric Tons CO_2e)

	2003	2008
Electricity	2,001,000	2,278,000
Natural Gas (Commercial Equipment)	36,000	39,000
Natural Gas (Heat and Other)	832,000	952,000
Petroleum (Commercial Equipment)	341,000	370,000
Petroleum (Heat and Other)	209,000	227,000
Steam	160,000	177,000
Totals	**3,580,000**	**4,044,000**

Source Notes

Electricity: Seattle City Light provided SCL-serviced (Seattle and some King County) building electricity consumption using total kWh and a breakdown of residential and non-residential electricity usage **(KC08-60-1_SCLkWh95-08)**. A further breakdown of non-residential kWh into commercial and industrial sectors was calculated from the Seattle City Light 2008 Annual Report **(08-60-4)**. PSE provided the remaining King County commercial electricity consumption **(KC08-61-1_PSE08** and **KC08-61-2_PSE03)**. Utility emission rates were calculated by multiplying fuel mix percentages by fuel-specific emissions factors **(KC08-63-1_FuelMixPSE-SCL)**.

Natural Gas (Commercial Equipment): Compressed natural gas (CNG) fuel use of commercial equipment in King County was estimated by PSCAA using EPA's NONROAD2008 model. PSCAA provided these estimates (reformatted and summarized in **KC08-41-1_NONROAD-EquipCalcs**).

Natural Gas (Heat and Other): PSE provided commercial building natural gas consumption for 2008 and 2003 **(KC08-61-1_PSE08** and **KC08-61-2_PSE03)**.

Petroleum (Commercial Equipment): Petroleum fuel use of commercial equipment in King County was estimated by PSCAA using EPA's NONROAD2008 model. PSCAA provided these estimates (reformatted and summarized in **KC08-41-1_NONROAD-EquipCalcs**).

Petroleum (Heat and Other): King County commercial oil use was estimated from 2008 Washington State home oil use, which is reported by the U.S. Energy Information Administration **(KC08-21-0_EIA_DistFuel-WA)**, scaled by the ratio of commercial employees in King County and Washington State.

Steam: PSCAA provided natural gas and back up oil use from the Seattle Steam and the University of Washington Steam Plant **(KC08-40-1_00-08ProcessData)**.

Calculation steps and data sources for electricity, natural gas (commercial equipment) and petroleum (commercial equipment), and natural gas (heat and other), petroleum (heat and other) and steam are listed in **KC08-00-1_MasterSpreadsheet_053111 'Electricity', 'Commercial- equip',** and **'Commercial- Heat & Hot Water'**, respectively.

Key Drivers and Uncertainties

The main driver of emissions from the commercial sector is energy use by businesses and public facilities. Specifically, demand for lighting, heat, and hot water drive these emissions.

Uncertainties in this sector are believed to be lower than for most other sectors, since data for the major sources of GHG emissions (natural gas and electricity) were provided by sales data from the utilities PSE and SCL.[13] Uncertainty in emissions from oil combustion are much higher, since these estimates rely largely on statewide data from the EIA scaled to King County by the relative number of commercial employees in the county to the state. This approximation assumes that the fuel used by commercial buildings is relatively constant across these scales, and would not necessarily account for benefits such as more efficient or larger buildings in the county. The alternative source of oil consumption data, PSCAA, is incomplete, as PSCAA only maintains data for facilities that are required to report emissions for years when reporting thresholds for other (non-GHG) pollutants are exceeded.

[13] However, note that some natural gas customers are known to purchase their natural gas directly from wholesalers, even though PSE delivers it. We assume that quantities purchased by these customers (which are sometimes referred to by PSE as "transport" customers since PSE only transports, but does not directly sell, the gas) are included in the natural gas consumption totals provided to us by PSE, but this could not be confirmed. Accordingly, it is possible that our estimates of emissions associated with natural gas are low throughout.

Industrial Sector

The industrial sector accounts for 15% of greenhouse gas emissions in King County. This sector includes emissions from industrial operations, the manufacturing of cement, steel, and glass, and fugitive gases associated with industrial equipment. Emissions include those associated with electricity consumption (i.e., from generation of the electricity by SCL and PSE), for which generation largely occurs outside King County.

Industrial Energy Use

Industrial operations include emissions from energy consumed by industrial facilities located in King County. Industrial operations are dominated by emissions from energy used to fuel manufacturing or other industrial equipment, rather than space heating and hot water as in the residential and commercial sectors. Industrial operations also include fuel use and greenhouse gas emissions from construction equipment, material handling, HVAC equipment, and other off-road machinery. Emissions from industrial operations are shown in Table 8.

Table 8. Industrial Energy Use Emissions (Metric Tons CO_2e)

	2003	2008
Electricity	535,000	504,000
Natural Gas (Industrial Equipment)	49,000	52,000
Natural Gas (Heat and Other)	523,000	511,000
Petroleum (Industrial Equipment)	686,000	729,000
Petroleum (Heat and Other)	85,000	134,000
Coal	286,000	338,000
Tire	17,000	17,000
Totals	**2,181,000**	**2,284,000**

Source Notes

Electricity: Seattle City Light provided SCL-serviced (Seattle and some King County) building electricity consumption using total kWh and a breakdown of residential and non-residential electricity usage **(KC08-60-1_SCLkWh95-08)**. A further breakdown of non-residential kWh into industrial and commercial sectors was calculated from the Seattle City Light 2008 Annual Report **(08-60-4)**. PSE provided the remaining King County industrial electricity consumption **(KC08-61-1_PSE08** and **KC08-61-2_PSE03)**. Utility emission rates were calculated by multiplying fuel mix percentages by fuel-specific emissions factors **(KC08-63-1_FuelMixPSE-SCL)**.

Natural Gas (Industrial Equipment): CNG fuel use of industrial equipment in King County was estimated by the Puget Sound Clean Air Agency using EPA's NONROAD2008 model. PSCAA provided these estimates (reformatted and summarized in **KC08-41-1_NONROAD-EquipCalcs**).

Natural Gas (Heat and Other): PSE provided industrial natural gas consumption for 2008 and 2003 **(KC08-61-1_PSE08** and **KC08-61-2_PSE03)**.

Petroleum (Industrial Equipment): Petroleum fuel use of industrial equipment in King County was estimated by PSCAA using EPA's NONROAD2008 model. Leslie Stanton at PSCAA provided these estimates (reformatted and summarized in **KC08-41-1_NONROAD-EquipCalcs**).

Petroleum (Heat and Other): King County industrial oil use was estimated from 2008 Washington State industrial oil use, which is reported by the U.S. Energy Information Administration **(KC08-21-0_EIA_DistFuel-WA)**, scaled by the ratio of industrial employees in King County and Washington State.

Coal: Coal-derived fuel is used in cement production. PSCAA provided point source data for Ash Grove **(KC08-40-1_00-08ProcessData)**. Lafarge cement provided self-reported data from their operations **(KC08-40-4_LafargeFuel03-09)**.

Tire: Tire-derived fuel is used in cement production. Ash Grove provided self-reported data from their operations **(08-41-0)**, as did Lafarge **(KC08-40-4_LafargeFuel03-09)**.

Calculation steps and data sources for electricity, natural gas (industrial equipment) and petroleum (industrial equipment), and natural gas (heat and other), petroleum (heat and other), coal, and tire are listed in **KC08-00-1_MasterSpreadsheet_053111 'Electricity', 'Ind- Small Equipment**, and **'Ind- Operations',** respectively.

Key Drivers and Uncertainties

Notable drivers of these emissions include demand for cement (which can vary substantially from year to year depending on construction activity) and other industrial products made in the region, including steel, glass, and aerospace equipment.

Industrial oil (petroleum) use is relatively uncertain, as estimates for oil use for heat and other applications was scaled from Washington State data from the EIA to King County by the relative number of industrial employees. This approximation assumes that the fuel used by industrial installations is relatively constant across these scales. Estimates of industrial fuel use for equipment are based on the EPA's NONROAD 2008 model and are also uncertain.[14] As a result of these uncertainties, emissions from industrial energy consumption are less certain than some other sectors.

Industrial Processes & Fugitive Gases

Industrial process emissions include greenhouse gases that are emitted directly from production of cement, steel, and glass, as well as the emissions from fugitive gases from electric switchgear equipment. With two cement plants in the City of Seattle in 2008, cement production is a significant contributor to the county's greenhouse gas emissions.[15] Additional sources of emissions associated here with industry are ozone-depleting substance (ODS) substitutes (mainly hydrofluorocarbons) used largely in refrigeration and air-conditioning equipment and sulfur hexafluoride released from electric switchgear insulation.[16] Industrial process and fugitive gas emissions totals are presented in Table 9 and Table 10, respectively.

Table 9. Industrial Process Emissions (Metric Tons CO_2e)

	2003	2008
Cement (Calcination)	411,000	395,000
Steel	3,000	3,000
Glass	37,000	37,000
Totals	**451,000**	**435,000**

Table 10. Industrial Fugitive Gas Emissions (Metric Tons CO_2e)

	2003	2008
ODS Substitutes	542,000	676,000
Switchgear Insulation	51,000	56,000
Totals	**593,000**	**732,000**

[14] It is worth noting that industrial equipment considered here includes equipment that could be considered the responsibility of other sectors. For example, airport, rail, and agriculture equipment are all considered in this emission source.

[15] Cement production ceased at one of the plants, the Lafarge cement plant, at the end of 2010.

[16] Emissions from substitutes for ozone-depleting substances (ODS) are assigned here to industry but include emissions that could be considered the responsibility of other sectors, such as releases of hydrofluorocarbons found in commercial and residential air conditioning and refrigeration equipment.

Source Notes

Cement: Cement process emissions were calculated by multiplying tons of clinker produced by the calcination factors. PSCAA provided the tons of clinker **(KC08-40-1_00-08ProcessData)**. Lafarge and Ash Grove provided the calcinations factors **(08-41-0** and **05-134)**.

Steel: Steel emissions are from Seattle's two manufacturers, Jorgensen (a forge) and Nucor (an electric arc furnace that produces crude steel). PSCAA provided production data from these facilities **(KC08-40-1_00-08ProcessData)**. To calculate emissions, the production data was multiplied by the nominal IPCC emission factor associated with electric arc furnaces, 1.25 kgCO_2/Mg steel. Nucor uses entirely recycled stock and Jorgensen is a forge (which shapes, not produces, steel), so there are no emissions associated with carbon lost from pig iron as there would be in a basic oxygen furnace **(05-127).**

Glass: Glass operations are from Seattle's Saint-Gobain Containers. PSCAA provided production data from this facility **(KC08-40-1_00-08ProcessData)**. To calculate emissions, tons of glass pulled were multiplied by the default emission factor for glass manufacturing **(KC08-40-2_IPCCGuide-MinIndust)** and adjusted by the ratio of recycled cullet used by Saint-Gobain **(KC08-40-3_RecyMatKC).**

ODS Substitutes: Emissions associated with substitutes for ozone-depleting substances were estimated with the EPA's State Inventory and Projection Tool **(KC08-42-1_SIT-IP-WA-ODS)** and scaling by the relative populations in Washington state and King County.

Fugitive Gases: Seattle City Light (SCL) provided fugitive SF_6 emissions for 2008 (**08-60-1).** 2003 emissions were scaled by SCL electricity totals for each year. PSE SF_6 emissions were estimated by multiplying total King County fugitive emissions from the 2005 PSCAA inventory **(KC08-102-0_PSCAA05Inventory)** by the fraction of electricity provided by PSE in the county.

Calculation steps and data sources for cement, steel and glass, and ODS substitutes and fugitive gases are listed in **KC08-00-1_MasterSpreadsheet_053111 'Ind- Process'** and **'Ind- Fug. Gases'**, respectively.

Key Drivers and Uncertainties

Demand for cement, and to a lesser degree, demand for steel and glass, are the dominant drivers of emissions from this subsector.

The emission factors for glass and steel production are defaults from IPCC guidelines, though more specific factors could be calculated if more were known about practices at the glass container (St. Gobain Containers) and steel (Nucor Steel, Jorgenson Forge) facilities. Yet while these emission factors have some uncertainty, both sources of process emissions are relatively small. Uncertainty in process emissions from cement is relatively low, as the production of each ton of cement clinker (the key component of cement) involves a chemical reaction that releases a fixed quantity of CO_2. Lastly, uncertainty in estimates of ODS substitutes and switchgear insulation is relatively high in both cases. For example, it would be beneficial to have a local estimate of ODS, rather than scaling down from statewide emissions.

Waste Sector

The waste sector includes emissions associated with one active landfill, ten closed landfills, and two wastewater treatment facilities in King County. Waste sector emissions represent less than 1% of GHG emissions in this King County Geographic Plus inventory.

Two distinct methodologies can be used to estimate emissions associated with landfills and waste disposal. This “geographic plus” inventory estimates waste-related fugitive landfill emissions using a “waste in place” methodology. Fugitive landfill emissions result from the unintended release of landfill gas from the decomposition of organic materials at a landfill or combustion or treatment of landfill gas in flares. This approach estimates the fugitive landfill gas emitted in the year 2008 as a result of all materials currently in landfills (no matter the year they were disposed) that are located within King County’s geographic border.

The other common method, called “waste commitment”, estimates fugitive landfill gas emissions associated with all waste generated from within King County in 2008 (and only 2008), regardless of when or where those emissions occur. This “waste commitment” methodology includes emissions even if they occur outside the King County geography. For example, it includes emissions from waste, generated by Seattle residents, that is hauled by train to a landfill in Arlington, Oregon. Estimating future emissions associated with waste generated in the present may align better with the policy choices available today (e.g., waste and recycling programs and infrastructure) than would counting the actual current emissions of in-region landfills as this Geographic Plus inventory does. For estimates of waste-related emissions using the “waste commitment” methodology, please see the companion *Supplemental Emissions Calculations* document. The consumption-based inventory also uses a waste commitment approach.

For more information on recommendations related to interpreting and using these results, see the summary report, *Greenhouse Gas Emissions in King County: An Updated Geographic Inventory, a Consumption-based Inventory, and an Ongoing Tracking Framework*..

Landfills & Wastewater Treatment

In landfills, organic materials decompose and generate landfill gas, which includes a mixture of methane and carbon dioxide. Landfills continue to generate landfill gas long after closing, although the quantity generated drops significantly over time. This GHG inventory includes estimates of landfill gas emitted at a number of closed landfills within King County[17], as well as from the active Cedar Hills Landfill.

[17] We were not able to collect sufficient data to estimate landfill gas emissions from the following closed landfills in King County: Bow Lake, Corliss, Duvall, Houghton, Puyallup; nor from the following closed landfills under the

King County operates two large regional wastewater treatment plants, West Point, located adjacent to Discovery Park within the Seattle city limits, and South Plant, located in Renton. King County also operates two other very small local treatment plants in the City of Carnation and on Vashon Island. Wastewater treatment generates methane and nitrous oxide.

Most of the GHGs generated at landfills and wastewater facilities are captured and flared (creating carbon dioxide and water) or used as renewable energy. GHGs emitted from landfills and wastewater treatment are estimated in Table 11.

Table 11. Waste Sector Emissions (Metric Tons CO_2e)

	2003	2008
Cedar Hills Landfill	108,000	111,000
Closed Landfills	106,000	102,000
Wastewater Treatment	4,000	4,000
Totals	**218,000**	**217,000**

Source Notes

Landfills:

Fugitive landfill emissions from King County's Cedar Hills landfill, the only significant active landfill in King County, were calculated based on landfill gas collection data provided by King County Solid Waste Division **(KC08-50-9_Cedar_Hills_CH4)**. It was estimated that the flaring system at the landfill combusted 98% of the methane collected **(KC08-50-11),** that the collection system recovered at least 90% of the total landfill gas generated **(KC08-50-10_Collection_Efficiency)**, and that 10% of methane not captured was oxidized to CO_2 **(KC08-50-2_LGOP)**. According to "Landfill Gas Management Definitions & Collection Efficiency" provided by King County Solid Waste Division **(KC08-50-10_Collection_Efficiency)** the 90% collection efficiency is conservative, and so this inventory may overstate the landfill gas emissions from Cedar Hills landfill. See the *Key Drivers and Uncertainties* section that follows the source notes for details.

Fugitive landfill emissions from four closed landfills in King County outside Seattle were taken from a report by AMEC Geomatrix Inc. **(KC08-50-3_Closed_Landfills)**.

Fugitive landfill emissions from six closed landfills within the City of Seattle were taken directly from the City of Seattle's 2008 GHG Inventory **(08-09-00)**.

Wastewater Treatment: King County calculated wastewater treatment emissions according to the Local Government Operations Protocol methodology **(KC08-50-2_LGOP)**, and provided these 2008 emissions for West Point and South Plant facilities **(KC08-50-1_WWT)**. Note that Carnation and Vashon emissions estimates are included in the South Plant calculations, as solids from these treatment plants are processed at South Plant.

Calculation steps and data sources for landfills and wastewater treatment are listed in **KC08-00-1_MasterSpreadsheet_053111 'Waste- Landfills'** and **'Waste- Wastewater'**, respectively.

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jurisdiction of Seattle: Midway, Kent-Highlands. However, these closed landfills are small and old enough that the landfill gas emissions are likely very small.

Key Drivers and Uncertainties

For older, closed landfills, data on actual measurement of landfill gas or the quantity and type of waste disposed was not always available, requiring other estimation methodologies (e.g., based on landfill area). Emissions from the closed landfills are therefore highly uncertain.[18]

A key driver of emissions from any landfill is the current landfill gas capture practices in place at each landfill, especially the Cedar Hills landfill, the only significant currently operating landfill in King County. According to King County Solid Waste Division analysis, at least 90% of the landfill gas generated at Cedar Hills is captured. This estimate is based on several considerations: (1) surface level concentrations of landfill gas are below the best available equipment detection limit of 100 ppm, (2) fugitive landfill gas emissions from the active cell are assumed to be minimal, since decomposition occurs mainly in semi-aerobic condition (since the active cell is not yet completely capped) and where King County uses a unique surface landfill gas horizontal collector system, minimizing any fugitive landfill gas, and (3) research by the Solid Waste Association of North America[19] indicates that for a landfill using comparable landfill gas collection technology, with landfill gas collection systems compliant to the standards the Cedar Hills system meets, landfill gas collection efficiency ranges between 84 percent to 98 percent with an average efficiency of 91.1%. Based on these points, King County Solid Waste Division estimates at least 90% collection efficiency; if actual collection efficiency was higher, then this inventory would overstate the amount of fugitive landfill emissions from the Cedar Hills landfill. The actual collection efficiency is a key uncertainty in estimating landfill emissions at the Cedar Hills landfill. An additional uncertainty is the rate at which methane that is not captured is oxidized to CO_2: we assumed 10% based on the *Local Government Operations Protocol* **(KC-08-50-2_LGOP**).

Key drivers of wastewater treatment emissions are King County population and the effectiveness of the methane capture and destruction systems at each treatment plant. The rate of methane capture, which is assumed to be 99% in calculations provided by King County **(KC-08-50-1)**, is likely uncertain, as is to what extent methane may escape through other means (e.g., in other parts of the wastewater treatment infrastructure before the digester).

Emissions from on-site combustion of wastes (e.g., burning of wastes in fireplaces or in backyards in rural areas) are not estimated.

Altogether, uncertainty in waste sector emissions is likely higher than for most other sectors. However, waste emissions represent less than 1% of King County's inventory, a conclusion that would not likely change significantly with further analysis of uncertainties or methods.

[18] For an estimate of the future GHG emissions associated with waste generated in years 2003 and 2008 in King County, see the companion *Supplemental Emissions Calculations* report.

[19] Landfill Gas Collection System Efficiencies. 2007. SWANA Applied Research Foundation- Landfill Gas Project Group. Available: http://www.mswmanagement.com/web-articles/landfill-gas-collection.aspx

Agriculture Sector

The agriculture sector accounts for 1% of total King County greenhouse gas emissions, and the majority of these emissions can be attributed to dairy cows and beef cattle. This sector includes emissions from enteric fermentation, manure management, and soil management. Emissions in King County have grown slightly in this category since 2003, a trend that is largely attributable to an increase in animal population. Within the agriculture sector, manure management is the largest source of greenhouse gases, accounting for over half of emissions from this sector.

Enteric fermentation refers to the production of methane (CH_4) as part of normal digestive process in livestock, especially cows and other ruminants, and varies by type of animal and amount and type of feed consumed (**KC08-103-4_US-GHG-1990to2007**).

Both CH_4 and nitrous oxide (N_2O) are released in the process of managing animal manures. Methane is released when manure decomposes anaerobically (as in lagoons), and much less so when it decomposes aerobically (as in drylots or on pasture). N_2O is released directly as part of the natural nitrification and denitrification of the organic nitrogen in livestock manure and urine. N_2O is also produced as a result of the volatilization of nitrogen as ammonia (NH_3) and oxides of nitrogen (NO_X) and runoff and leaching of nitrogen during treatment, storage, and transportation (**KC08-103-4_US-GHG-1990to2007**).

In the Puget Sound area, typically, manure is initially stored in lagoons and later sprayed onto fields in the spring and summer (**KC08-102-0_PSCAA05Inventory**), though some efforts have been underway to promote and install manure digesters to capture the methane.

Nitrous oxide is also released from soils, depending on agricultural soil management practices. Nitrous oxide is produced naturally in soils through the microbial processes of nitrification and denitrification. When nitrogen availability in soils is increased (through application of fertilizer, for example), N_2O emissions can also increase. (**KC08-103-4_US-GHG-1990to2007**).

Agriculture emissions from these categories are presented in Table 12, below.

Table 12. Agriculture Emissions (Metric Tons CO_2e)

	2003	2008
Enteric Emissions from Livestock	52,000	57,000
Manure Management	85,000	94,000
Soil Management	7,000	6,000
Total	**145,000**	**158,000**

Source Notes

Agriculture emissions were calculated using data from USDA National Agricultural Statistics Service (NASS) census data **(KC08-101-1_07CensusAg-WAStateCounty** and **KC08-101-0_02CensusAg)** and the EPA's inventory of U.S. greenhouse emissions. The estimation methodology draws upon previous PSCAA inventory work, as well as EPA's Climate Leaders **(KC08-105-1_ClimateLeadersGHGProtocol)** and IPCC guidelines **(KC08-105-2_IPCCGuide-LivestockManure)**. Enteric fermentation emissions were calculated by multiplying King County livestock populations by animal-specific emission factors **(KC08-103-1_US-GHG-1990to2000** and **KC08-103-3_US-GHG-1990to2004Annex)**. Manure management emissions were derived from data on animal population, typical animal mass, volatile solid emissions factors, maximum methane generation potential, a composite methane conversion factor, excreted nitrogen, and nitrous oxide emissions factors **(KC08-103-3_US-GHG-1990to2004Annex** and **KC08-102-0_PSCAA05Inventory)**. Soil management emissions were calculated by scaling direct and indirect emissions from national totals based on relative cropland area **(KC08-103-4_US-GHG-1990to2007)**.

Calculation steps and data sources are listed in **KC08-00-1_MasterSpreadsheet_053111 'Agr'**.

For reference, livestock populations from the USDA's 2002 and 2007 censuses (used here to approximate populations in 2003 and 2008, respectively) are documented below.

Count of animals	**2002**	**2007**
Beef Cattle	8,730	11,490
Beef Cow	2,376	3,009
Milk Cow	11,423	10,025
Horse	5,227	6,941
Sheep	1,780	1,751
Swine	559	798
Goat	165	289
Mink	2,972	3,899
Poultry	8,983	12,849

Key Drivers and Uncertainties

The parameters which have the largest impact on emissions in this sector are the number and type of farm animals (manure management and enteric fermentation), farm area (soil management), and manure treatment methods (manure management).

Under this inventory methodology, which relies strongly on national averages, local policies and measures that affect agricultural emissions – such as those that influence feed or fertilizer practices – would not necessarily be reflected in a regular GHG inventory. Other efforts that reduce the greenhouse gas emissions impact of manure treatment, such as through use of anaerobic digesters or field spreading, could also be estimated, although tracking changes in such practices over time could be challenging.

A key assumption in making calculations based on animal populations is that the available, bi-decadal census data is representative of the years of interest. In this inventory, it is assumed that 2007 and 2002 census data is representative of 2008 and 2003 populations, respectively.

The calculations for manure management are subject to uncertainty due to coarse estimates of manure treatment systems and associated conversion and emissions factors. For example, the methane conversion factor (MCF, which represents the potential for methane production for a type of manure management system) in this inventory is assumed to be the average of a factor for liquid/slurry and uncovered anaerobic lagoon, for the average annual temperature in the region. This assumption is made to accommodate the dominant practices in King County, but is therefore not sensitive to other practices (including use of digesters or dry spreading) used in the county. These assumptions are consistent with those in the PSCAA inventory report (**KC08-102-0_PSCAA05Inventory**), though future inventories could refine this method.

Agricultural soil emissions are calculated through a top-down method, scaling down from total land area and farm acreage in the United States to King County. This approach does not consider differing crop types and farm practices, such as fertilizer application rates, in King County.

Overall, uncertainty in agricultural GHG emissions is higher than for most other sectors. However, due to the small emissions in this sector relative to other sectors, further effort to reduce this uncertainty may not be warranted at this time.

Land Use Change Sector

King County contains significant stocks of carbon in forests. When trees and other biomass are removed from a site to prepare for development or other uses, these carbon stocks are lost and CO_2 emissions result when, for example, the land-clearing debris is burned or left to decay.[20]

Residential development is a significant driver for land-clearing in King County. This inventory includes an estimate of the land-clearing emissions due to residential development in both 2003 and 2008. Estimates are based on records of residential building permits issued by King County and an assessment of the average carbon lost per acre due to land-clearing.

Table 13 presents estimates of CO_2 released as a result of land-clearing for residential development.

Table 13. Land Use Change Emissions (Metric Tons CO_2e)

	2003	2008
Residential Development	123,000	53,000
Totals	**123,000**	**53,000**

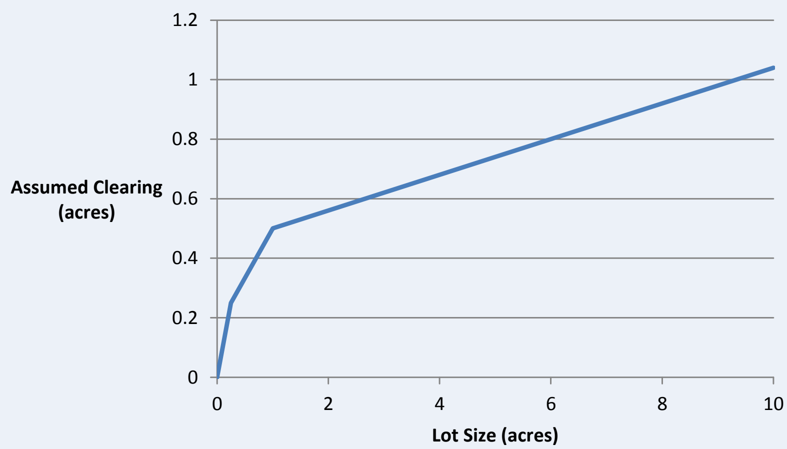
Forest land (including urban forests) can also remove, or sequester, CO_2 from the atmosphere. Estimates of carbon sequestration on forest land in King County are included in the companion *Supplemental Emissions Calculations* document, which also addresses other sources of emissions avoided, sequestered, or stored (e.g., storage in landfills or emissions avoided due to recycling programs).

[20] For an assessment of the relative GHG emissions from other possible end-uses of woody biomass other than combustion or on-site decomposition, see Lee, Carrie, Peter Erickson, Michael Lazarus, and Gordon Smith. 2010. *Greenhouse gas and air pollutant emissions of alternatives for woody biomass residues: Final Draft Version 2.0*. Stockholm Environment Institute - U.S. Center for the Olympic Region Clean Air Agency, November.

Source Notes

The area of parcels issued building permits in 2003 and 2008 were obtained from the King County Department of Assessments database (**KC08-80-1_Assessor_Database**). We queried the database for the first issuance of permits of type "building, new" for each residential parcel in years 2003 through 2008. Calculations are documented in **KC08-80-5_Assessor_Data_Analysis.**

Parcels were assumed to start at 41% canopy cover **(KC-08-80-2_Carbon Stocks)**. Parcels up to 0.25 acres were assumed to be 100% cleared. Parcels between 0.25 and 1 acres were assumed to be 50% cleared (at 41% canopy cover). Parcels over 1 acre were assumed to have 0.5 acres plus 0.06 acres cleared of forest for each additional acre of parcel size. The following chart describes this assumed relationship graphically. The clearing rate equation for parcels above 1 acre was based on a regression analysis of prior data collected by Gordon Smith based on aerial photos of development parcels in King County **(KC08-80-3_GHG_Snoqualmie)**. The clearing rates for parcels less than one acre were based on judgment of Gordon Smith as to a development threshold (0.25 acres) below which all of the lot would likely be cleared.



The above-ground carbon content of trees on land cleared was assumed to be 56 tons of carbon per hectare, or 83 tons CO_2e per acre, per research by the University of Washington researchers **(KC-08-80-2_Carbon Stocks)** and assumes that any land cleared started at a 41% canopy cover, the average canopy coverage of three transects extending across King County in that study. We increase this figure by 21% to include the below-ground carbon content of trees (e.g., coarse roots) per information provided by the U.S. Forest Service **(KC08-80-4_USFS_CCT)** and to be consistent with the assessments of forest carbon presented in the companion *Supplementary Emissions*

Key Drivers and Uncertainties

The key driver for emissions from land clearing is assumed here to be residential development. Land clearing for other types of uses (e.g., commercial development, agriculture) is assumed to be small relative to residential development and is not quantified here.

Uncertainty exists in each of the key variables, including the actual year that clearing was conducted (we assign it here to the year in which the first building permit was issued), the number of acres of forest cover actually cleared in each parcel, and the starting carbon stocks of the forest cleared. Further work to analyze aerial photos of the particular parcels permitted in each year, though time-consuming, could help refine these estimates.

Attachments

Attachment A: Source documentation

The formal inventory is a dataset consisting of electronic files. These data files are divided into the following categories:

Index file – A single index file, <KingCounty2008GHGInventory-DatasetIndex.xlsx>, lists names, descriptions, and sources of all other files in the inventory.

Source files – These files are numbered KC08-00-00 to KC08-100-00. The files are organized by category in the following format:
KC08-00 Inventory
KC08-10 Transportation
KC08-20 Buildings
KC08-40 Industry
KC08-50 Waste
KC08-70 Population and Employment
KC08-80 Land Use
KC08-60 Electricity
KC08-100 Agriculture

Calculation files – File KC08-00-1 is the master calculation file for the inventory, and includes at least the highest-level calculations for every datum reported in this document. Every table describing the inventory in this document is duplicated from <KC08-00-1.xlsx>.

Every datum in the calculation files is traceable to one of the source files through the KC08-XX-XX number provided in the "call no." column of most of the calculation files. These sources files are listed below in Table 15. In addition, some source files from prior inventory work in Seattle are referenced. These source files are in the format 08-XX-XX (*2008 Seattle Community Greenhouse Gas Inventory*) or 05-XX-XX (*2005 Inventory of Seattle Greenhouse Gas Emissions: Community & Corporate*), and are maintained by the City of Seattle Office of Sustainability & Environment (OSE).

Table 14. Catalog of Source Documents

KC08-00-0	**Inventory**		
KC08-00-1	Master Spreadsheet	.xlsx	MasterSpreadsheet_MMDDYY
KC08-10-0	**Transportation**		
KC08-11-0	**Road**	folder	
KC08-11-2	Trips and VMT for King County, by vehicle type	.xls	TripsVMT-KC
KC08-11-3	2009 Transit GHG Emissions Reporting for CCX	.xls	KCM-Motorbus
KC08-11-4	National Transit Database (NTD) 2008 files - Data Tables: T17 Energy Consumption	.xls	T17EnergyCons
KC08-11-5	King County Department of Transportation - Metro Transit Division (King County Metro) - 2008 Agency Profile	.pdf	NTD-KCMetro08
KC08-11-6	King County Department of Transportation - Metro Transit Division (King County Metro) - 2003 Agency Profile	.pdf	NTD-KCMetro03
KC08-11-7	Central Puget Sound Regional Transit Authority (ST) - 2008 Agency Profile	.pdf	NTD-ST08
KC08-11-8	Central Puget Sound Regional Transit Authority (ST) - 2003 Agency Profile	.pdf	NTD-ST03
KC08-11-9	Correction factor for average daily (from weekday) VMT	.docx	VMTcorr
KC08-11-10	Table 5.1: Summary Statistics for Heavy Single-Unit Trucks, 1970–2009	.xls	SingUnitTruck
KC08-11-11	Table 5.2: Summary Statistics for Combination Trucks, 1970–2009	.xls	CombTruck
KC08-11-12	Table 4-11: Passenger Car and Motorcycle Fuel Consumption and Travel	.xls	Passenger_Motorcycle
KC08-11-13	Table 4-12: Other 2-Axle 4-Tire Vehicle Fuel Consumption and Travel	.xls	Light_truck
KC08-11-14	2009 and 2010 Energy Consumption Non-Rail	.xls	KCM-Motorbus10
KC08-12-0	**Marine & Rail**	folder	
KC08-12-1	Puget Sound Maritime Air Emissions Inventory (2007)	.pdf	PS05MaritimeInv
KC08-12-2	Port of Seattle Container and Tonnage Statistics Reporting System, "Seattle Harbor 10 year history of cargo volumes handled: 2000-2009."	.xlsx	POS-Tonnage
KC08-12-3	2008 montly ferry routes	.xls	FerryRoutes
KC08-12-4	Weighting calculations for the Fauntelroy-Vashon- Southworth ferry route	.xlsx	FVS-weight
KC08-12-5	Geographic Allocation of Nonraod Engine Population Data to the State and County Level, EPA420-R-05-021, December 2005	.pdf	GeogAllocNONROAD
KC08-12-6	Port of Seattle Seaport Statistics: Cruise Passengers	.xlsx	CruisePass
KC08-14-0	**Air**	folder	
KC08-14-1	Method for allocating SeaTac air emissions to King County	.xlsx	SeaTacRatio
KC08-14-2	2008 Seattle-Tacoma International Airport Activity Report	.pdf	AnnActReport08
KC08-14-3	Sea-Tac Jet Fuel Consumption	.doc	SeaTacFuel
KC08-14-4	2005 Seattle-Tacoma International Airport Activity Report	.pdf	AnnActReport05
KC08-14-5	2003 Seattle-Tacoma International Airport Activity Report	.pdf	AnnActReport03
KC08-20-0	**Buildings**		
KC08-20-1	American Community Survey (2008) - House Heating Fuel (Occupied Housing Units)	.csv	ACS08HeatFuel
KC08-20-2	American Community Survey (2003) - House Heating Fuel (Occupied Housing Units)	.csv	ACS03HeatFuel
KC08-21-0	Sales of Distillate Fuel Oil by End Use (Washington) - from EIA's Independent Statistics and Analysis, Petroleum Navigator	.xls	EIA-DistFuel-WA
KC08-22-0	Heating Degree Days and Cooling Degree Days for Sea-Tac airport	.xlsx	HDD_CDD
KC08-23-0	American Community Survey (2010) - House Heating Fuel (Occupied Housing Units)	.xls	ACS10HeatFuel
KC08-24-0	2010 Process Data	.xlsx	08-10ProcessData
KC08-40-0	**Industry**		
KC08-40-1	2000-2008 Process Data	.xls	00-08ProcessData
KC08-40-2	2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol. 3: Industrial Processes and Product Use, Chp. 2: Mineral Industry Emissions	.pdf	IPCCGuide-MinIndust
KC08-40-3	Waste Monitoring Program: Market Assessment for Recyclable Materials in King County, Final Report (2006)	.pdf	RecyMatKC
KC08-40-4	Fuel usages from Lafarge Plant	.xls	LafargeFuel03-09
KC08-40-5	CO2 measurements (from the stacks) in 2006 from several facilities	.xls	CO2_AOP_Sources_2006_data
KC08-41-1	NONROAD 2008 - King County Fuel Consumption Data and Calculations	.xlsx	NONROAD-EquipCalcs
KC08-42-1	State Inventory and Projection Tool: IP Module	.xls	SIT-IP-WA-ODS
KC08-42-2	U.S. Census Bureau, American Factfinder: United States -- States, 2008 Population Estimates	website	WApop
KC08-43-1	Data on Economic Value Added by Industry from the 2007 U.S. Economic Census	.xlsx	Ind_ValueAdded
KC08-50-0	**Waste**		
KC08-50-1	Wastewater calculations	.xls	WWT
KC08-50-2	Local Government Operations Protocol for the quantification and reporting of greenhouse gas emissions inventories (2008)	.pdf	LOGP
KC08-50-3	Applicability of Greenhouse Gase Mandatory Reporting Rules to Closed Rural Landfills at Cedar Falls, Enmclaw, Hobart and Vashon Island	.pdf	Closed_Landfills
KC08-50-4	Waste emissions calculations	.xlsx	Waste_calcs
KC08-50-5	EPA WARM model	.xls	WARM_v11_exploded
KC08-50-6	King County (ex-Seattle) municipal solid waste disposal quantities	.xlsx	KingCountyDisposal
KC08-50-7	Seattle municipal solid waste disposal quantities	.xlsx	SeattleDisposal
KC08-50-8	Calculations for recycling benefits	.xlsx	Recycle_calcs
KC08-50-9	Landfill gas flow rate and methane fraction	.xlsx	Cedar_Hills_CH4
KC08-50-10	Landfill gas management definitions and collection efficiency	.doc	Collection_efficiency
KC08-50-11	Landfill flare combustion efficiency	.doc	Cedar_Hills_combustion
KC08-60-0	**Electricity**		
KC08-60-1	SCL geodata sheet - kWh consumption 1995-2008	.xls	SCLkWh95-08
KC08-61-1	King County 2008 Electricity and Natural Gas Usage	.xls	PSE08
KC08-61-2	King County 2003 Electricity and Natural Gas Usage	.xls	PSE03
KC08-63-1	Fuel mix reporting emissions factors calculated for PSE and SCL	.xls	FuelMixPSE-SCL
KC08-64-1	SCL geodata sheet - kWh consumption 1995-2010	.xls	SCLkWh10
KC08-65-1	King County 2010 Electricity and Natural Gas Usage	.xlsx	PSE10
KC08-70-0	**Population and Employment**		
KC08-70-0	Population Estimates States	.csv	Pop_States
KC08-70-1	Population Estimates Counties	.csv	Pop_Counties
KC08-70-2	Population Estimates Cities	.csv	Pop_Cities
KC08-70-3	Population Estimates Nation	.csv	Pop_Nation
KC08-70-4	Employment Estimates King County, Washington State, and the U.S.	.xlsx	Employment
KC08-70-5	Population Estimates Counties 2010	.xlsx	Pop_Counties_2010
KC08-80-0	**Land Use**		
KC08-80-1	King County Assessor Database (as assembled as a Microsoft Access database from data files downloaded from King County website)	.mdb	Assessor_Database
KC08-80-2	Terrestrial Carbon Stocks Across a Gradient of Urbanization: A Study of the Seattle, WA Region	.pdf	Carbon_Stocks
KC08-80-3	Analysis of Greenhouse Gas Emission Effects of King County's Acquisition of Development Rights to Snoqualmie Tree Farm	.doc	GHG_Snoqualmie
KC08-80-4	USFS Carbon Calculation Tool biomass carbon stocks for King County, Washington	.xls	USFS_CCT
KC08-80-5	Analysis of King County Assessor Database	.xls	Assessor_Data_Analysis
KC08-100-0	**Agriculture**		
KC08-100	**2007 Census of Agriculture**	folder	07CensusAg
KC08-100-1	2007 Census of Agriculture: Washington State and County Data, Vol. 1, Geographic Area Series, Part 47, AC-07-A-47.	.pdf	07CensusAg-WAStateCounty
KC08-100-2	2007 Census of Agriculture: Introduction	.pdf	07CensusAg-Intro
KC08-100-3	2007 Census of Agriculture: Washington: Counties	.pdf	07CensusAg-WACountiesMap
KC08-100-4	2007 Census of Agriculture: United States	.pdf	07CensusAg-US
KC08-101-0	2002 Census of Agriculture	.pdf	02CensusAg
KC08-102-0	PSCAA, "2005 Air Emission Inventory for King, Kitsap, Pierce, and Snohomish Counties" (2008)	.pdf	PSCAA05Inventory
KC08-103-0	**Inventory of U.S. Greenhouse Gas Emissions and Sinks**	folder	US-GHG-EmissSinks
KC08-103-1	Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2000 (2002); EPA 430-R-02-003	.pdf	US-GHG-1990to2000
KC08-103-2	Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004 (2006); EPA 430-R-06-002	.pdf	US-GHG-1990to2004
KC08-103-3	Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004 (2006); EPA 430-R-06-002; All Annexes	.pdf	US-GHG-1990to2004Annex
KC08-103-4	Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007 (2009)	.pdf	US-GHG-1990to2007
KC08-103-5	Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007 (2009), Annexes	.pdf	US-GHG-1990to2007Annex
KC08-105-0	**Manure Management**	folder	ManureManagement
KC08-105-1	EPA, "Climate Leaders Greenhouse Gas Inventory Protocol Offset Project Methodology for Project Type: Managing Manure with Biogas Recovery Systems," version 1.3. 2008.	.pdf	ClimateLeadersGHGProtocol
KC08-105-2	2006 IPCC Guidelines for National Greenhouse Gas Inventories; Volume 4: Agriculture, Forestry and Other Land Use; Chapter 10: Emissions from Livestock and Manure Management	.pdf	IPCCGuide-LivestockManure

Attachment B: Population Information

In several cases it was necessary to estimate emissions by scaling by population from other years, or from the state to county level. The population figures used in these estimates are listed in Table 15 below.

Table 15. Population Information by Area and Employment Type

	2003	2008
King County		
Residents	1,769,753	1,884,242
Commercial Employees	926,409	1,005,634
Industrial Employees	104,316	110,885
Washington State		
Residents	6,113,262	6,566,073
Commercial Employees	2,180,230	2,409,221
Industrial Employees	283,569	292,142

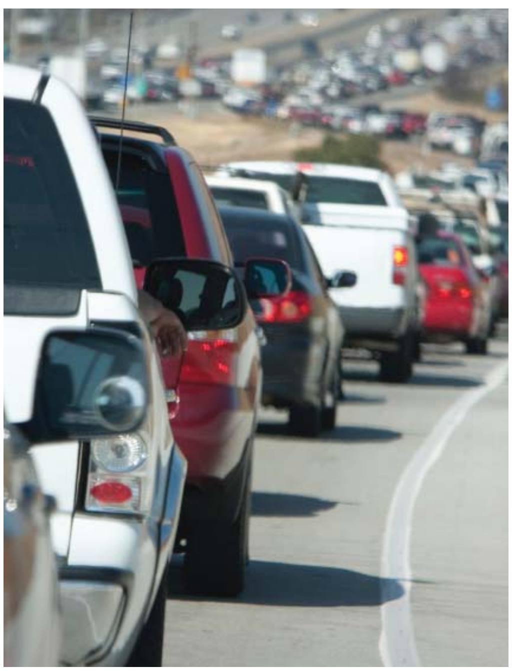
Source Notes

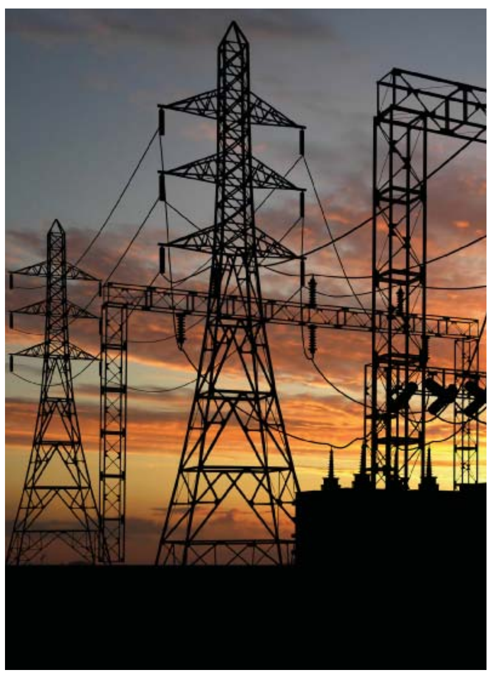
Population: Resident populations were all acquired from the U.S Bureau of the Census Population Estimates Program (www.census.gov/popest/). Population estimates are from **KC08-70-0, KC08-70-1, KC08-70-2,** and **KC08-70-3.**

Employees: King County and Washington State commercial and employee totals are from the Washington State Employment Security department **(KC08-70-4_Employment)**.

Greenhouse Gas Emissions in King County

Appendix C: Supplemental Emissions





King County

SEI STOCKHOLM ENVIRONMENT INSTITUTE

2008 King County Community Greenhouse Gas Emissions Inventory: Supplemental Emissions Calculations

December 8, 2011

http://www.kingcounty.gov/climate

climatechange@kingcounty.gov

Stockholm Environment Institute – U.S. Center
for the King County Department of Natural Resources and Parks

Authors: Chelsea Chandler, Peter Erickson, and Michael Lazarus (SEI);
Shannon Donegan (Cascadia Consulting Group)

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Introduction

This report presents estimates of other sources of greenhouse gas emissions (GHGs), as well as estimates of GHGs avoided or sequestered as a result of actions in King County. This report is a companion to two greenhouse gas inventories conducted simultaneously for King County using two different methodologies:

- *The "Geographic Plus" Methodology*, which estimates the GHG emissions associated with cars and trucks, buildings, waste, agriculture, and other sources of emissions in King County.
- *The Consumption Methodology,* which estimates all emissions associated with consumption of goods and services in King County (including all citizen and government spending), no matter where the emissions occur.

The emissions sources or benefits described in this report do not fit neatly into either of these other two emissions inventories, yet they are important in describing King County's contributions to GHG emissions and in identifying potential means of supporting emissions reductions.

The other emissions sources or benefits discussed in this report include:[1]

- Municipal solid waste disposal using a "waste commitment" perspective;
- Carbon stored in disposed waste;
- Emissions benefits of recycling;
- Carbon sequestered in forests;
- Offsets retired by Seattle City Light;
- Emissions benefits of public transit.

These emissions are not considered part of either the "geographic plus" or consumption-based inventory for a variety of reasons, from seeking to avoid double-counting (e.g., for future emissions associated with waste disposal in the present) to the fact that negative emissions (whether due to recycling or offsets) are generally not considered in emissions inventories. Accordingly, these emissions sources or benefits may not simply be added to the totals displayed in either the "geographic plus" or consumption-based emissions inventories.[2] This project's summary report, *Greenhouse Gas Emissions in King County: An Updated Geographic Inventory, a Consumption-based Inventory, and an Ongoing Tracking Framework* recommends how to consider these other sources or benefits alongside other emissions sources in a comprehensive GHG measurement framework.

Municipal Solid Waste (MSW) Disposal

Two distinct methodologies can be used to estimate emissions associated with landfills and waste disposal. The "geographic plus" inventory estimates waste related emissions using a "waste in place" methodology. That approach estimates the emissions in the year 2008 as a result of all materials currently in landfills (no matter the year they were disposed) that are located within King County's geographic border. Refer to the Geographic Plus Inventory, Waste Sector section, to see the estimated fugitive landfill emissions.

The other common method, called "waste commitment", estimates emissions associated with all waste generated from within King County in 2008 (and only 2008), regardless of when or where those emissions actually occur.[3] This "waste commitment" methodology, employed in

[1] These are not the only other emissions sources or benefits that could potentially be tracked. Others may be identified in the upcoming phase of this project devoted to developing a tracking and measurement framework.
[2] Note that the consumption based inventory uses a portion of the calculation of "waste commitment" emissions to characterize emissions associated with disposal of post-consumer goods.
[3] Based on a review of WARM supporting documents (ICF. 2009. "*WARM component-specific decay rate methods*."Memorandum from ICF International to United States Environmental Protection Agency. October 30, 2009), it appears that EPA's WARM model counts methane released up to 100 years after disposal. After this period, it is assumed that no more methane is released and any remaining carbon is permanently stored.

calculations presented below, includes emissions even if they occur outside the King County geography or after 2008. For example, it includes emissions from waste, generated by Seattle residents, that is hauled by train to an Arlington, Oregon landfill.[4] Both methods include estimates of fugitive landfill emissions that result from the unintended release of landfill gas from the decomposition of organic materials at a landfill or combustion or treatment of landfill gas in flares. When organic materials are landfilled, as they decay, they produce methane and carbon dioxide. Methane is measured in the waste commitment method because the methane emissions would not occur if the materials were not landfilled. The carbon dioxide that results from the decaying materials is not counted under the waste commitment method because it is considered part of the natural carbon cycle of growth and decomposition.[5]

The waste commitment methodology estimates the total quantity of fugitive methane expected from the garbage disposed of in the inventory year, throughout its entire decay process in the landfill. The decay process takes many years, so the fugitive methane occurs only partly during the inventory year, and partly in future years. Emissions in the table below are unique in this aspect (since emissions in the "geographic plus" inventory occur solely in 2003 or 2008). Because the waste commitment emissions shown in Table 1 account for all future emissions from materials disposed in 2008, it is not appropriate to directly compare these emissions with those in the *Geographic Plus* inventory. Estimating future emissions associated with waste generated in the present may align better with the policy choices available today (e.g., waste and recycling programs and infrastructure) than would counting the actual current emissions of in-region landfills.

Other emissions are also associated with municipal solid waste (MSW) generated in King County: namely, fossil fuel combustion associated with transporting waste to landfill, processing waste at the landfill, maintaining the landfill using heavy equipment, and other general activities required to maintain the landfill. These other emissions are also estimated below, in Table 1.

[4] Seattle's waste is disposed at the Arlington landfill, with an assumed 75% collection efficiency, lower than the at-least-90% collection efficiency at King County's Cedar Hills landfill.

[5] US EPA. 2010. "Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM): Introduction & Background". http://epa.gov/climatechange/wycd/waste/downloads/background-and-overview10-28-10.pdf; p.14

Table 1. Waste Management Emissions (Metric Tons CO_2e)

	2003	2008
Transportation to and Processing at Landfills	44,000	39,000
Fugitive Landfill Emissions Commitment	207,000	182,000
Totals	**251,000**	**222,000**

Key Drivers and Uncertainties

The key drivers of MSW disposal are personal and business consumption, which influence how much waste is generated, personal behavior (e.g., reuse, recycling), and alternative management infrastructure (e.g., recycling facilities). The key driver of landfill emissions is the presence and efficiency of a landfill gas collection system.

Several uncertainties exist in our assessment of emissions associated with MSW waste disposal. Most critically, we adjust the EPA's estimates of future fugitive methane generation at landfills by estimated collection efficiencies of fugitive landfill gas at the two dominant landfills that receive waste generated in King County, assuming that these collection efficiencies remain constant in the future. The landfill gas collection efficiencies are relatively uncertain (see source notes below and the Waste Section of the *Geographic Plus* inventory for more details), although landfill gas collection efficiencies are likely to improve over time as collection systems are improved and refined. Additionally, by using conservative collection efficiency estimates, emissions are not likely to be more than the totals estimated in this inventory. In addition to the collection efficiency, waste composition is an important variable in the amount of methane generated in landfills. We used studies conducted by King County Solid Waste Division and Seattle Public Utilities to estimate what fraction of different types of waste are generated in each year, although there is some uncertainty in these estimates.

Source Notes

MSW Disposal: Fugitive emissions from MSW were calculated by applying emission factors from version 11 of the EPA Waste Reduction Model (WARM) **(KC08-50-5_WARM_v11_exploded)** to the tons of waste disposed from King County, including Seattle, and adjusting the emission factors to account for rates of landfill gas collection efficiency at the two landfills: 90% at King County's Cedar Hills landfill and 75% at the Arlington landfill to which the City of Seattle sends its waste **(KC08-50-4_Waste_calcs)**. See the Waste Sector of the Geographic Plus Emissions Inventory for more details on the estimates of landfill gas collection efficiencies. Tons of waste disposed from King County are provided in **(KC08-50-6_KingCountyDisposal)**. Tons of waste disposed from Seattle are estimated in **(KC08-50-7_SeattleDisposal)**. Transportation and processing emissions for King County were calculated by applying fuel specific emission factors to King County's total fuel use in 2008 **(KC08-50-4_Waste_calcs)**. These estimates include emissions related to transporting and processing garbage, heavy equipment use to maintain the landfill, and related general maintenance activities. This estimate includes 151,829 gallons of 100% biodiesel equivalent, which were estimated by King County to result in roughly 57% less lifecycle emissions compared to fossil fuel diesel. Fuel use for 2003 was estimated based on the 2008 ratio of gallons of fuel per tons of waste. Transportation and processing emissions for Seattle's waste were calculated by entering the distance from Seattle to Arlington (254 miles) into WARM **(KC08-50-4_Waste_calcs).**

MSW-related Carbon Storage

The majority of MSW consists of organic matter. When organic waste is buried in a landfill, a portion decays, releasing methane and carbon dioxide, but the remaining portion remains buried in the landfill indefinitely. This remaining portion represents carbon storage, since the carbon in the waste was originally extracted from the atmosphere by means such as a food plant, garden vegetation, or a tree harvested for forest product. Table 2 lists the estimated carbon storage associated with waste disposed in landfills.

As for the fugitive methane commitment described above, the values in Table 2 are calculated for the waste disposed in the listed calendar year, but represent the storage enduring after waste decay has stabilized, many years in the future.

Table 2. Carbon Storage Associated with Landfilling of Municipal Solid Waste (Metric Tons CO_2e stored)[6]

	2003	2008
Carbon storage	-499,000	-440,000

Key Drivers and Uncertainties

As for MSW disposal, the key drivers of landfill carbon storage are personal and business consumption, individual behavior, and alternative management infrastructure. Similar uncertainties also exist in our estimates for carbon storage in landfills as for fugitive methane emissions: for example, we assume that materials that store carbon when disposed in landfills (e.g., wood) remain in the landfill, undisturbed, indefinitely, as in the EPA's WARM model.

Source Notes

MSW Sequestration: Carbon sequestration from MSW was calculated by applying emission factors from the EPA Waste Reduction Model (WARM) **(KC08-50-5_WARM_v11_exploded)** to the tons of waste disposed from King County, including Seattle **(KC08-50-4_Waste_calcs)**. Tons of waste disposed from King County were calculated based on data provided by the King County Solid Waste Division **(KC08-50-6_KingCountyDisposal)**. Tons of waste disposed from Seattle were calculated based on data provided by Seattle Public Utilities **(KC08-50-7_SeattleDisposal)**.

[6] In 2006, King County Solid Waste Division conducted its own analysis of carbon sequestration in its Cedar Hills landfill. Using waste composition data from King County's 1994 waste characterization report, the 2006 report concluded that Cedar Hills landfill sequestered 493,000 $MTCO_2$e in 2003 and 492,000 $MTCO_2$e in 2008. For more detail, please refer to Okereke,Victor. "Analysis of Carbon Sequestration in the Cedar Hills Regional Landfill." Presented at *SWANA'S 21st Annual Pacific Norhtwest Regional & Canadian Symposium*. April 5-7, 2006.

Emissions Avoided from Recycling Programs in King County

Recycling programs in King County result in emissions from their operations, but also avoid emissions associated with disposal of MSW and manufacturing of new materials and products – emissions that largely occur outside King County.

In general, the benefit of avoided materials manufacture is significantly more than the emissions associated with the recycling infrastructure. In other words, recycling programs yield a significant net GHG benefit.

Similarly, composting programs result in both carbon storage and minimal CO_2 emissions from transportation and processing. Carbon storage results from the effects of compost application on soil carbon restoration and humus formation.[7]

Estimating the avoided emissions that can result from recycling programs (or any other source of avoided emissions) can be challenging, as doing so involves assessing emissions reductions relative to what otherwise would have happened, or to "business as usual". One approach used by other communities (including the City of Seattle) has been to estimate the benefits of recycling relative to if all the material was instead disposed. However, other approaches have taken a more conservative (and arguably more realistic) approach to estimating "business as usual", instead estimating benefits relative to national average or "common practice" recycling rates.[8] Below we report results using both of these methods.

Table 3. Emissions Associated with Recycling Programs in King County (Metric Tons CO_2e)

	Relative to 100% Disposal		Relative to National Average Recycling Rates	
	2003	**2008**	**2003**	**2008**
Avoided Transportation to Landfills[9]	-25,000	-37,000	-8,000	-15,000
Avoided Landfill Emissions Commitment	-156,000	-225,000	-51,000	-79,000
Foregone Carbon Storage	532,000	823,000	123,000	209,000
Recycling Process and Avoided Manufacturing	-1,841,000	-2,442,000	-525,000	-750,000
Composting Process and Avoided Manufacturing	-49,000	-77,000	-19,000	-30,000
Totals	**-1,539,000**	**-1,959,000**	**-480,000**	**-664,000**

Note that some of the benefits of recycling (those related to energy savings at manufacturers due to using recycled materials at national average rates) are accounted for in the companion consumption-based GHG inventory. The consumption-based inventory does not fully capture

[7] Composting also emits CO_2 from the decomposition of organic source materials, but because these emissions are biogenic, they are not counted toward (anthropogenic) GHG emissions.
[8] For example, see *The Washington State Consumer Environmental Index* by Jeff Morris et al (2007) or the Climate Action Reserve's offset protocol for programs that collect and compost food waste, both of which assess benefits relative to some measure of national average or "common practice" recycling rates. In addition, the EPA WARM tool upon which our estimates are based is intended to assess the emissions benefits of a change in practices from some initial condition to an alternative practice.
[9] Net of transportation to recyclables processing facilities.

the benefits of recycling to the extent King County recycling (a) exceeds national averages; or (b) leads to forest carbon sequestration that would not otherwise have occurred (e.g., due to recycling of paper) – a carbon flux that is not included in the consumption-based inventory.

Key Drivers and Uncertainties

Similar to MSW disposal, the key drivers of recycling are personal and business consumption, individual behavior, and alternative management infrastructure. Uncertainties are large and likely greater than any other sector.

Uncertainty arises primarily due to the very nature of measuring the benefits of recycling relative to what would have otherwise happened. Characterizing this "counterfactual" requires guesswork. Even though the EPA has performed extensive analysis to attempt to characterize the benefits of recycling against "business as usual" in the various sectors of the economy that are engaged in recycling (from collection programs, to processing infrastructure to global commodities markets, to manufacturers that use recycled feedstocks), significant uncertainties still arise and limit our ability to fully assess the GHG benefits of recycling.

Uncertainties also arise from the calculation of composting emissions. For example, EPA's WARM model currently assumes that the methane (CH_4) that results from anaerobic decomposition during composting is oxidized to CO_2 before it escapes from the compost pile, though some may actually escape as CH_4. In addition, the EPA's WARM model does not quantify some potential benefits of compost: namely, the possibility that compost-amended soils may have an enhanced ability to sequester carbon beyond that carbon contained in the original compost, as well as the possibility that use of compost could displace the use of fertilizers or pesticides. These remain areas for further research.

Despite the uncertainties and the range of benefits estimated in Table 3, these results indicate that recycling and composting programs together provide a significant negative emission, meaning they offset or reduce emissions that would otherwise occur.

Source Notes

Recycling: Emissions from recycling were calculated by applying emission factors from the EPA Waste Reduction Model (WARM) **(KC08-50-5_WARM_v11_exploded)** to the tons of material recycled in King County and Seattle, both in total and also as compared with the national average recycling rate for each material **(KC08-50-8_MarginalRecycle_calcs)**. Tons of waste recycled in King County were calculated based on data provided by the King County Solid Waste Division **(KC08-50-8_MarginalRecycle_calcs)**. Tons of waste recycled in Seattle were calculated based on data provided by SPU **(KC08-50-8_MarginalRecycle_calcs)**. The national average recycling rates for each material were derived from two reports from the U.S EPA's Office of Resource Conservation and Recovery (2008 and 2003 data tables available at http://www.epa.gov/osw/nonhaz/municipal/msw99.htm).

Forest Carbon Sequestration

King County contains over 800,000 acres of forest land – land that contains large stocks of carbon.[10] Carbon is lost when land is cleared and carbon is (in most cases) gained when trees grow.

Table 4 presents estimates of the net annual flux of carbon from King County forest land: an annual gain of 440,000 metric tons CO_2e. The U.S. Forest Service does not provide sufficient data to enable separate estimates for 2003 and 2008, as in other sectors of this GHG inventory.

Table 4. Forestry Sector Emissions (Metric Tons CO_2e)

	1996-2006 (annual change)
Forestry	-440,000

As noted above, there are two components of this flux: sequestration by trees growing on lands that remain forest, and carbon loss on lands cleared of trees. Given the available data, it is not possible to clearly or definitively distinguish these two individual components. However, an approximation can be made by considering the change in acreage that the USFS considers to be forest land. In particular, USFS data indicates that, since 1996, an average of 4,400 acres of forest land were converted to other (i.e., non-forest) uses annually in King County (KC08-80-4_USFS_CCT). At an approximate average carbon density of 100 tons CO_2e per acre, that would yield roughly 440,000 tons of CO_2e of forest stocks removed annually.[11] To yield a net carbon sequestration of 440,000 tons CO_2e as reported in Table 4, then, annual sequestration on forest land that remains forest land would need to be 880,000 tons annually.[12] Interestingly, this figure is similar to a calculation for King County's prior, 2003 GHG Inventory, where it was projected that forest lands in King County could sequester 830,000 tons CO_2e annually.

Therefore, given this preliminary calculation and the finding in King County's prior, 2003 GHG Inventory, it seems reasonable to conclude that (rounded to the nearest hundred-thousand) about 800,000 to 900,000 tons of CO_2e is sequestered annually in King County forest lands, with

[10] Our calculations are based on U.S. Forest Service (USFS) data concerning forest land. USFS defines *forest land* as "land with at least 10 percent cover (or equivalent stocking) by live trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. To qualify, the area must be at least 1.0 acre in size and 120.0 feet wide… …Treecovered areas in agricultural production settings, such as fruit orchards, or treecovered areas in urban settings, such as city parks, are not considered forest land." For further details, see http://www.fs.fed.us/rm/pubs/rmrs_gtr245.pdf.

[11] 100 tons CO_2e per acre is the value used in the calculations in the companion *Geographic Plus* inventory, based on KC-08-80-2 adjusted upward to count belowground biomass per KC-08-80-4. It is a coincidence that the net annual gain in carbon stocks of 440,000 tons CO_2e is the same (though with opposite sign) as this rough estimate of carbon stocks removed. Note that 100 tons per acre CO_2e is lower than the overall average of forests in King County of approximately 231 tons CO2e per acre based on source KC-08-80-4_USFS_CCT. We use 100 tons CO_2e per acre to be consistent with the calculations in the *Geographic Plus* inventory. This carbon density is based on a University of Washington Study of transects in King County from downtown Seattle into rural forested areas; the carbon density on these transects may more closely approximate the densities on land cleared for other uses than the overall average forest carbon stock that includes national forest land and old-growth forest.

[12] Calculated as 440,000 – (-440,000) = 880,000.

about 400,000 tons CO_2e removed, of which about 100,000 tons CO_2 is removed due to residential development (as we discuss in the *Geographic Plus* inventory).[13] The remaining carbon stocks removed from forest lands – estimated at roughly 300,000 tons CO_2e – go to unknown fates. We do not have sufficient information to characterize whether these stocks were lost due to clearing for some other land use (e.g., for road-building to support residential development, to commercial development, or to other land uses) or whether these stocks are not actually removed. For example, the removed stocks could simply have been reassigned in the US Forest Service assessment to a type of land use other than forest land, or perhaps instead due to statistical differences or changes in methodology between the US Forest Service's 1996 and 2006 estimates.[14] Additional, ongoing work by the University of Washington using satellite data may help future analysts better characterize change in carbon stocks in King County.[15]

Key Drivers and Uncertainties

As noted above, given limited data, it is not possible to fully ascertain the key drivers for loss of forest carbon stock in King County. Forest carbon stock losses due to one key driver – residential development – where estimated in the companion *Geographic Plus* inventory. Further research would be needed to understand other land conversions.

Several uncertainties exist, including the fact that USFS methodologies may not be completely consistent between the 1996 and 2006 estimates used here. In addition, these estimates include only forest carbon on lands classified by the USFS as forest land. Additional carbon is sequestered (and lost) in urban forests and suburban lands. Other data sources (e.g., satellite data) would be needed to conduct a fuller assessment of all biomass carbon stocks in King County.

Source Notes

Annual forest sector emissions were calculated based on interpolating an annual flux of forest carbon in above- and below-ground portions of live trees from average 1996 and 2006 forest carbon stocks provided for King County by the U.S. Forest Service **(KC08-80-4_USFS_CCT).**

[13] In the *Geographic Plus* inventory, we estimated that 123,000 tons CO_2 were removed in 2003 and 53,000 tons CO_2 in 2008. Given uncertainties and year-to-year variations, we say "about 100,000 tons" here.

[14] Our analysis of King County permit records indicates that, in 2003, over 3,000 acres were permitted for residential development. If most of these acres were previously forest land, then some fraction of the carbon stocks "lost" from forest land may not be lost, but instead remain on the portion of rural residential parcels that are not cleared for development.

[15] The UW's Urban Ecology Research Laboratory is using Landsat satellite data to quantify changes in carbon stocks in the Puget Sound region.

Offsets Retired by Seattle City Light

Seattle City Light generates most of its electricity from hydro and wind power, but some emissions are associated with the power City Light purchases on the market. Since 2005, City Light has invested in greenhouse gas reduction projects that offset the emissions associated with its electricity supply.

City Light emissions are presented in Table 5, below. Seattle City Light purchased offsets for the 2008 emissions. For more information on City Light's offset program, see the City of Seattle's 2008 GHG Inventory **(08-09-00)**[16] or contact Seattle City Light's Environmental Affairs Division.

Note that the reduction in Seattle City Light's electricity emissions between 2003 and 2008 was due largely to a reduction in supply from coal-fired electricity plants.

Table 5. Seattle City Light Electricity Emissions (Metric Tons CO_2e)
Offset Were Purchased for 2008 Emissions

	2003	2008
Residential	89,000	58,000
Commercial	142,000	96,000
Industrial	36,000	20,000
Total	**267,000**	**175,000**

Source Notes

Calculation steps and data sources are listed in **KC08-00-1_MasterSpreadsheet_123010 'Electricity'**.

Emissions Avoided Due to Public Transit in King County

Public transit produces GHG emissions through the vehicles and facilities used to provide service, but transit can also reduce emissions from private vehicles. Transit can lead to emissions benefits due to:

- **Mode shift:** avoided car trips through shifts from private automobiles to transit;
- **Land use:** additional avoided, or shorter, car trips due to transit's role in enabling compact communities that facilitate shorter trips, walking and cycling, and reduced car use and ownership; and
- **Congestion relief:** improved operating efficiency of private automobiles that can result from reduced idling and stop-and-go traffic.

The *Geographic Plus* inventory estimated King County Metro's annual emissions from buses (diesel) and vanpools (gasoline) at 117,000 metric tons CO_2e in 2008. King County Metro's own

[16] http://www.seattle.gov/climate/

estimates of 2008 emissions is 128,000 metric tons CO_2e and also includes emissions from trolley buses, additional rolling stock, and facilities, all sources that are included elsewhere in the *Geographic Plus* inventory and not specifically assigned to Metro.

Estimating the emissions benefits of transit are difficult because, as for recycling or GHG offsets, doing so involves assessing what otherwise would have happened had the activity (in this case, providing bus and other transit service) not otherwise occurred. Of course, knowing exactly what would have happened otherwise, or "business as usual," is impossible, but methods have been developed to estimate the impacts, typically with large uncertainties.

In particular, the American Public Transportation Association (APTA) has developed a recommended practice to estimate the avoided emissions from each of the three emissions displacement categories above.[17] Some transit agencies, such as New York City and Chicago have completed analysis of their impact using variations of the APTA method. For example, New York estimated avoided emissions by comparing land use and travel patterns for less dense areas, both national as well as adjacent areas that are not served by the Metropolitan Transportation Authority (MTA). They write:

> "Without MTA, GHG emissions could be more than 18 million tons per year… …or more than 25 percent greater than current GHG emissions. This is as conservative estimate that assumes that, without MTA, the region could have sprawled to look like the average U.S. land use. If the MTA Region became even more like low public transport, car-based cities, savings could be as high as 44 million tons per year."[18]

MTA estimated that of the three categories (mode shift, land use, congestion relieve), the land use effect provided the largest GHG benefits for New York City, greater than the mode shift and congestion benefits combined.

King County Metro Transit is currently exploring how to estimate the overall impact of King County transit service and hopes to report estimates in future inventories.

Note that the *Geographic Plus* inventory and the tracking framework recommended in the summary report *Greenhouse Gas Emissions in King County* already account for the benefits of transit, since they account for the emissions from all road travel (both private vehicles and transit), even as they are not able to attribute the specific benefits of transit relative to a "business as usual" scenario.

Sources

For further information on sources cited in this short report, please see the appendices to the *Geographic Plus* GHG inventory.

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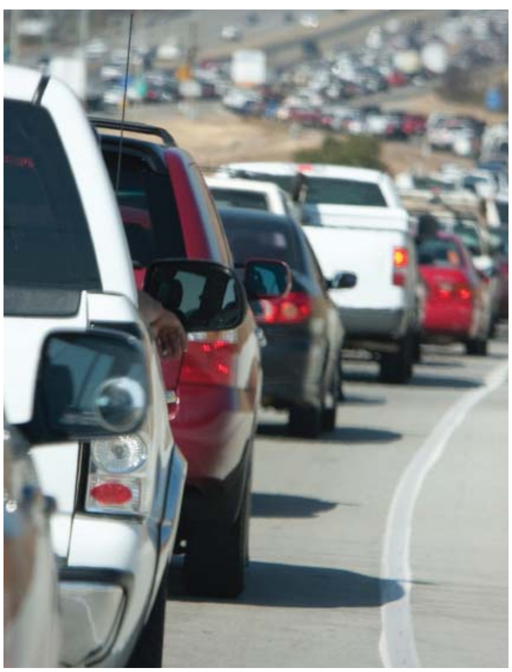
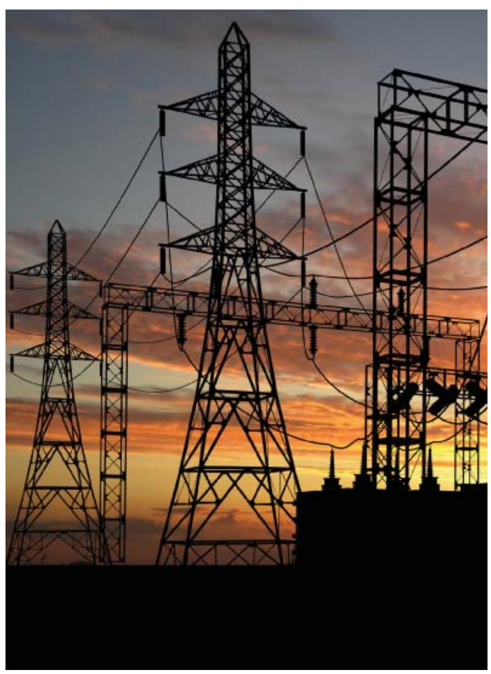
[17] *Quantifying Greenhouse Gas Emissions from Transit*, APTA Standards Development Program, August 2009. http://www.aptastandards.com/Portals/0/SUDS/SUDSPublished/APTA_Climate_Change_Final_new.pdf

[18] http://www.mta.info/sustainability/pdf/MTA%20Carbon%20Model%20Report%20&%20Presentation.pdf

Greenhouse Gas Emissions in King County

Appendix D: Consumption-based Inventory





King County

SEI STOCKHOLM ENVIRONMENT INSTITUTE

2008 King County Community Greenhouse Gas Emissions Inventory: Consumption Methodology

Estimates of the Greenhouse Gases Released to Produce, Transport, Sell, Use, and Dispose of Goods and Services Consumed in King County

September 1, 2011

Stockholm Environment Institute – U.S. Center
(www.sei-us.org)
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Technical report citation: Stanton, E.A, Bueno, R., Cegan, J, and Munitz, C. (2011). *King County Community Greenhouse gas Emissions Inventory – Consumption Methodology: Technical Report.* Somerville, MA: Stockholm Environment Institute-U.S. Center. http://www.sei-us.org.

CBEI model citation: Stanton, E.A., Bueno, R. and Munitz, C. (2011). *Consumption-Based Inventory (CBEI)*. Version 2.0 (March 2011). Somerville, MA: Stockholm Environment Institute-U.S. Center. http://sei-us.org/projects/id/199.

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Overview

This document presents one of two companion greenhouse gas (GHG) emissions inventories for King County, Washington. The inventory described in this report estimates all emissions associated with consumption of goods and services in King County (including all citizen and government spending), no matter where the emissions occur. This inventory is accompanied by the *2008 King County Community Greenhouse Gas Emissions Inventory: Geographic Plus Methodology.* That inventory estimates the release of GHG emissions from cars and trucks, buildings, waste, agriculture, and other sources of emissions within King County in 2008, including some sources (e.g., electricity production) that occurred outside King County's borders. A third, companion document includes *Supplemental Emissions Calculations* that don't fit neatly into either inventory, such as from recycling of solid waste or storing carbon in landfills. Lastly, a summary report, *Greenhouse Gas Emissions in King County: An Updated Geographic Inventory, a Consumption-based Inventory, and an Ongoing Tracking Framework*, discusses how the inventories fit together and recommends an ongoing tracking framework for King County to use on a regular basis.

The Consumption-Based Emissions Inventory[1] (CBEI) provides a different vantage point on greenhouse gas emission responsibility. Conventional inventories assign emissions to geographic regions based on the location of their release: A loaf of bread is manufactured in King County, releasing (for illustrative purposes) 1 metric ton of carbon dioxide equivalent (CO_2-e) into the atmosphere, and King County is assigned that 1 metric ton CO_2-e in its geographic emissions inventory. These geographic-based inventories show how much emissions are released where – an essential first step in implementing mitigation policies.

The geographic basis is an important way of viewing emissions responsibility, but it is not the only way. There is increasing interest in attributing emissions not only to the jurisdiction from which they are released (for example, the location of a bakery), but also to the end users of goods and services (the consumers that purchase the bread). Really, every ton of CO_2-e has two hats to wear: it "belongs" to its location of emission, and it "belongs" to its location of consumption.

A consumption-based analysis notes that the bread was produced in King County, but then considers a series of follow-up questions: Who purchased the bread? And furthermore, if someone in King County purchases bread: Where was it produced, and how much emissions were released in its production? What emissions were generated by production of the materials that went into that bread? What materials went into those materials? And so on.

CBEI's consumption-based methodology tracks financial flows and attributes greenhouse gas emissions to the "consumption" (the end use or final purchase, not as an input to production or for resale) of goods and services. Every purchase that we make is "embedded" with greenhouse

[1] Stanton, E.A., Bueno, R. and Munitz, C. (2011). Consumption-Based Inventory (CBEI). Version 2.0 (March 2011). Somerville, MA: Stockholm Environment Institute-U.S. Center. http://sei-us.org/projects/id/199.

gases; CBEI makes the consumers of goods and services accountable for the emission of greenhouse gases in those commodities' production and distribution. Every region is assigned the emissions embedded in the goods and services used by its households (and a few other kinds of "final consumers" discussed below), and no region is assigned emissions for goods produced in-region but purchased elsewhere. The result is a shift in emission attribution from producers to consumers. For regions that import more embedded emissions than they export (such as most urban areas and many higher-income areas), consumption-based emissions will be higher than in a geographic inventory accounting. For regions that export more embedded emissions (such as areas with a lot of industrial production or petroleum extraction), consumption-based emissions will be lower than in a geographic inventory.

The CBEI model begins with King County 2008 "Geographic Plus" Greenhouse Gas Inventory (SEI 2010) data on: 1) the emissions released by the use of fuel and electricity in (and waste disposal from) residential and government buildings in the area, and 2) emissions released by industrial and commercial activities in the area. The industrial and commercial inventory data are combined with King-County-specific IMPLAN[2] input-output economic data that tracks supply chains from raw materials, to "intermediate goods" (materials, including fuels and electricity, used to produce other goods and services), to the final goods and services sold to consumers. IMPLAN economic data are widely used by jurisdictions throughout the United States to create economic forecasts, inform budget projections, and analyze the expected impact of economic development projects.

Using IMPLAN data, CBEI tracks supply chains both within and outside the King County borders and classifies emissions as occurring in one of three areas: inside King County, outside of King County but inside the United States, and outside of the United States. CBEI uses inventory data from the King County Geographic Plus inventory, the U.S. Environmental Protection Agency, and a detailed study of U.S. international trade in embedded emissions to create emissions coefficients (tons of CO_2-e per dollar spent) for each area and for each of 440 different kinds of goods and services. Consumption-based emissions are calculated by multiplying King County's consumption (in dollars) of goods and services from each area by that area's emissions coefficients (see Figure 1). Then CBEI adds end-use emissions from fuels burned and wastes disposed of by households and government entities within King County as calculated in the Geographic Plus inventory.

[2] Minnesota IMPLAN Group Inc. (2010). IMPLAN Economic Modeling. Version 3.0. Hudson, WI. http://implan.com.

Figure 1: CBEI Calculation Summary

King County Consumption (in dollars)	x	Emissions Coefficients (tons CO_2-e/$)	=	King County Embedded Emissions (tons CO_2-e)
of King-County-made goods and services	x	King County	=	from King County
of U.S. (outside of King County) made goods and services	x	United States	=	from rest of the United States
of foreign goods and services	x	Imports to the U.S.	=	from other countries
			SUB-TOTAL	**King County Embedded Emissions (tons CO_2-e)**
			+	King County End-Use Emissions (tons CO_2-e)
			TOTAL	**Total King County Consumption-Based Emissions (tons CO_2-e)**

This consumption-based methodology is not meant to replace geographic greenhouse gas inventories, but rather to complement them. Both viewpoints – geographic and consumption-based accounting – are valid ways to approach emissions accountability, and both are useful for different types of decision-making – by residents, governments and businesses.

The next section provides a non-technical description of the CBEI model. In Section 0, King County consumption-based emission results for 2008 are presented. The technical CBEI methodology is described in detail in Section 0.

Key Terms

Commodities – goods and services

Consuming Sector – the final good or service purchased (for example, bread)

Consumption –final (end use) purchase of goods and services. Consumption excludes business purchases of inputs to production or products for resale.

Consumption-Based Inventory – emissions inventory based on consumer responsibility: emissions released as a result of consumer purchases from an area are attributed to that area

Direct Emissions – those emitted in producing the final good or service (for example, emissions released at an electric power plant)

Embedded Emissions – emissions from industrial and commercial activities necessary to produce and distribute goods and services . Sometimes called "embodied" or "upstream" emissions.

Emissions Coefficients – the amounts of greenhouse gases released per dollar of economic activity in a particular industrial or commercial sector and a particular geographic area**.** Also called emissions intensities.

Emitting Sector – the type of production occurring at the time of emission (for example, wheat farming)

End-Use Emissions – emissions from households and government entities use of fuel, electricity, and waste disposal services

Final Consumers – purchasers of goods and services for end use: households, government entities, and (for investment purposes only) businesses. Business purchases of inputs to production or products for resale are not part of consumption.

Final Demand – the purchase of goods and services by households and government, and businesses' investment in capital goods and net inventory

Geographic Inventory – emissions inventory based on geographic responsibility: emissions released from an area are attributed to that area

Goods – material products for market purchase (bread, steel, automobiles)

Gross Demand – final demand plus intermediate demand

Hybrid Inventory – an emissions inventory that includes elements of both geographic and consumer-based responsibility

Indirect Emissions – those emitted further upstream in the production process (for example, emissions from refining and distributing the petroleum products used to generate electricity)

1.1. Consumption versus Geographic-Based Emissions Inventories

Greenhouse gas emissions can be view either in terms of *geographic* (sometimes called "*production*") *responsibility* or *consumer responsibility*. Geographic responsibility attributes emissions strictly by the location of their emission: all emissions physically released in King County belong to King County. Consumer responsibility takes a different view: all emissions caused by consumer purchases in King County belong to King County, regardless of where they were physically emitted. For the world as a whole (or for any economy that does not trade outside its borders), total emissions by geographic responsibility must equal total emissions by consumer responsibility.

Emissions inventories often mix and match between geographic and consumer perspectives. King County's 2008 "Geographic Plus" Greenhouse Gas Inventory (SEI 2010) is a hybrid, containing both geographic and consumption-based elements. Figure 2 reports responsibility assignments used for each of three kinds of emissions inventories. GEO is an archetypal geographic inventory; HYBRID is an example of a geographic inventory that includes some consumer responsibility elements; and CBEI is the SEI-US Consumption-Based Emissions Inventory.[3]

Figure 2: Emissions Responsibility Assignments

		Geographic Responsibility	Consumer Responsibility
End Use:	**Fuels, Buildings**	GEO, HYBRID, CBEI	
	Fuels, Transportation	GEO	HYBRID, CBEI
	Electricity	GEO	HYBRID, CBEI
	Waste Disposal	GEO	HYBRID, CBEI
Industrial/Commercial		GEO, HYBRID	CBEI
LULUCF		GEO, HYBRID	

Figure 2 breaks greenhouse gas emissions into several types that, together, are comprehensive and exhaustive; that is, all greenhouse gas emissions fall into one, and only one, of these types.

[3] Responsibility assignments in the geographic (GEO) and hybrid (HYBRID) inventories have been generalized across many similar inventory methods, quite a few of which vary from these examples. The Consumption-Based Emissions Inventory (CBEI) refers only to the responsibility assignments in the SEI-US model; other models of the emissions embedded in consumption differ.

- *End Use*, including:
    - Fuels for burned for heating and appliances in buildings
    - Fuels burned for transportation
    - Electricity
    - Waste disposal
- *Industrial/Commercial*, energy and non-energy greenhouse gas emissions from the production and sale of consumer products
- *LULUCF*, or land use, land-use change, and forestry

For *end-use emissions from fuels used in buildings*, geographic and consumer responsibility amount to the same thing – the end purchaser of the fuel always is present at the location of emission. All types of inventories estimate the same value for these emissions. The use and disposal phases of the CBEI model presented in this report these end-use emissions as estimated in the Geographic Plus inventory plus the upstream emissions associated with producing the fuels burned for these end uses.

End-use emissions from transportation fuels, electricity and waste disposal are assigned strictly to their physical location of emission in a geographic inventory, but there is a recent trend towards hybrid inventory methodologies, like King County's Geographic Plus inventory, that approach some of these end-use emission types from the point of view of consumer responsibility. A strict geographic inventory would include emissions from the electricity produced in King County, the transportation fuels burned in King County, and the wastes disposed of in King County. The Geographic Plus inventory instead includes emissions from electricity used by King County consumers, regardless of where the electricity was produced and air travel by King County consumers, regardless of where the fuel was burned. The Geographic Plus inventory also departs from a pure geographic perspective for ground transportation and waste emissions. For ground transportation, the inventory counts half of the emissions associated with all vehicle trips that cross the county border and all the emissions associated with vehicle trips that occur entirely within King County.[4] For waste emissions, the primary Geographic Plus inventory takes a pure geographic perspective, but a supplemental calculation counts all emissions associated with waste disposal by King County consumers in 2008, even if those emissions occur outside King County (and in future years, as materials, such as food waste, decompose in the landfill). Additional supplemental calculations (documented in the companion *Supplemental Emissions* Calculations document) estimate the emissions benefits of recycling in King County.

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[4] While this is not technically a consumption-based approach (since we have no way of knowing whether those trips were by King County consumers or not), the result is likely very similar to the emissions associated with all regional vehicle trips by King County residents. For more information on this method, see SEI (2010).

Geographic inventories, as well as King County's hybrid Geographic Plus inventory, include *industrial/commercial emissions* based on geographic responsibility: emissions from industrial production and commercial establishments located in King County are assigned to King County, regardless of whether the goods produced are purchased in King County or exported. CBEI assigns industrial/commercial emissions based instead on consumer responsibility as discussed below.

The final emission type, *land use, land-use change, and forestry*, is approached almost exclusively from a position of geographic responsibility: LULUCF emissions, positive or negative, that take place in King County are assigned to King County. Many geographic and hybrid inventories leave this category out all together, or include net sequestration as an addendum to the main inventory. CBEI excludes LULUCF.

1.2. Emissions Responsibility in CBEI

The CBEI model estimates the total emissions accountability of a given area in a given year based on the viewpoint that emissions are the responsibility of the consumers that use fuel, electricity, goods and services. This "consumer responsibility" logic turns conventional inventories' "geographic responsibility" on its head, making it possible to look at the relationship between trade in goods that have emissions embedded in them (that is, greenhouse gases were emitted in the production of the traded goods) and local, national, and global greenhouse gas mitigation efforts.

King County's CBEI estimates the greenhouse gas emissions resulting from the purchase of goods and services by King County consumers. The terms "consumer" and "consumption" are critical to understanding the meaning of consumption-based results and relating these results to those of other emission inventories. **Consumption** refers to the final use of commodities – in economics, "final demand" – where goods and services are purchased solely for their use and not for resale or as inputs into the production of other goods and services. **Consumers** may be households, government entities, or, in some special cases, businesses. The vast majority of a business' purchases, however, is *not* consumption – a topic we return to below.

CBEI approaches emissions responsibility exclusively from a consumer perspective, as shown in Figure 3. In assigning emissions responsibility, CBEI's differs from the hybrid Geographic Plus inventory in its treatment of industrial/commercial emissions. In fact, CBEI is really the combination of two inventory methods, with some adjustment made for double-counting between them. CBEI brings together King County's existing hybrid Geographic Plus inventory with a newly developed inventory of "embedded" emissions.

Figure 3: Comparing Inventory Methods

		Geographic	Geographic Plus	SEI-US' CBEI
Consumer End Use:	Fuels, Buildings	geographic responsibility = consumer responsibility		
	Fuels, Transportation	geographic responsibility	like consumer responsibility*	consumer responsibility
	Electricity		consumer responsibility	
	Waste Disposal		both geographic & consumer**	
Industrial/Commercial		geographic responsibility (but for electricity)***		consumer responsibility

* King County's Geographic Plus inventory counts emissions associated with half of all vehicle trips that cross the county border, which is similar to a consumption approach. It counts all emissions associated with consumer air travel.

** King County's primary Geographic Plus inventory takes a geographic approach, but a supplemental calculation of "waste commitment" emissions was also conducted.

*** The Geographic Plus inventory counts emissions associated with electricity use, regardless of where they occur.

Embedded emissions are industrial/commercial emissions approached from a consumer responsibility perspective. Using input-output economic data, each consumer purchase can be traced backward through its production process all the way to its raw materials, making it possible to estimate the total “embedded” emissions caused by the purchase and distribution of that commodity. Embedded emissions exclude end-use emissions from the use and disposal of goods after the consumer purchase. For example, the embedded emissions in purchasing a car are the emissions from its construction and sale, not from its end use: burning gasoline in its engine.

The estimation of embedded emissions combines economic data with “emission intensities” that are calculated using the Geographic Plus inventory’s industrial/commercial emissions. For each type of commodity, emissions released in King County are divided by the value of production in King County. Each sector’s emissions intensity is presented in tons of CO_2-equivalent per dollar. CBEI calculates separate emissions intensities for goods produced in King County, in the United States but outside of King County, and in foreign countries for import into the United States.

In the CBEI consumption-based results, the embedded emissions from King County's purchases of consumer goods and services are divided into three pre-purchase phases: production, pre-purchase transportation, and retail/wholesale. Two additional phases report end-use emissions: use, and post-consumer disposal (see Figure 4).

Figure 4: Five Phases of the SEI-US' CBEI Model

Emission Type	Life-Cycle Phase	Inventory Sources
Embedded Emissions	Production	**From** CBEI Embedded Pre-Purchase model **minus deleted** emissions from electricity and waste disposal and **minus transferred** indirect emissions for fuel and electricity (to use phase) and waste disposal (to post-consumer disposal phase)
	Pre-Purchase Transportation	
	Retail/Wholesale	
End-Use Emissions	Use	**From** Geographic Plus inventory end-use fuel and electricity **plus transferred** indirect emissions for fuel and electricity
	Post-Consumer Disposal	**From** Geographic Plus inventory end-use waste disposal **plus transferred** indirect emissions for waste disposal

CBEI's methodology for estimating embedded emissions overlaps with the Geographic Plus inventory's estimation of end-use emissions for two types of purchases: electricity and waste disposal services. To avoid double counting, CBEI deletes its *direct* emissions estimates for these two sectors (direct emissions are those emitted at the electrical generator, landfill, or incinerator) but retains important information about *indirect* emissions further upstream in the production process (for example, emissions from refining and distributing the petroleum products used to generate electricity). CBEI's use and disposal emissions are the end-use emissions estimated in the Geographic Plus inventory, plus indirect emissions from the production and distribution of fuels and electricity, and disposal of wastes, that are calculated in the model's embedded pre-purchase phases and then transferred to the use and disposal phases.

1.3. Model Organization

Emissions are organized by type of consumer, commodity type, life-cycle phase, and location of emission. Before reporting more detailed information about CBEI calculations, this section presents a primer on the model's organization.

Type of Consumer

CBEI's consumption-based emissions are attributed to three types of consumers:

- King County ***households*** purchase commodities for their final use, including goods (such as food, electronics, household furnishings, and cars), services (such as haircuts or tax preparation), fuel for vehicles and home heating, and electricity for household lights, electronics, and appliances. In 2008, 62 percent of King County's final demand came from households (see Table 9 below).
- King County-based local, state and federal ***government*** entities purchase commodities for final use, including goods (like office supplies or food consumed in a prison), fuel, and electricity used in government facilities. King County-based federal government activities were responsible for 3 percent of final demand, while local and state government activities accounted for 8 percent. Transfer payments (government payments made directly to households, for example, social security) are not included in King County-based federal government activities (except to the extent that King County state/local governments or households use the transfer payments to engage in consumption). CBEI does not estimate King County residents' "share" of or "contribution" to (via taxes or voting) out-of-county emissions resulting from federal government activities (e.g. foreign affairs, military, etc.).
- The vast majority of businesses' purchases is not direct consumption, but rather support for the production of goods and services for household or government consumption. ***Business investment*** purchases, or the equipment or inventory that businesses purchase but do not sell in a given year, are treated as direct consumption by businesses. Business investment accounted for 27 percent of King County's final demand in 2008. (This is an unusually high share for investment demand. For comparison, U.S. investment was 15 percent of total final demand.) Emissions associated with construction of nonresidential buildings are included under business investment consumption, while emissions associated with construction of residential buildings are reported under household consumption.

Most business purchases are of "intermediate" goods and services that are combined to produce new goods and services for sale. In input-output economic data (and in the CBEI model) these intermediate purchases can be linked together into a supply chain from raw materials to intermediate goods to final goods.

But a few kinds of business purchases do not easily conform to classification by supply chain. Wheat, yeast, water, and electricity are combined to make bread – these intermediate goods become the bread. The mixers, ovens and bakery building are also essential to making bread, but they don't become the bread. These durable goods – equipment and infrastructure – are used to make products year in and year out. They depreciate; they receive maintenance or retro-fitting; and over a machine or a building's lifetime it may be utilized in the production of many different products. Because of these complexities, in CBEI durable goods are treated, not as a part of the supply chain that becomes the final good, but rather as a special kind of final consumption called business investment. Net inventory (inventory at the end of this year less inventory at the end of last year) is included in business investment for a similar reason – it has not yet become part of a final purchased good, so there is no supply chain to which to attach it.

In CBEI, emissions from King County businesses' purchase of equipment, construction of buildings, and net inventory are attributed to King County.5 Just like households and government entities, businesses can consume final goods that are not accountable to whoever buys the businesses' products. This logic may seem incongruous at first but consider two points. First, this approach is used throughout the field of economics, and is central to the standard methodology for calculating gross domestic product used in every country around the world. Second, businesses investing in equipment and buildings cannot know how much (or even what) goods will be produced as a result. They may go out of business this year or in 50 years; they may decide to sell these investments, or the equipment may break down or become obsolete. There is no reasonable set of assumptions with which to tie business investments to all of the future products they might produce. Emissions from business investments, then, are attributed as consumption in the jurisdictions in which these purchases are made, and can be part of these jurisdictions long-term emission abatement strategy.

Commodity Type

Commodities are classified in 440 sectors. These sectors are aggregated to 62 subcategories and 16 categories (see Figure 5).

- ***Sectors:*** CBEI data are calculated and reported in 440 types of industries (or, equivalently, 440 types of commodities produced by these industries). About one-tenth of these commodity sectors have little or no "final demand" in King County – that is, King County's consumers do not buy these products. Instead, they are purchased by businesses to make intermediate products for sale to other businesses, or goods and services for final consumption. (See the Appendix for a full mapping of sectors, sub-categories and categories.)

- ***Sub-categories:*** The 440 commodity sectors are grouped into 62 sub-categories.6

- ***Categories:*** The 62 sub-categories are grouped into 16 categories: Appliances, heating, ventilation and air conditioning (HVAC); Appliances, other; Clothing; Concrete, cement and lime; Construction; Electronics; Food and beverages; Forest products; Fuel, utilities, waste; Healthcare; Home, yard, office; Retailer and wholesale; Services; Transportation services; Vehicles and parts; and Other.

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5 Note that the CBEI model treats residential construction, normally part of the "investment" category in National Income and Product Accounting, as a type of household consumption.

6 Categories that are not further subdivided are counted as both categories and subcategories. For example, clothing is both a category and a subcategory.

The change in emissions responsibility from geographic-based industrial/commercial emissions to consumer-based embedded emissions is one of two main differences between CBEI and the Geographic Plus inventory. A second critical difference is that hybrid inventories such as the Geographic Plus sort emissions by the emitting sector, while CBEI sorts emissions by the consuming sector. The emitting sector refers to the type of production occurring at the time of emission – wheat farming, yeast manufacture, water and natural gas utilities. The consuming sector refers to the final purchased good or service responsible for the embedded emissions – bread. In

Figure 6, all of the emitting sectors have counterparts as consuming sectors. Bread consumed in King County includes emissions from numerous emitting sectors, just a few of which are shown here.

Figure 5: CBEI's Categories and Subcategories

Appliances, HVAC	**Healthcare**
Appliances, other	Healthcare services
Lighting fixtures and bulbs	Medicines and other healthcare supplies
Ranges and microwaves	**Home, yard, office**
Refrigerators and freezers	Home furnishings
Washers and dryers	Household supplies
Other appliances	Lawn and garden
Clothing	Media and office supplies (except paper)
Concrete, cement and lime	**Retailer and wholesale**
Construction	Retailers
Non-residential construction	Wholesale
Prefabricated buildings	**Services**
Residential construction and remodeling	Banks, financial, legal, real estate, insurance
Electronics	Building services
Computer service and equipment	Education and day care
Other electronics	Hotels, motels, entertainment, media
Food and beverages	Other services
Beverages	**Transportation services**
Condiments, oils and sweeteners	Car rental, repair and wash
Dairy	Transportation services, air
Fresh fruit, nuts and vegetables	Transportation services, mass transit
Frozen food	Transportation services, rail
Grains, baked goods, cereals, roasted nuts, nut butters	Transportation services, truck
Poultry and eggs	Transportation services, water
Processed fruit, nuts and vegetables	Transportation services, other
Red meat	**Vehicles and vehicle parts**
Restaurants	Aircraft
Seafood	Cars and light trucks
Other food and agriculture	Heavy duty trucks
Forest products	Other road vehicles
Paper and cardboard	Railroad rolling stock
Other processed forest products	Ships and boats
Unprocessed forest products	Vehicle parts
Fuel, utilities, waste	**Other**
Gasoline, heating fuels, other petroleum products	
Natural gas distribution	
Oil and gas extraction	
Power generation and supply	
Waste management	
Water- sewage and other systems	

Figure 6: Emissions Embedded in Bread and Light Bulbs

		Consuming Sector										
		Bread	Electricity	Filaments	Glass	Light bulbs	Natural gas	Silica	Tungsten	Water	Wheat	Yeast
Emitting Sector	Bread manufacturers	X										
	Electric utilities	X				X						
	Filament manufacturers					X						
	Glass manufacturers					X						
	Light bulb manufacturers	X				X						
	Natural gas utilities	X										
	Silica mining					X						
	Tungsten mining					X						
	Water utilities	X				X						
	Wheat farmers	X										
	Yeast manufacturers	X										

In geographic and hybrid inventories industrial/commercial emissions are commonly classified by the type of process that releases emissions. CBEI first calculates emissions according to a similar classification logic, disaggregated into 440 emitting sectors (for example, tungsten and silica mining, filament and glass manufacture, water and electric utilities in

Figure 6). But before combining its results with the Geographic Plus inventory's end-use emissions, CBEI reclassifies both embedded and end-use emissions by consuming sector. Embedded pre-purchase emissions are sorted by the final good or service that is consumed (in this example, light bulbs), and end-use emissions are sorted by the type of vehicle or appliance using the energy (end-use electricity to power light bulbs), or the type of good that is disposed of (waste emitted from landfilling or incinerating light bulbs).

Location of Emission

The emissions embedded in final goods and services may occur within King County, inside the United States but outside of King County, or outside of the United States:

- ***King County*** emissions are from King County production for King County consumption. It includes upstream requirements of production for King County consumption only when the intermediate products are made in King County.
- ***Inside-US-Outside-KC*** emissions are from United States (other than King County) production for King County consumption. It includes U.S.-made upstream requirements of production for King County consumption.

- ***Foreign*** emissions are from foreign production for King County consumption. It includes foreign-made upstream requirements of production for King County consumption.

Both material goods and services can be imported. King County consumers "import" foreign services whenever they make an overseas financial transaction, use overseas technical support for a computer problem, or receive the results of an X-ray analyzed by an overseas radiologist – all common practices. Services are also "imported" into King County from the rest of the United States whenever King County consumers purchase a service from outside the county.

Life-Cycle Phases

Finally, CBEI's consumption-based emissions are divided into five life-cycle phases: production, pre-purchase transportation, wholesale and retail, use, and post-consumer disposal.

Embedded pre-purchase emissions:

- ***Production phase:*** Emissions from the manufacture of consumer goods are classified as production-phase emissions. For example, in the case of a cookie, this phase includes not only emissions released by the cookie factory, but also the emissions that resulted from all of the supplies purchased by the manufacturer: flour, chocolate, water, and electricity. Final consumer products also can be services, such as a haircut or tax preparation. Emissions that result from the operation of a hair salon, and all of the emissions from the products purchased for use in the salon, are also production-phase emissions.

- ***Pre-purchase transportation phase:*** Consumer products, and the supplies necessary to manufacture them, often make several stops on their way from factory to retail store. Transportation emissions from intermediate producer (the makers of the flour and chocolate in the example of cookie manufacture) to final producer (the cookie factory) to wholesale warehouse to retail store are classified as pre-purchase transportation. To be clear, this life-cycle phase does not include post-purchase transportation (bringing the cookies home from the store – these emissions are captured in the vehicles and parts category of the "use phase").

- ***Wholesale and retail phase:*** Wholesale warehouses and retail stores cause greenhouse gas emissions primarily from lighting, electronics and temperature control. This phase includes the direct emissions of wholesalers and retailers, and upstream emissions from goods and services purchased by wholesale and retail businesses (including electricity and fuel).

End-use emissions:

- ***Use phase:*** Some products cause emissions in their use by the final consumer. For example, heating fuel causes emissions when burned in the consumer's furnace and gasoline causes emissions when burned in the consumer's car engine. Electricity emissions are also classified as a part of the use phase – the use of a computer or a light causes emissions from electricity generation. Use phase emissions include emissions at the point of combustion, as well as supply-chain emissions associated with the fuels that are combusted (e.g., emissions from petroleum refineries and coal mines).

- ***Post-consumer disposal phase:*** The final life-cycle phase is disposal. This phase includes only the emissions that result from the post-consumer landfilling or incineration of products. This phase does not include emissions that result from industrial or commercial waste, which are instead classified as production emissions. This phase does not include any "credits" for emissions reductions resulting from recycling or composting, except to the extent that recycling and composting reduce emissions from landfilling and combustion.

Geographic, hybrid, and consumption-based inventories share a common scope of analysis: the emissions related to (by location of emission or by location of consumption) a particular geographic area in a particular year. Embedded emissions (production, pre-purchase transportation, retail/wholesale) result from products purchased by King County in 2008, and end-use emissions (use and post-consumer disposal) result from fuels burned and waste disposed of by King County in 2008. The focus of the analysis is on the activities of King County as a whole, and not on individual households, or purchases of single goods. The life-cycle phases in CBEI are subdivisions of the total King County emissions in 2008, from a consumer responsibility perspective. In contrast, a true life-cycle analysis follows a single good from cradle to grave. CBEI embraces the idea of cradle-to-grave responsibility by dividing its emissions into activities that relate to each phase of the single-year "life cycle."

For example, a true life-cycle emissions analysis of a car would follow that car from the raw materials that went into its production, through the production process, through pre-purchase transportation, retail and wholesale activities, to its purchase, use in combination with gasoline, and eventual disposal. CBEI does not estimate the emissions of a single car; it estimates the emissions related to King County residents' purchasing and driving cars in 2008. For the production, pre-purchase transportation, and retail/wholesale phases, car emissions result from all car purchases made in King County in 2008. For the use phase, car emissions result from King County residents' driving cars in 2008. For the post-consumer disposal phase, car emissions result from King County residents' disposal of cars in 2008.

CBEI results are best viewed from the vantage point of the planner or policymaker considering what can be done to reduce their jurisdiction's aggregate annual emissions responsibility. These results cannot help households make decisions about when it is best to invest in a new car or household appliance in order to reduce lifetime greenhouse gas emissions. This being said, the CBEI apparatus does include an additional "demand modeler" tool for detailed analysis. Using this tool, an analyst can explore the embedded emissions implications of customized consumption profiles. The CBEI demand modeler results, however, only include embedded pre-purchase emissions, and not end-use (use and disposal phase) emissions.

1.4. Understanding CBEI

CBEI results include the complete impacts of King County 2008 consumption, divided into three embedded pre-purchase phases (production, pre-purchase transportation, and wholesale-and-retail distribution) and two end-use phases (use and post-consumer disposal). CBEI's first three "pre-purchase" phases estimate the embedded emissions from the purchase of commodities; that is, they include both the direct emissions from the production of goods and services purchased by King County consumers, and the indirect emissions from the production of inputs into those consumer goods. The use and post-consumer disposal phases estimate end-use emissions that occur after goods and services are purchased by consumers. The use phase includes the direct and indirect emissions from fuel used by the area's households and government entities, and the direct and indirect emissions from the generation of electricity used by households and governments.7 The post-consumer disposal phase includes the direct and indirect emissions from households' and governments' waste disposal, both from landfilling and (where applicable) the incineration of solid wastes.

CBEI models consumption-based greenhouse gas emissions for a given locality and a single year. King County 2008 CBEI follows four steps to model the consumption-based emissions of goods and services purchased for final use in King County. The first step constructs emission coefficients – kg CO_2-e per dollar – for King County, the United States, and foreign imports into the United States for 440 types of goods and services. The second step models emissions from the production, wholesale, retail and transportation of goods and services up to the point of sale; this intensive, input-output analysis represents the bulk of CBEI calculations. The third step reorganizes these results from emitting sector to consuming sector. The final step adds two post-purchase end-use phases and adjusts the pre-purchase phases for double-counting.

King County's pre-purchase emissions are calculated by multiplying emissions intensities in kilograms of CO_2-e per dollar by the gross demand (final plus intermediate) for the 440 sectors. Final demand is the purchase of goods and services by households and government, and firms' investment in capital goods and net inventory. The intermediate demand included in CBEI is the upstream inputs needed to produce final demand. This type of methodology is often referred to as "input-output life-cycle analysis," for its use of input-output matrices that track the flow of money (as a measure of production activity) through the supply chain for various commodities. Unlike true life-cycle analysis, which typically traces materials through the life-cycle, the elementary flows in input-output life-cycle analysis are in dollars.

7 CBEI follows the convention of treating electricity emissions as "use" emissions, as if they occurred after the electricity was purchased. Alternatively, electricity could be viewed as a service that contains embedded emissions. For consistency with all other goods and services, CBEI first calculates electricity emissions as embedded in the purchased service, then discards the direct end-use results of this calculation and replaces them with the end-use electricity emissions estimated in the Geographic Plus inventory to which are added CBEI's calculation of the indirect emissions from end-use electricity generation.

Consumption, or final demand, is the purchase of goods and services by households and government, and businesses' investment in capital goods or net inventory. All economic data used in CBEI are taken from IMPLAN (MIG 2010) databases. IMPLAN is a leading economic modeling software product that includes national and county income and production accounts data, as well as input-output models of the U.S. and King County economies developed using data from the U.S. Commerce Department's Bureau of Economic Analysis, the U.S. Bureau of Labor Statistics, the U.S. Census Bureau, and other sources. IMPLAN's input-output matrices estimate the indirect (intermediate or upstream materials and equipment) requirements of production, from all sectors, that are needed to produce a unit of any one industry's output for both the United States and King County; IMPLAN data also include estimates of foreign imports and imports from the rest of the United States to King County. This input-output analysis makes it possible for CBEI to model upstream emissions impacts.

The following sections describe each step of CBEI model calculations in turn:

- Step 1: Emissions coefficients
- Step 2: Intermediate pre-purchase emissions by emitting sector
- Step 3: Reorganizing results from emitting sector to consuming sector
- Step 4: Final results, adding use and disposal emissions

Step 1: Emissions Coefficients

"Emissions coefficients" (or emissions intensities) are the amounts of greenhouse gases released per dollar of economic activity in a particular industrial or commercial sector and a particular geographic area. The first step in CBEI model calculations is the construction of three sets of 440 emissions coefficients (for each of the 440 sectors in IMPLAN data), each for a different area: King County, the United States, and foreign imports to the United States.[8] Each coefficient estimates the greenhouse gas emissions intensity of producing a particular type of good or service in a particular location.

For the King County coefficients, industrial/commercial emissions from the Geographic Plus inventory for 2008 are allocated to the 440 sectors. In some cases, the Geographic Plus inventory includes details about particular industries or commercial enterprises, and these emissions are assigned accordingly. Where less detail is available, emissions are assigned to groups of sectors in proportion to the King County economic output of each sector. For example, the Geographic Plus inventory assigns 51,331 mt CO_2-e to "Natural Gas (Industrial Equipment) – Industrial". CBEI allocates these emissions to 278 manufacturing sectors, in proportion to their King County economic output. Each of these sectors also receives emissions from several other categories in the Geographic Plus inventory. Emissions from the Geographic

[8] For technical reasons, CBEI calculations require the construction of two additional sets of emissions coefficients (for a total of five), as discussed in detail in Section 0.

Plus inventory are the numerators of these emissions coefficient ratios. The denominators are the King County economic output of each sector.

For the United States emissions coefficients, the CBEI model uses 2008 industrial/commercial emissions from the U.S. Environmental Protection Agency's Greenhouse Gas Inventory Report (EPA 2010). Again, where sufficient details are provided, emissions are assigned to specific sectors; where there is less detail, emissions are assigned to groups of sectors in proportion to their U.S. economic output. To supplement the level of industrial detail available in this inventory, we use a 2006 U.S. Energy Information Agency report on greenhouse gas emissions from U.S. manufacturing (Schipper 2006). These are the most up-to-date industrial emissions data available, and there use was recommended to us by the EIA.[9] The denominators for the U.S. emissions coefficient ratio are the U.S. economic outputs of each sector.

For emissions coefficients for foreign imports to the United States, we rely on greenhouse gas emissions intensity data from the Multi-Regional Input-Output (MRIO) International Emissions Data 2004 project (Stanton et al. 2011) The MRIO research effort has constructed emission intensity factors for trade between 87 countries or regions in 2004 – the most recent data year available. CBEI maps the MRIO emissions intensities for imports into the United States onto its 440 IMPLAN sectors.

There is one exception to this framework for constructing emissions coefficients in CBEI. The model only allows for three locations of emissions for every type of production, but for electricity there are four location options with corresponding emission intensities: (1) generated within King County, (2) the power pool used within King County, (3) the rest of the United States, and (4) imports to the United States. While the electricity coefficients for the United States and U.S. imports are constructed as described above, the King County electricity coefficient represents the intensity of electricity purchased in county (the power pool as a whole), and not the electricity made in county in a strict geographic accounting. The denominator for the King County electricity coefficient is the full electricity emissions (residential, commercial, and industrial) used in King County from the Geographic Plus inventory. The numerator is the electricity output (or economic activity) in dollars for King County.

This method gives the best estimation of the embedded emissions in commodities made and purchased in King County. It does, however, muddy the distinction between electricity consumption emissions released in the King County and Inside-U.S.-Outside-King County locations of emissions. In CBEI, all electricity end-use emissions – direct and indirect – are classified as having been released Inside-U.S.-Outside-King County. All other end-use emissions – direct fuel use and waste disposal – are classified as having been released from the King County geographic area.

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[9] Personal communication with Stephanie Battles, U.S. Energy Information Administration, October 2010.

Step 2: Intermediate Pre-Purchase Emissions by Emitting Sector

Emissions calculations take the dollar value of King County's consumer purchases (called final demand) – classified into 440 types of commodities – and use "input-output" analysis to calculate the upstream (supply chain) production requirements of these purchases, also called "intermediate" or "indirect" demand. For example, the purchase of a washing machine by a household (final demand) requires an upstream chain of business-to-business purchases: the washing machine factory purchases steel, plastic, wiring, and electricity; the steel foundry purchases iron and coal; and so on. Final demand for each commodity creates intermediate demand for other commodities. The sum of final demand and intermediate demand for any given commodity is called "gross demand." Gross demand is organized by the emitting sector. The gross demand of clothing would be the final demand of clothing (direct purchases of clothing by consumers), plus the intermediate demand for clothing resulting from final demand for all commodities (such as the purchase of uniforms by hotels and the purchase of scrubs by hospitals). Demand is measured in dollars.

In CBEI, the gross (final plus intermediate) demand for all commodities purchased by King County consumers is multiplied by the appropriate emissions coefficient (emissions per dollar) for each commodity to calculate the resultant emissions. Gross demand is divided into production in three regions: King County, outside King County but inside the United States, and imports from other countries. Gross demand for products made in King County is multiplied by King County's emissions intensities; gross demand for products made in the rest of the United States is multiplied by U.S. emissions intensities; and demand for products made in other countries is multiplied by the emissions intensities for foreign imports into the United States.[10]

In this intermediary step, embedded pre-purchase emissions in the clothing category, for example, are not the full embedded emissions of clothing purchases; if a consumer's purchase of clothing results in upstream emissions from the clothing industry's purchase of appliances, electronics, or fuel, these emissions are classified as appliances, electronics or fuel, and are not readily observable as having resulted from the purchase of clothing. Similarly, if a consumer's purchase of hotel stays, doctor's visits, or computers results in upstream emissions from the clothing industry (associated with the manufacture of clothing for housekeeping staff or medical scrubs, or clean-room "bunny suits"), these emissions are classified as clothing, and are not readily observable as having resulted from the purchase of hotel stays, doctor's visits, or computers.

The intermediate emissions calculated in this manner are classified as production, pre-purchase transportation, or wholesale/retail, and are reported on an industry and location basis. For example, in order to produce cars sold in King County, auto companies must purchase steel and other inputs. The emissions from production of the steel used to make these cars are included in the CBEI intermediate calculation of production emissions, since they are part of the

[10] The CBEI methodology for calculating the emissions embodied in King County's foreign imports is slightly different from that of King County's domestic imports and King County production for in-county consumption. These differences are explained in more detail in the methodology section of this report.

embedded emissions of cars sold in King County. Those emissions, however, are reported as steel industry emissions. In this intermediate step, a similar principle of classification applies to all other emissions from production of inputs or intermediate goods: All emissions are assigned to the industries that produce them (e.g. steel), even when the emissions are embedded in a final good in another industry (e.g. cars).

Step 3: Reorganizing Results from Emitting Sector to Consuming Sector

The CBEI model estimates the consumption-based emissions of King County's final demand for goods and services. Emissions "upstream" of the consumer (embedded pre-purchase emissions) are first classified according to emitting industry (in Step 2 above), allowing users to observe the share of emissions originating in each of 440 industries.

Running CBEI in its "life-cycle analysis" mode reorganizes the pre-purchase results according to commodities consumed. Both classification systems (by emitting sector and by consuming sector) result in the same grand total of emissions for the King County pre-purchase emissions, but very different allocations of emissions among sectors. CBEI's pre-purchase results by consuming sector are the embedded emissions of each and every sector of King County consumption separately. Emissions are assigned to the sector of the good or service consumed. For example, emissions from the production of any good or service that are associated with the consumption of clothing (cotton growing, dye manufacture, and advertising) are assigned to clothing.

Imagine an economy with just three production sectors and three types of final goods: wheat, electricity, and steel. CBEI first calculates the total consumption-based emissions for this economy using the Geographic Plus emissions inventory (to establish in-region emission coefficients) along with economic data. The emissions are organized by emitting sector; that is, the purchase of final goods in the King County results in emissions from the production of wheat, electricity, and steel. Emissions that result from the *production* of wheat are assigned to the wheat sector, from electricity to the electricity sector, and from steel to the steel sector. These are the embedded pre-purchase emissions of King County's total consumption by emitting sector.

In Step 3 of the CBEI model, emissions are reorganized by the sector of consumption: the purchase of wheat in King County results in emissions from producing wheat, but also in upstream emissions from producing electricity and steel used for farm operations. All emissions that result from the end-use *consumption* of wheat are assigned to the wheat sector, regardless of how and where they were produced. All emissions resulting from the end-use consumption of electricity are assigned to the electricity sector, and all emissions resulting from the end-use consumption of steel are assigned to the steel sector. This is a single-year "life-cycle analysis" of each sector of King County's consumption, where the results sum to total single-year King County consumption-based pre-purchase emissions.

Because of the way the IMPLAN economic data are organized, the CBEI pre-purchase results for a given commodity category do not include emissions from wholesalers, retailers, or the transportation of a final commodity from factory to wholesaler to retailer; rather, these results are broken out in the pre-purchase transportation and wholesale/retail phases. Wholesale, retail and pre-purchase transportation are treated as services purchased by consumers. When particular categories of consumption are shown to have pre-purchase transportation or wholesale/retail phase emissions in final consumption-based emissions, these emissions result from producer's purchases of these services (such as, transporting wheat from farm to factory). In buying a cookie, for example, the consumer buys – separately – the cookie; the transportation that was necessary to move the cookie and its raw materials from field, to factory, to wholesaler, to retailer; the storage services of the wholesaler; and the retail services of the store. All of these emissions are included in the pre-purchase total, but cookie pre-purchase transportation emissions, for example, are not linked to cookie production emissions.

Step 4: Final Results, Adding Use and Disposal Emissions

In a final step, emissions from two additional life-cycle phases are added to the pre-purchase results organized by consuming sector, after adjustments to avoid double counting. The calculation of CBEI's use and post-consumer disposal phases includes additional emissions from direct fuel use not included in the pre-purchase model, and a transfer of some emissions from the pre-purchase model to the use and disposal phases. Fuels are an important category of King County's consumer purchases, but the pre-purchase model only includes the upstream impacts of refining and distributing fuels, and of businesses' burning fuels to make and transport products; it does not include the use phase impacts of consumers burning fuels in their cars and furnaces.

Use-phase calculations take the Geographic Plus inventory's emissions from households and governments end-use of fuel and electricity and add them to the indirect emissions from refining and distributing fuels (for direct use and to generate electricity). These emissions are then allocated to the sectors representing the appliance and vehicles that use fuels and electricity. Indirect emissions from end-use fuel and electricity purchases, and direct emissions from end-use electricity purchases, are subtracted from the pre-purchase results in order to avoid double-counting.

Post-consumer disposal phase emissions calculations are taken from supplemental materials to the Geographic Plus inventory.[11] CBEI's pre-purchase emissions embedded in waste disposal are deleted to avoid double counting. End-use disposal emissions are allocated to various commodities in proportion to the types of items found in King County's municipal waste. Again, post-consumer disposal phase emissions are not classified according to the service purchased (waste disposal), but instead according to the types of commodities that King County consumers throw away.

[11] Note that emissions for waste disposal included in King County's emissions coefficients (and, therefore, the pre-purchase CBEI results) and the waste disposal emissions included in CBEI's post-consumer disposal phase are based on a "waste commitment" methodology. Data sources are given in the methodology section of this report.

Limitations and Uncertainties

CBEI's embedded pre-purchase emission results are not measurements; they are the best possible estimates given the availability of data. The economic data underlying CBEI's pre-purchase model are IMPLAN data, including input-output and other production data for King County and for the United States as whole; domestic and foreign import shares for each type of good purchased in King County; and consumption data for households, government entities, and business investment in King County. All IMPLAN data are estimated, as are all economic data used by governments and reported in the media: gross domestic product, the inflation rate, the unemployment rate – these are all estimates.

CBEI emission results are estimates, but, of course, many of the emissions totals presented in geographic and hybrid greenhouse gas inventories are also estimates, based on calculations of the average emission intensities of fuels, industry self-reporting on emissions from production, or elaborate systems for approximating the number of vehicle miles traveled and the average fuel efficiency of those vehicles. When measurement is not possible – as is the case for most economic and much physical data – the practice of using good estimates is commonplace.

IMPLAN estimates the consumption of households in every ZIP code, county and state of the United States based on annual data from the national Consumer Expenditure Survey,[12] a relatively small-scale survey that excludes several states each year, disguises the origins of surveys from several other states, and samples fewer than 100 households in each of the smaller states, and up to (roughly) 2,000 households in each of the largest states. The Consumer Expenditure Survey does not have enough respondents to give an accurate picture of consumption in any county or in most states. In order to customize these national data so they apply to each smaller area, IMPLAN divides the respondents into nine income groups. Using consumption profiles for each income group and income distribution data from the very large-scale American Community Survey and the U.S. Census, IMPLAN estimates each area's household expenditures.[13]

Given the availability of data, this is the most accurate method for estimating local area consumption. Indeed, detailed analysis of Consumer Expenditure Survey data by region shows that, after controlling for income, there are only very small differences in consumption patterns across regions, with the exception of a few categories of goods: transportation fuels, heating fuels, and electricity (see Stanton and Ackerman 2010). Fuel and electricity consumption do vary by income, but they also vary by climate and population density (Stanton et al. 2010). IMPLAN household consumption estimates for fuel and electricity, then, are likely to be inaccurate. Note, however, that for fuel and electricity CBEI uses its pre-purchase emissions analysis only to estimate the indirect emissions from refining and distributing fuels. For the

[12] Bureau of Labor Statistics (n.d.). *Consumer Expenditure Survey*. Washington, DC: U.S. Department of Labor. Available at http://www.bls.gov/cex/.

[13] U.S. Census Bureau, American Community Survey (annual), http://www.census.gov/acs/www/, and 2000 U.S. Census, http://www.census.gov/main/www/cen2000.html.

direct emissions from burning fuels and generating the electricity used by consumers, CBEI uses the end-use emissions calculated by the Geographic Plus inventory.

The CBEI model is a work in progress, designed to utilize the best data available today and the best assumptions about the relationships between those data in order to estimate consumption-based emissions for sub-national regions of the United States. An important part of the model still under development is the translation of “producer prices” from IMPLAN data (the price paid for something at the factory door) to the more intuitive “consumer prices” (the price paid at a store). This organization of IMPLAN data makes it necessary for CBEI to treat the services of the retailer as a separate purchase – the dollars spent to buy bread are not readily connected to the retail “margin” (the mark-up that the retailer charges). In a future version of CBEI, we hope to use IMPLAN’s margin data to make this connection and present emissions for purchases made at the store, not the factory.

A final limitation of CBEI is its transferability to another region or year. In principle, creating a King County CBEI for 2009 would be fairly straightforward; the more similar the categories of emissions given in the 2009 Geographic Plus inventory, the simpler this process would be. Introducing King County IMPLAN data for 2009, and updating the various emissions coefficients and the mapping of use and disposal emissions to end-use sectors, however, is complicated and labor-intensive. Transferring CBEI to another jurisdiction is still more complicated, both technically and legally. Inventories vary greatly in their categorization of emissions – in CBEI development, we construct new mappings for each jurisdiction from scratch. It is also the case that IMPLAN data for King County and for the United States are embedded in the CBEI model, and these data cannot be transferred according to the terms of the IMPLAN licensing agreement. (When a CBEI project is complete, we transfer our license for IMPLAN data used in the project to the client.) Our long-range plan is to build a version of CBEI that would be generic and publically accessible, along with instructions for purchasing and importing IMPLAN data, constructing emissions coefficients, etc.

Using CBEI to Measure Policy Impacts

Greenhouse gas emissions inventories are often intended to inform a policy debate regarding local-area mitigation efforts. Abatement policies could affect emissions in a number of ways that can be tracked by observing changes in annual inventories. For the emissions embedded in consumer products, some of the most likely observable policy effects include:

- Local policies could affect local emission intensities (lowering emissions per dollar spent). In CBEI, this impact would be recorded in annual changes to King County’s emissions coefficients.
- National policy could affect national emissions intensities. In CBEI, this impact would be recorded in annual changes to U.S. emission coefficients.
- Global policies or policies elsewhere in the world could affect the emissions intensities of imports to the United States. In CBEI, this impact would be recorded in changes to the

foreign emission coefficients, although there would be some lag, as these data are not annual. The most recent available data are for 2004.

- Local policies could affect local fuel and electricity consumption patterns. In CBEI this impact would be recorded in the Use phase, which takes its data from the hybrid inventory.
- Local policies could affect local non-energy consumption patterns such that local consumption (by income group) became atypical for the United States. For CBEI to record this impact, IMPLAN data must be supplemented by additional data sources.

Options for supplementing CBEI's non-energy consumption data to monitor changes in local consumption patterns can take a few different forms. To observe the impact of policies aimed at reducing overall consumption, year-to-year changes in the jurisdiction's sales tax receipts (adjusting for any variation in rates) could be used to scale IMPLAN consumption data. One scaling factor could be applied to all non-energy consumption, or – if some disaggregation of sales tax sources exists – different scaling factors could be applied to a few different categories of emissions.

To observe the impacts of policies aimed at reducing the consumption of particular products, an annual survey of selected retail establishments could reveal changes in consumption patterns for specific, targeted items. With this information, scaling factors could be constructed for IMPLAN's consumption data for the targeted products. This survey of retailers could be as large or as small as time and budget allows. For many products, requesting multi-year sales data from the largest retailers could provide a very rich data source.

King County 2008 Consumption-Based Emissions, Results and Analysis

2.1. Relationship to Geographic Plus Inventory

Calculation of the CBEI 2008 consumption-based inventory for King County begins with the King County's 2008 "Geographic Plus" Greenhouse Gas Inventory (SEI 2010). Emissions from the King County's Geographic Plus inventory are used in two ways in CBEI calculations: first, Geographic Plus industrial and commercial emissions are used to construct emission intensities for King County-based production; and second, Geographic Plus end-use emissions are the basis for the use and disposal phases.

Table 1 shows the allocation of Geographic Plus emissions towards these two purposes. (Note that end use electricity and waste disposal emissions are needed to calculate the correct emissions intensities for King County production, but estimates of the emissions embedded in King County's purchase of electricity and waste disposal services are replaced with more accurate data on end-use emissions provided by the Geographic Plus inventory.) The consumption-based inventory results presented below have been adjusted to remove any double counting.

Table 1: King County's Geographic Plus Inventory by Emission Type, 2008

(million mT CO2-e)	Industrial/Commercial Emissions	End-Use Emissions
King County 2008 Geographic Plus	**12.18**	**11.05**
Transportation	**5.26**	**6.06**
Residential		5.97
Government		0.09
Industrial/Commercial	5.26	
Electricity	**2.29**	**2.54**
Residential		2.06
Government		0.49
Commercial	1.79	
Industrial	0.50	
Direct Fuel Use	**3.26**	**2.35**
Residential		2.07
Government		0.29
Commercial	1.46	
Industrial	1.80	
Process and Fugitive Gases	**1.20**	
Waste		**0.09**
Agriculture	**0.16**	

Note: Waste emissions shown in this table are based on "waste commitment" calculations and are taken from supplemental materials to the Geographic Plus inventory.

Source: Authors' calculations based on SEI (2010).

CBEI calculations result in 47.75 mT CO_2-e in embedded pre-purchase emissions (see Table 2). To this, the Geographic Plus end-use emissions are added (11.05 mT CO_2-e) and adjustments are made for double-counting (-3.81 mT CO_2-e). Final consumption-based emissions for King County in 2008 are 54.99 mT CO_2-e. In the context of the United States, King County is an urban, relatively affluent area where most of what is consumed is imported from outside the county, and most of what is produced is purchased by consumers outside the county. King County's consumption-based emissions are more than double (235 percent) of the emissions estimated in King County's 2008 Geography Plus inventory (23.35 mT CO_2-e).

Table 2: Final Consumption-Based Emissions, King County 2008

	(million mT CO2-e)
Embedded Pre-Purchase Emissions	47.75
Geographic Plus End-Use Emissions	11.05
Correction for Double-Counting Direct Emissions from Electricity and Waste	-3.81
Final Consumption-Based Emissions	**54.99**

Source: CBEI Version 2.0 (Stanton et al. 2011) for King County 2008.

2.2. King County's Consumption-Based Inventory

Table 3 reports King County's 2008 consumption-based emissions by life-cycle phase totaling 54.99 million metric tons CO_2-e. Production-phase emissions account for 62 percent of the total; pre-purchase transportation, 9 percent; wholesale and retail, less than 2 percent; use 27 percent; and post-consumer disposal less than 1 percent. In interpreting these results it is important to recall two points discussed in detail in Section 1:

- Vehicles and vehicle parts production emissions are the emissions embedded in cars purchased in King County in 2008, while this category's use emissions are the end-use emissions from King County driving in 2008. Production emissions relate only to the cars purchased in 2008; use emissions relate to all cars driven in 2008.
- Pre-purchase emissions for each category include only the emissions embedded in a product when it leaves the factory. Emissions wholesale and retail activities (such as the electricity from running a freezer at a retail store), and from transportation to wholesalers and retailers, are included in the consumption-based emissions results but are not connected to the purchase of specific goods and services. Instead these

emissions are embedded in wholesale, retail, and pre-purchase transportation services (as if the consumer made separate purchases of, for example, (1) a bag of frozen corn, and (2) the service provided by the supermarket that sold the corn).

Table 3: King County 2008 Consumption-Based Emissions by Life-Cycle Phase

(million mT CO2-e)	GHG Emissions by Phase					
	Production	Pre-Purchase Transportation	Wholesale/ Retail	Use	Post-Consumer Disposal	Total
King County Total Emissions	**33.969**	**4.783**	**0.881**	**14.993**	**0.366**	**54.992**
Appliances, HVAC	0.026	0.002	0.000	4.523	0.000	4.551
Appliances, other	0.259	0.011	0.000	2.300	0.001	2.571
Clothing	1.323	0.012	0.000	0.000	0.000	1.337
Concrete, cement and lime	0.003	0.000	0.000	0.000	0.000	0.003
Construction	3.692	0.433	0.024	0.000	0.063	4.212
Electronics	1.795	0.070	0.006	0.554	0.001	2.427
Food and beverages	7.052	0.552	0.015	0.000	0.131	7.750
Forest products	0.257	0.018	0.000	0.000	0.037	0.313
Fuel, utilities, waste	0.097	0.004	0.000	0.000	0.000	0.101
Healthcare	2.853	0.212	0.011	0.000	0.004	3.080
Home, yard, office	3.067	0.245	0.013	0.060	0.104	3.488
Retailer and wholesale	1.586	0.206	0.780	0.000	0.003	2.575
Services	4.494	0.283	0.008	0.000	0.016	4.801
Transportation services	0.448	2.244	0.003	0.000	0.000	2.696
Vehicles and vehicle parts	3.459	0.294	0.011	7.555	0.003	11.322
Other	3.558	0.195	0.009	0.000	0.004	3.767

Source: CBEI Version 2.0 (Stanton et al. 2011) for King County 2008.

Table 4 reports King County's 2008 consumption-based emissions by type of consumer. Household emissions account for 76 percent of the total; business investment, 19 percent; and government, 5 percent. Recall that business investment refers to emissions embedded in businesses purchase of capital goods and net inventory, which cannot be associated with final purchases by households and governments (see discussion in Section 1).

As shown in Table 5, the largest categories are Vehicles and vehicle parts (21 percent) and Food and beverages (14 percent). These are also the largest categories of emissions from household consumption: Vehicles and vehicles parts (21 percent), and Food and beverages (18 percent).

Table 6 reports consumption-based emissions by subcategory. Cars and light trucks is the subcategory with the greatest emissions (11 percent), followed Appliances, HVAC (8.3 percent), and Other (7 percent). No other subcategories exceed 5 percent of consumption-based emissions.

Table 4: King County 2008 Consumption-Based Emissions by Consumer Type

(million mT CO2-e)	GHG Emissions by Type of Consumer			
	Household	**Government**	**Investment**	**Total**
King County Total Emissions	**41.743**	**3.045**	**10.205**	**54.992**
Appliances, HVAC	3.925	0.620	0.007	4.551
Appliances, other	2.085	0.477	0.009	2.571
Clothing	1.330	0.007	0.000	1.337
Concrete, cement and lime	0.002	0.001	0.000	0.003
Construction	0.600	0.437	3.175	4.212
Electronics	1.106	0.251	1.070	2.427
Food and beverages	7.644	0.091	0.015	7.750
Forest products	0.264	0.049	0.000	0.313
Fuel, utilities, waste	0.090	0.008	0.003	0.101
Healthcare	2.995	0.034	0.051	3.080
Home, yard, office	1.770	0.037	1.681	3.488
Retailer and wholesale	2.351	0.015	0.208	2.575
Services	4.498	0.229	0.074	4.801
Transportation services	2.403	0.125	0.168	2.696
Vehicles and vehicle parts	8.804	0.371	2.146	11.322
Other	1.878	0.292	1.597	3.767

Source: CBEI Version 2.0 (Stanton et al. 2011) for King County 2008.

Table 5: King County 2008 Consumption-Based Emissions, Share by Category

(million mT CO2-e)	GHG Emissions by Type of Consumer			
	Household	**Government**	**Investment**	**Total**
King County Total Emissions	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Vehicles and vehicle parts	21.1%	12.2%	21.0%	20.6%
Food and beverages	18.3%	3.0%	0.1%	14.1%
Services	10.8%	7.5%	0.7%	8.7%
Appliances, HVAC	9.4%	20.4%	0.1%	8.3%
Construction	1.4%	14.3%	31.1%	7.7%
Other	4.5%	9.6%	15.6%	6.8%
Home, yard, office	4.2%	1.2%	16.5%	6.3%
Healthcare	7.2%	1.1%	0.5%	5.6%
Transportation services	5.8%	4.1%	1.6%	4.9%
Retailer and wholesale	5.6%	0.5%	2.0%	4.7%
Appliances, other	5.0%	15.6%	0.1%	4.7%
Electronics	2.6%	8.3%	10.5%	4.4%
Clothing	3.2%	0.2%	0.0%	2.4%
Forest products	0.6%	1.6%	0.0%	0.6%
Fuel, utilities, waste	0.2%	0.3%	0.0%	0.2%
Concrete, cement and lime	0.0%	0.0%	0.0%	0.0%

Source: CBEI Version 2.0 (Stanton et al. 2011) for King County 2008.

Table 6: King County 2008 Consumption-Based Emissions by Subcategory

(million mT CO2-e)	GHG Emissions by Type of Consumer			
	Household	**Government**	**Investment**	**Total**
King County Total Emissions	**41.743**	**3.045**	**10.205**	**54.992**
Appliances, HVAC	**3.925**	**0.620**	**0.007**	**4.551**
Appliances, other	**2.085**	**0.477**	**0.009**	**2.571**
Lighting fixtures and bulbs	0.808	0.334	0.001	1.143
Ranges and microwaves	0.325	0.025	0.000	0.350
Refrigerators and freezers	0.346	0.094	0.000	0.440
Washers and dryers	0.420	0.019	0.000	0.439
Other appliances	0.186	0.004	0.008	0.198
Clothing	**1.330**	**0.007**	**0.000**	**1.337**
Concrete, cement and lime	**0.002**	**0.001**	**0.000**	**0.003**
Construction	**0.600**	**0.437**	**3.175**	**4.212**
Non-residential construction	0.000	0.412	2.134	2.545
Prefabricated buildings	0.001	0.001	0.001	0.002
Residential construction and remodeling	0.600	0.024	1.041	1.664
Electronics	**1.106**	**0.251**	**1.070**	**2.427**
Computer service and equipment	0.385	0.110	0.963	1.459
Other electronics	0.720	0.141	0.107	0.968
Food and beverages	**7.644**	**0.091**	**0.015**	**7.750**
Beverages	0.823	0.001	0.001	0.825
Condiments, oils and sweeteners	0.155	0.001	0.000	0.157
Dairy	0.828	0.019	0.000	0.848
Fresh fruit, nuts and vegetables	0.339	0.001	0.003	0.343
Frozen food	0.200	0.001	0.000	0.201
Grains, baked goods, cereals, roasted nuts, nut butters	0.786	0.006	0.000	0.792
Poultry and eggs	0.475	0.002	0.000	0.476
Processed fruit, nuts and vegetables	0.231	0.005	0.000	0.236
Red meat	1.292	0.028	0.000	1.320
Restaurants	1.804	0.021	0.000	1.825
Seafood	0.068	0.002	0.011	0.081
Other food and agriculture	0.642	0.004	0.000	0.646
Forest products	**0.264**	**0.049**	**0.000**	**0.313**
Paper and cardboard	0.245	0.043	0.000	0.288
Other processed forest products	0.019	0.005	0.000	0.024
Unprocessed forest products	0.000	0.000	0.000	0.001
Fuel, utilities, waste	**0.090**	**0.008**	**0.003**	**0.101**
Gasoline, heating fuels, other petroleum products	0.000	0.000	0.000	0.000
Natural gas distribution	0.000	0.000	0.000	0.000
Oil and gas extraction	0.006	0.004	0.003	0.014
Power generation and supply	0.000	0.000	0.000	0.000
Waste management	0.000	0.000	0.000	0.000
Water- sewage and other systems	0.083	0.004	0.000	0.087

Table 6 (continued): King County 2008 Consumption-Based Emissions by Subcategory

(million mT CO2-e)	GHG Emissions by Type of Consumer			
	Household	Government	Investment	Total
King County Total Emissions	**41.743**	**3.045**	**10.205**	**54.992**
Healthcare	**2.995**	**0.034**	**0.051**	**3.080**
Healthcare services	2.419	0.002	0.000	2.421
Medicines and other healthcare supplies	0.576	0.032	0.051	0.659
Home, yard, office	**1.770**	**0.037**	**1.681**	**3.488**
Home furnishings	0.453	0.002	0.014	0.470
Household supplies	0.841	0.013	0.001	0.856
Lawn and garden	0.298	0.012	0.003	0.313
Media and office supplies (except paper)	0.176	0.010	1.662	1.849
Retailer and wholesale	**2.351**	**0.015**	**0.208**	**2.575**
Retailers	1.901	0.000	0.074	1.975
Wholesale	0.450	0.015	0.135	0.600
Services	**4.498**	**0.229**	**0.074**	**4.801**
Banks, financial, legal, real estate, insurance	1.375	0.030	0.000	1.405
Building services	0.012	0.003	0.000	0.014
Education and day care	0.885	0.025	0.000	0.910
Hotels, motels, entertainment, media	1.285	0.035	0.013	1.333
Other services	0.941	0.136	0.061	1.138
Transportation services	**2.403**	**0.125**	**0.168**	**2.696**
Car rental, repair and wash	0.267	0.003	0.000	0.270
Transportation services, air	0.955	0.043	0.038	1.036
Transportation services, mass transit	0.043	0.005	0.000	0.049
Transportation services, rail	0.033	0.004	0.009	0.046
Transportation services, truck	1.033	0.063	0.120	1.217
Transportation services, water	0.026	0.004	0.000	0.030
Transportation services, other	0.045	0.003	0.000	0.048
Vehicles and vehicle parts	**8.804**	**0.371**	**2.146**	**11.322**
Aircraft	0.007	0.061	2.027	2.095
Cars and light trucks	6.141	0.090	0.000	6.231
Heavy duty trucks	2.276	0.117	0.066	2.459
Other road vehicles	0.147	0.001	0.002	0.149
Railroad rolling stock	0.000	0.001	0.011	0.012
Ships and boats	0.044	0.034	0.016	0.094
Vehicle parts	0.190	0.067	0.024	0.281
Other	**1.878**	**0.292**	**1.597**	**3.767**

Table 7 reports King County's 2008 consumption-based emissions by location of emissions. Note that a large fraction of emissions associated with Services were released outside King County. Consumers frequently purchase services from outside of King County (by using an electronic service, or by taking a trip outside of the county). In addition, services providers located within King County purchase intermediate goods and services from outside of King County; for example, a King County hair dresser will purchase shampoo and styling gel made outside of King County.

Table 7: King County 2008 Consumption-Based Emissions by Location

(million mT CO2-e)	GHG Emissions by Location of Emission			
	King County	**Inside-US-Outside-KC**	**Foreign**	**Total**
King County Total Emissions	**15.154**	**25.882**	**13.957**	**54.992**
Appliances, HVAC	2.580	1.957	0.015	4.551
Appliances, other	0.240	2.139	0.191	2.571
Clothing	0.006	0.066	1.265	1.337
Concrete, cement and lime	0.000	0.001	0.001	0.003
Construction	0.738	2.338	1.135	4.212
Electronics	0.154	1.270	1.003	2.427
Food and beverages	0.483	5.457	1.810	7.750
Forest products	0.040	0.177	0.096	0.313
Fuel, utilities, waste	0.008	0.062	0.032	0.101
Healthcare	0.348	2.038	0.694	3.080
Home, yard, office	0.653	1.618	1.217	3.488
Retailer and wholesale	0.522	1.597	0.455	2.575
Services	0.830	2.882	1.089	4.801
Transportation services	0.527	1.149	1.019	2.696
Vehicles and vehicle parts	7.656	1.752	1.914	11.322
Other	0.368	1.379	2.020	3.767

Source: CBEI Version 2.0 (Stanton et al. 2011) for King County 2008.

In 2008, King County consumption of coffee and tea resulted in 0.046 million mT CO_2-e. Only 4 percent of these emissions originated within King County; 54 percent were released in the rest of the United States, and 42 percent were released outside of the United States.

2.3. Emissions Intensity Comparison

King County consumers purchase commodities that are made in King County, made in the rest of the United States, and made in foreign countries. Because emissions intensities (emissions per dollar) differ in each of these production locations, if King County residents were to change their purchasing habits – buy more foreign-made products, for example – King County's consumption-based emissions inventory would change. Table 8 compares King County's consumption-based emissions with the estimated emissions if King County consumers continued to buy the same dollar-value of items, but chose to buy them from the rest of the United States or from foreign countries; these comparisons are made for pre-purchase emissions only (not for use and disposal phase emissions[14]) and are organized by consuming sector.

Table 8: Emissions Results with Adjusted Emissions Intensities

	(millions of mT CO2-e)				
	King County Pre-Purchase Emissions (King County)	In-County Final Demand at US Intensities (KC at US)	In-U.S. Final Demand at US-Import Intensities (KC&US at Foreign)	Ratio of KC-at-US to King County	Ratio of KC&US-at-Foreign to King County
King County Emissions	**47.749**	**55.105**	**86.256**	**1.154**	**1.806**
Appliances, HVAC	0.028	0.028	0.038	1.010	1.373
Appliances, other	0.270	0.272	0.335	1.006	1.239
Clothing	1.336	1.345	1.504	1.006	1.126
Concrete, cement and lime	0.003	0.004	0.002	1.177	0.785
Construction	4.149	4.876	8.941	1.175	2.155
Electronics	1.871	1.959	2.967	1.047	1.585
Food and beverages	7.619	8.074	10.247	1.060	1.345
Forest products	0.276	0.285	0.343	1.033	1.243
Fuel, utilities, waste	8.217	11.613	12.241	1.413	1.490
Healthcare	3.077	3.287	9.604	1.068	3.122
Home, yard, office	3.324	3.452	9.207	1.038	2.770
Retailer and wholesale	2.572	2.943	8.235	1.144	3.202
Services	4.785	5.301	9.490	1.108	1.983
Transportation services	2.695	4.059	4.252	1.506	1.578
Vehicles and vehicle parts	3.764	3.871	4.589	1.028	1.219
Other	3.763	3.739	4.261	0.994	1.132

Source: CBEI Version 2.0 (Stanton et al. 2011) for King County 2008.

Table 8 does not compare emissions intensities. Instead, it compares actual 2008 emissions with emissions in two "what-if" scenarios: (1) what if everything purchased in King County that is made in King County were instead made in the rest of the United States (at U.S. average emission intensities); and (2) what if everything purchased in King County that is made in the U.S. (including in King County) were instead made in another country (at the average emissions intensities of current U.S. imports). Purchasing King County-made commodities from the rest of

[14] Pre-purchase emissions are reported before adjustment for double-counting.

the United States would increase 2008 emissions by 15 percent. Purchasing U.S.-made commodities from other countries would increase 2008 emissions by 81 percent.

Technical Model Description

The CBEI model estimates the consumption-based greenhouse gas emissions of a particular area in a particular year. This section discusses the CBEI technical methodology in detail.

Abbreviations:

King County = Study Area = SA

Inside-U.S.-Outside-SA = UX

United States including SA = US

Outside of the United States = Foreign = FR

3.1. Step 1: Emissions Coefficients

In the CBEI model, greenhouse gas coefficients represent the quantity of emissions released per dollar of activity in each IMPLAN sector. CBEI calculates direct coefficients (the emissions intensity of a production process, not including upstream effects) for the Study Area and the United States, and uses existing data for direct plus indirect coefficients (including upstream effects) for foreign imports to the United States. (The original data for foreign emissions intensities are available only in the direct+indirect form.)

CBEI's direct coefficients are the per dollar emissions, by sector, that result only from activities in the originating production sector; direct coefficients do not include indirect, or upstream, emissions. Production sectors are based on industrial and commercial IMPLAN codes (1 to 427), which correspond to NAICS codes 11 to 81. Sectors 428 to 440 do not have direct emissions,[15] although they might have direct+indirect emissions if their indirect emissions are positive.

Direct coefficients are presented in CBEI in kg CO_2-e per dollar of industrial and commercial output for 2008. Separate direct coefficients are calculated for Study Area and the United States based on Study Area and U.S. emissions inventories and economic output, respectively.

Direct coefficients:

Dcoef_SA Study Area direct coefficients

Dcoef_US U.S. direct coefficients

[15] IMPLAN sectors 361 and 428 to 440 have no direct greenhouse gas emissions, although they may purchase inputs that required emissions for their production. Most of these sectors are purely labor. A few (scrap, used goods) are trade in second-hand materials; all greenhouse gas emissions from the production of these materials are assigned to their first use. Owner-occupied dwellings refers to the "service" of owning or renting a home; the manufacturing and transport of construction materials, emissions associated with construction activities, and fuel and electricity emissions of owning or renting a home are counted elsewhere in the model.

King County Direct Coefficients

Data:

King County's 2008 "Geographic Plus" Greenhouse Gas Inventory (SEI 2010)

Emission allocations:

See KC08-00-1_MasterSpreadsheet_123010 CBEI Mapping.xlsx for a full mapping of the Geographic Plus inventory to King County direct coefficients.

- Transportation: Several data sources are used to allocate transportation emissions household, government, and commercial uses and relevant IMPLAN sectors; see "KC2008 Transportation Allocation.xlsx" for calculations and detailed methodology.
- Electricity: All end-use electricity emissions are allocated to Sector 31, "Electricity, and distribution services."
- Commercial building emissions from direct fuel: After removing government from total commercial (based on the government share of commercial heating and cooling emissions[16]), these emissions are allocated to all commercial sectors (319-427) in proportion to their gross output (GO_SA).
- Industry direct fuel, process, and fugitive gases: Allocated to the appropriate IMPLAN sectors using supplemental data on NAICS and SIC codes.[17] In the few cases where no information was available to assign emissions to particular IMPLAN sectors, these emissions are allocated to all industrial sectors (41-318), or to all industrial sectors not otherwise accounted for with specific emission assignments, in proportion to their gross output (GO_SA).
- Waste, landfills: Waste disposal emissions are based on a "waste-in-place" methodology, and are taken from supplement materials to the Geographic Plus inventory.
- Waste, wastewater treatment: Allocated to Sector 33, "Water, sewage treatment, and other utility services."
- Agriculture: Enteric emissions from livestock and manure management are allocated to Sectors 11-14; soil management is allocated to sectors 1-10.

Study Area direct coefficients:

[16] U.S. Energy Information Administration (2008), Table B18, Table A1, see "KC2008 CBEI Sources for Direct Coefficients.xlsx."

[17] Data obtained from EDGAR (SEC n.d.) and the "Bridge between NAICS and SIC" in the 1997 Economic Census (U.S. Census Bureau 1997).

$$\text{Dcoef\_SA} = \frac{\text{SA total production emissions}}{\text{GO\_SA}}$$

where GO_SA (defined below) is SA economic output by sector

Note that here, and throughout this methodology, calculations are for each of 440 sectors, unless otherwise noted. For simplicity sake, we omit the subscript indicating the sector number throughout.

U.S. Direct Coefficients

Data:

Emission of Greenhouse Gases in the United States 2008 (U.S. Energy Information Administration 2009)

Emission allocations:

- Transportation: Several data sources are used to allocate transportation emissions household, government, and commercial uses and relevant IMPLAN sectors; see "KC2008 Transportation Allocation.xlsx" for calculations and detailed methodology.
- Electricity: Allocated to Sector 31, "Electricity, and distribution services".
- Industry energy: Allocated to specific IMPLAN sectors in proportion to U.S. EIA 2001 data (Schipper 2006).

Industry non-energy: Allocated to specific sectors or groups of sectors based on U.S. EIA 2008 data (EIA 2009(EIA 2009 Table 15, "U.S. Carbon Dioxide Emissions from Other Sources, 1990-2008")(EIA 2009 Table 15, "U.S. Carbon Dioxide Emissions from Other Sources, 1990-2008"), and allocated to sectors within these groups in proportion to their gross output (GO_US).

- Commercial: Allocated to all commercial sectors (319-427) in proportion to their gross output (GO_SA).
- Other gases: Allocated to specific sectors or groups of sectors based on U.S. EIA 2008 data (EIA 2009) and allocated to sectors within these groups in proportion to their gross output (GO_US).

U.S. direct coefficients:

$$\text{Dcoef\_US} = \frac{\text{US total production emissions}}{\text{GO\_US}}$$

where GO_US (defined below) is U.S. economic output by sector

Foreign Direct+Indirect Coefficients

Data:

Multi-Regional Input-Output (MRIO) International Emissions Data 2004 (Peters 2010)

Direct+indirect coefficient calculations from CBEI direct coefficients:

DIcoef_CBEI_US U.S. direct+indirect coefficients (generated by CBEI model)

1. Transpose Dcoef_US from column to row vector.
2. $\text{DIcoef\_CBEI\_US\_Transpose} = \text{Dcoef\_US\_Transpose} \times \text{TypeI\_Matrix\_US}$
3. Transpose DIcoef_CBEI_US_Transpose from row to column vector.

Direct+indirect coefficients from Peters data:

DIcoef_IM_US U.S. "imports" direct+indirect coefficients (for foreign final and intermediate goods used in foreign final products imported to the United States)

DIcoef_GL_US U.S. "global" direct+indirect coefficients (for foreign intermediate goods used in U.S. final products)

U.S. Import Coefficients: DIcoef_IM_US

4. Calculate values using Peters international data set by sector (i):
   a. Emissions coefficient for final imports into the U.S. in i sectors:

   $$\text{PetersDIcoef\_Imports\_US} = \frac{(\text{US total emissions} - \text{US global emissions})}{(\text{US total output} - \text{US global output})}$$

   b. Value of final imports into the U.S. in i sectors:

   $$\text{PetersImports\_US} = \text{US total output} - \text{US global output}$$

5. Peters international GHG coefficient data (2001 dollars) in sectors (i) are converted to 2006 dollars using the U.S. CPI-U.
6. Each IMPLAN sector (j) is mapped to 1 to 3 Peters (2008 dollars) sectors (i). In some cases several GTAP sectors fall under a single IMPLAN sector, and vice versa. Groupings of GTAP sectors into IMPLAN sectors are unique such that 57 GTAP sectors (i) become 51 GTAP-sector groups (m):

   $$\text{i} = 57 \text{ GTAP sectors}$$

   $$\text{j} = 440 \text{ IMPLAN sectors}$$

   $$\text{k} = \text{1st/2nd/3rd GTAP sector per IMPLAN sector}$$

$\mathrm{i(j,k)}$ maps IMPLAN to GTAP

$\mathrm{m(j) = i(j,1)}$ - in practice, there are 51 unique values of m

n = a GTAP sector or group of 2 or 3 sectors, all mapped to the same IMPLAN sector (i.e., a value taken on by m(j))

7. $\mathrm{DIcoef\_IM\_US\_unweighted_j = \frac{\sum_k (PetersDIcoef\_Imports\_US_{i(j,k)} * PetersImports\_US_{i(j,k)})}{\sum_k PetersImports\_US_{i(j,k)}}}$

8. $\mathrm{US_{TCO_n} = \sum_j US_{TCO_j}}$, summed over all j for which $\mathrm{m(j) = n}$

9. $\mathrm{US\_TCOxDIcoef\_CBEI\_US_n = \sum_j (DIcoef\_CBEI\_US_j * US\_TCO_j)}$, summed over all j for which $m(j) = n$

10. $\mathrm{PetersWeight_j = \frac{US\_TCOxDIcoef\_CBEI\_US_{m(j)}}{US\_TCO_{m(j)}}}$

11. $\mathrm{DIcoef\_IM\_US_j = DIcoef\_IM\_US\_unweighted_j * \left(\frac{DIcoef\_CBEI\_US_j}{PetersWeight_j}\right)^{0.5}}$

U.S. Global Coefficients: DIcoef_GL_US

1. Calculate values using Peters international data set by sector (i):

   a. U.S. global emission coefficients (for U.S. final production including domestic and imported intermediate goods – direct+indirect):

   $$\mathrm{PetersDIcoef\_Global\_US = \frac{US\ global\ emissions}{US\ global\ output}}$$

   b. U.S. domestic-only emissions (for U.S. final production including only domestic intermediate goods – direct+indirect):

   $$\mathrm{PetersDIcoef\_DomesticOnly\_US = US\ domestic\ only}$$

   c. Ratio of Peters U.S. global to Peters U.S. domestic-only emissions:

   $$\mathrm{PetersCoefRatio = \frac{PetersDIcoef\_Global\_US}{PetersDIcoef\_DomesticOnly\_US}}$$

   d. Value of production in the U.S. by sector:

   $$\mathrm{PetersGlobal\_US = US\ global\ output}$$

2. Each IMPLAN sector (j) is mapped to 1 to 3 Peters (2006 dollars) sectors (i). In some cases several GTAP sectors fall under a single IMPLAN sector, and vice versa. Groupings of GTAP sectors into IMPLAN sectors are unique such that 57 GTAP sectors (i) become 51 GTAP-sector groups (m):

$$i = 57 \text{ GTAP sectors}$$

$$j = 509 \text{ IMPLAN sectors}$$

$$k = \text{1st/2nd/3rd GTAP sector per IMPLAN sector}$$

$i(j,k)$ maps IMPLAN to GTAP

3. $$\mathrm{CoefRatio}_j = \frac{\sum_k \left(\mathrm{PetersCoefRatio}_{i(j,k)} * \mathrm{PetersGlobal\_US}_{i(j,k)}\right)}{\sum_k \mathrm{PetersGlobal\_US}_{i(j,k)}}$$

4. $$\mathrm{DIcoef\_GL\_US}_j = \mathrm{CoefRatio}_j * \mathrm{DIcoef\_CBEI\_US}_j$$

3.2. Step 2: Intermediary Pre-Purchase Emissions by Emitting Sector

Final Demand

Final demand data are extracted from IMPLAN databases as "regional institutional demand"[18] for the Study Area and for the United States in producer prices and terms. IMPLAN reports final demand for four types of institutions responsible for expenditures: personal or household consumption; Study-Area-based federal government; state and local government entities; and business investment expenditures in capital formation and net inventory replacement (see Table 9). Final business investment demand does not include other business-to-business transactions. (Note that, as is standard in economic analysis, these data include the "service" provided by government salaries and benefits, and government purchases, but exclude transfer payments such as Social Security or unemployment compensation.[19])

King County's final demand in 2008 was 0.9 percent of total final demand in the United States:

[18] "Regional institutional demand" is IMPLAN's term for final demand for commodities by households and government, plus firms' investment in equipment or inventory.

[19] Government expenditures on employment (just like other pure-labor sectors such as household domestic work) have direct emissions coefficients of zero; labor by itself does not cause greenhouse gas emissions. Any emissions associated with government employees spending their salaries (as consumers) are accounted for as part of "household" final demand, so there is no double-counting of emissions.

Table 9: Final Demand for King County and United States, 2008 (millions $)

	Households	State and Local Government	Federal Government	Business Investment	Total
King County					
million $	$93,313	$11,699	$4,129	$40,458	$149,599
percent	62.4%	7.8%	2.8%	27.0%	100.0%
United States					
million $	$10,299,248	$2,147,637	$1,114,883	$2,377,205	$15,938,973
percent	64.6%	13.5%	7.0%	14.9%	100.0%

Source: IMPLAN 2008 data for King County (MIG 2010).

CBEI multiplies final demand by IMPLAN input-output matrices to calculate gross (or direct plus indirect) demand. Gross demand is calculated for the Study Area (including the Study Area's final and intermediate purchases of commodities produced in the Study Area); and Inside-US-Outside-SA (including the Study Area's final and intermediate purchase of commodities produced Inside-US-Outside-SA, and intermediate purchases used to produce final products consumed in King County produced Inside-US-Outside-SA). Gross demand for each location of production is then multiplied by the appropriate emissions coefficients (Study Area or U.S.). (Note that final and intermediate demand for foreign commodities – including King County's final and intermediate purchase of commodities produced in foreign countries – are calculated somewhat differently because of data constraints as described below.)

"Producer prices and terms" indicates that IMPLAN's reported final demand in a given commodity sector reflects payments to that commodity's production sector, not the retail price paid by the ultimate purchasers of the commodity. Few purchases are made directly from industrial sectors. Instead, finished products typically pass through several hands before reaching the customer, and a portion of each consumer dollar spent on any product is retained by wholesale, retail, and transportation firms. For example, for a $1 cookie purchase, 25 cents is estimated, on average, to be retained by the retailer, 9 cents is paid to the wholesaler, 3 cents goes to pre-purchase transportation, and 63 cents is paid to the manufacturer. The portions retained by businesses other than the producer are the margin or mark up.

CBEI does not include any calculation of final demand from margining activities that would associate a particular good's emissions with the share of each consumer dollar spent on retail, wholesale, and transportation of a good before purchase. Instead, CBEI takes the dollars spent by King County consumers on margining activities (retail, wholesale, and transportation) to be separate purchases of these services – the convention followed in IMPLAN demand data.

IMPLAN data (where xx is the data year):

SAxx_CD_10000 Study Area 20xx Commodity Demand by 10000 (Household) Institution

SAxx_CD_11000 Study Area 20xx Commodity Demand by 11000 (Federal Government) Institution

SAxx_CD_12000 Study Area 20xx Commodity Demand by 12000 (State and Local Government) Institution

SAxx_CD_14000 Study Area 20xx Commodity Demand by 14000 (Investment) Institution

SAxx_CD_IntmStudy Area 20xx Commodity Demand, Intermediate

SAxx_IM_10000 Study Area 20xx Imports by 10000 (Household) Institution

SAxx_IM_11000 Study Area 20xx Imports by 11000 (Federal Government) Institution

SAxx_IM_12000 Study Area 20xx Imports by 12000 (State and Local Government) Institution

SAxx_IM_14000 Study Area 20xx Imports by 14000 (Business Investment) Institution

SAxx_TCO Study Area 20xx Total Commodity Output

SAxx_EX_Frn Study Area 20xx Exports, Foreign

SAxx_EX_Dom Study Area 20xx Exports, Domestic

TypeI_Matrix_SA Study Area 20xx Type I Multiplier Matrix

USxx_CD_Inst United States 20xx Commodity Demand by All Institutions

USxx_CD_Intm United States 20xx Commodity Demand, Intermediate

USxx_IM_Inst United States 20xx Imports by All Institutions

USxx_IM_IntmUnited States 20xx Imports, Intermediate

USxx_TCO United States 20xx Total Commodity Output

TypeI_Matrix_US United States 20xx Type I Multiplier Matrix

Data year adjustment (where yy is year under study):

SAxx_GDP GDP for study area in IMPLAN data year xx (in xx year dollars)

SAyy_GDP GDP for study area in emissions data year yy (in xx year dollars)

USxx_GDP GDP for United States in IMPLAN data year xx (in xx year dollars)

USyy_GDP GDP for United States in emissions data year yy (in xx year dollars)

$$SAxxtoyy\_GDPratio = \frac{SAyy\_GDP}{SAxx\_GDP}$$

$$USxxtoyy\_GDPratio = \frac{USyy\_GDP}{USxx\_GDP}$$

If IMPLAN data year and emissions data year are the same, both ratios are set equal to 1. If IMPLAN data year and emissions data year differ, then all dollar-denominated data are multiplied by Study Area or U.S. ratios, as appropriate. After these ratios area applied, the variables are renamed removing “SAxx_” for study area variables and “xx” (but leaving “US_”) for U.S. variables.

Foreign import rate:

FIR_10000 =

…if CD_10000 = 0 or IM_10000 = 0, then 0

…otherwise (CD_10000 and IM_10000 not equal to 0):

Minimum of:

$$\frac{\mathrm{IM\_10000}}{\mathrm{CD\_10000}}$$

or

$$\frac{\mathrm{US\_IM\_INST}}{\mathrm{US\_CD\_INST}}$$

Identical calculations for 10000, 11000, 12000, 14000

Final demand by production geography:

Study Area Final Demand for Study Area products:

$$FD\_10000\_SA = CD\_10000 - IM\_10000$$

Study Area Final Demand for U.S. products:

$$FD\_10000\_US = CD\_10000 \times (1 - FIR\_10000)$$

Study Area Final Demand for foreign products:

$$FD\_10000\_FR = CD\_10000 \times FIR\_10000$$

Identical calculations for all institutions: 10000, 11000, 12000, 14000

Gross demand by production geography:

Study Area Gross Demand for Study Area final products and Study Area intermediate production used in Study Area final production:

$$GD\_10000\_SA = TypeI\_Matrix\_SA \times FD\_10000\_SA$$

Study Area Gross Demand for Inside-US-Outside-SA final products and Inside-US-Outside-SA intermediate goods used in final products purchased in Study Area:

$$GD\_10000\_UX = GD\_10000\_US - GD\_10000\_SA$$

Note: GD_10000_UX is restricted to non-negative numbers.

where:

Study Area Gross Demand for U.S. final products and U.S. intermediate goods used in final products purchased in Study Area:

$$GD\_10000\_US = TypeI\_Matrix\_US \times FD\_10000\_US$$

Note: GD_10000_US is restricted to be equal to or greater than $\mathrm{FD\_10000\_US}$.

Identical calculations and restrictions for 10000, 11000, 12000, 14000

Total Gross Output (an input to direct coefficient development):

$$GO\_SA = SA\_TCO$$

$$GO\_US = US\_TCO$$

Greenhouse Gas Emissions

Greenhouse gas emissions are reported in CBEI in thousands of metric tons of CO_2-e and are calculated as follows (see Figure 7):

- Emissions from Study Area consumption of Study-Area-made final commodities are the product of the Study Area's in-area gross demand and the Study Area direct coefficients for each of the 440 IMPLAN sectors.
- All other emissions from the Study Area's consumption of U.S.-made final commodities (including Inside-US-Outside-SA indirect emissions from the Study Area's consumption of U.S.-made final commodities) are the product of the Study Area's U.S. gross demand and the U.S. direct coefficients less the product of the Study Area's in-area gross demand and the Study Area direct coefficients.
- Foreign emissions results from the Study Area's consumption of final products are calculated in two pieces:

- The Study Area's final demand for foreign-made goods is multiplied by the MRIO direct+indirect coefficients for "U.S. imports."
- Emissions from the production of foreign-made intermediate goods used in the Study Area and Inside-US-Outside-SA production for the Study Area's final consumption are the product of the Study Area's U.S. final demand and the "U.S. global" direct+indirect coefficients less CBEI's U.S. direct+indirect coefficients.

Figure 7: CBEI Emission Calculation Schematic

<table>
<tr><th>Final production locale:</th><th rowspan="2">Study Area (SA)</th><th rowspan="2">Inside-US-Outside-SA (UX)</th><th rowspan="2">Foreign (FR)</th></tr>
<tr><th>Stage of production by locale:</th></tr>
<tr><td>Final Production</td><td colspan="2" rowspan="3">SA direct+indirect demand * SA direct coefficient + UX direct+indirect demand + US coefficient</td><td rowspan="4">FR1 = FR direct demand * "Import" direct+indirect coefficient</td></tr>
<tr><td>Intermediate production: SA (used in final production by column)</td></tr>
<tr><td>Intermediate production: UX (used in final production by column)</td></tr>
<tr><td>Intermediate production: FR (used in final production by column)</td><td colspan="2">FR2 = US direct demand * "Global - US" direct+indirect coefficient</td></tr>
</table>

Note: FR = FR1 + FR2

Source: CBEI Version 2.0 (Stanton et al. 2011).

Emissions coefficients:

- SA production of final and intermediate goods (direct)
- U.S. production of final and intermediate goods (direct)
- "U.S. Imports": FR production of final goods sold to United States (direct+indirect)
- "U.S. Global": FR production of intermediate goods sold to United States (direct+indirect)
- U.S. production of final and intermediate goods (direct+indirect)

Two ways to calculate emissions (depending on emissions coefficient data availability):

Emissions = Direct demand * direct+indirect coefficient

where, Direct coefficient * I/O matrix = direct+indirect coefficient

Emissions = Direct+indirect demand * direct coefficient

where, I/O matrix * Direct demand = direct+indirect (gross) demand

Emissions calculations:

Emissions released in the Study Area from Study Area consumption:

$$EM\_10000\_SA = GD\_10000\_SA \times Dcoef\_SA$$

Emissions released Inside-US-Outside-SA from Study Area consumption:

$$EM\_10000\_UX = GD\_10000\_UX \times Dcoef\_US$$

Emissions released outside of the United States from Study Area consumption:

$$EM\_10000\_FR = (FD\_10000\_FR \times DIcoef\_IM\_US) +$$

$$(FD\_10000\_US \times (DIcoef\_GL\_US - DIcoef\_CBEI\_US))$$

Identical calculations for 10000, 11000, 12000, 14000

Pre-purchase emissions correction:

For transparency in presentation, the 14000 emissions results for sectors 37 and 38 (residential construction and remodeling) are added to the 10000 results for sectors 37 and 38. This change is made for all locations of emission (SA, UX, and FR) and all phases. That is, all emissions related to residential construction that would otherwise be classified as business investment consumption (a convention in economics) are instead classified as household consumption.

Greenhouse Gas Emissions by Phase

Designating emission phases:

- Each sector's emissions belong to one and only one life-cycle phase.
- Unless otherwise specified, all sectors' emissions belong to the "production" phase.
- The following sectors' emissions belong to the "pre-purchase transportation" phase:
    - 332-338 transportation sectors
- The following sectors' emissions belong to the "wholesale+retail" phase:
    - 319 wholesale trade
    - 320-331 retail sectors

EM_10000_SA_Prd Household, study-area, production-phase emissions

EM_10000_SA_Trn Household, study-area, pre-purchase-transportation-phase emissions

EM_10000_SA_WhR Household, study-area, wholesale-retail-phase emissions

Identical calculations for 10000, 11000, 12000, 14000 and SA, UX, FR

3.3. Step 3: Reorganizing Results From Emitting Sector To Consuming Sector

To reclassify pre-purchase emissions from their emitting sectors to their consuming sectors, CBEI is run in its “Life-Cycle-Analysis” mode:

- Standard CBEI results are the pre-purchase consumption-based emissions of the Study Area as a whole.
- To calculate the pre-purchase emissions for each sector of final demand separately requires re-running CBEI 440 times using the appropriately circumscribed demand vector (i.e., demand for each sector is run separately).
- Study Area consumption-based emissions are reorganized on this principle by running CBEI for each of the Study Area’s 440 sectors of demand individually and recording the total emissions generated by that run as that sector’s emissions.
- This method results in the same total CBEI emissions for the SA as a normal run, but a different distribution of emissions across sectors.

3.4. Step 4: Final Results, Adding Use and Disposal Emissions

Final CBEI results add use and post-consumer disposal emissions to the pre-purchase emissions, organized by consuming sector, and adjust for double counting.

Use and Disposal results:

- Use and post-consumer disposal phase emissions (and, therefore, final CBEI results) are calculated at the sub-category level and cannot be presented by sector.
- Use and disposal emissions (and final results) are reported for three institutions only: households, and a combined “government” institution (local and state government plus federal government), and investment.

EM_10000_SA_Use Household, study-area, use-phase emissions

EM_10000_SA_Dsp Household, study-area, post-consumer disposal-phase emissions

EM_11000+12000_SA_Use Government, study-area, use-phase emissions

EM_11000+12000_SA_Dsp Government, study-area, post-consumer disposal-phase emissions

Use Phase

The use life-cycle phase includes all post-purchase emissions, with the exception of disposal emissions. Specifically, the use phase consists of emissions from direct fuel use by households and government (for heating or other appliances), household and government transportation from the Geographic Plus inventory, households and governments direct electricity emissions from the Geographic Plus inventory, and the indirect emissions for household and government fuel and electricity purchases as calculated in the pre-purchase model. Indirect emissions in the use phase are sector-specific the ratio of indirect to direct emissions from the pre-purchase results multiplied by the end-use emissions from the Geographic Plus inventory.

Use phase calculations disaggregate fuel and electricity emissions into the categories and sub-categories of commodities that utilize fuel and electricity – cars, furnaces, appliances, electronics, lighting, etc. (Double-counting is corrected by subtracting from the pre-purchase results the indirect fuel and direct+indirect electricity emissions included in the use phase, as described below.) For calculations, see KC2008 Use and Disposal.xlsx; for data sources see KC08-00-1_MasterSpreadsheet_123010 CBEI Mapping.xlsx and KC2008 Use and Disposal Sources.xlsx.

Post-Consumer Disposal Phase

The post-consumer disposal life-cycle phase consists of emissions from post-consumer waste in landfills and waste combustion.[20] Emissions from household and government purchase of waste disposal services are calculated in supplemental materials to the King County 2008 Geographic Plus inventory (SEI 2010) and disaggregated into the categories and sub-categories of commodities that become waste products. (Double-counting is corrected as described below.) For calculations see KC2008 Use and Disposal.xlsx; for data sources see KC08-00-1_MasterSpreadsheet_123010 CBEI Mapping.xlsx and KC2008 Use and Disposal Sources.xlsx.

Final Consumption-Based Emissions Results

Final consumption emissions for the production, pre-purchase transportation, and wholesale+retail phases are the pre-purchase emissions by consuming sector for these phases, summed across sub-categories (i.e., there are no sector results) and summed across the 11000 and 12000 institutions (for a single "government consumer"), with a few adjustments (below), and renamed as, for example, 5P_EM_10000_SA_Prd (where 5P refers to "five-phase" results).

There is some double counting between the pre-purchase model and the use and post-consumer disposal phases. In order to correct for this double counting it is necessary to zero

[20] Landfill emissions here are calculated on the basis of future lifetime emissions from each year's disposal (sometimes called "methane commitment"). An alternative method, "waste in place," estimates each year's actual emissions from past and present disposal; the existing King County 2008 Geographic Plus inventory (SEI 2010) uses the latter method.

out the following emissions in the five-phase results from the production, pre-purchase transportation, and wholesale/retail phases:

5P_EM_10000, sub-category "Gasoline, heating fuels, other petroleum"

5P_EM_11000+12000, sub-category "Gasoline, heating fuels, other petroleum"

5P_EM_10000, sub-category "Natural gas distribution"

5P_EM_11000+12000, sub-category "Natural gas distribution"

5P_EM_10000, sub-category "Power generation and supply"

5P_EM_11000+12000, sub-category "Power generation and supply"

5P_EM_10000_SA, sub-category "Waste management"

5P_EM_11000+12000_SA, sub-category "Waste management"

3.5. CBEI Demand Modeler

CBEI "Demand Modeler" is a separate tool used to calculate emissions for a user-determined subset of Study Area final demand (that is, dollar values of King County demand defined by economic sector and by type of consumer – households, federal government, local and state government, and investment). The "Modeler" can be used to view the consumption-based emissions of the demand for a single IMPLAN category, subcategory or sector, where emission results are disaggregated by emitting industry, type of consumer, life-cycle phase, and location of emission. Emission results for a single sector of demand can be viewed in the intermediary CBEI pre-purchase results by consuming sector emissions, but to see emissions by contributing emitting sectors or to do analysis based on custom demand profiles, it is necessary to do a sector-specific analysis using the Modeler.

This method can be used to determine the (emitting) sector-by-sector emissions associated with that actual or speculative demand for a single commodity sector. For example, if the user enters a demand profile representing King County's consumption of cheese, the CBEI "Modeler" would return sector-by-sector emissions from all of the direct and upstream purchases associated with King County's consumption of cheese.

3.6. CBEI in Access and Excel

System Overview

The controller program for the CBEI system, written in Microsoft Access, is *CBEI.accdb*.

The main back-end database files for the system are in *CBEI_Data.accdb*, another Access database file.

Accessory functions are provided in other Access databases, including:

- *CBEI_Mapping_Data.accdb*
- *CBEI_Foreign_yyyy.accdb*
- *CBEI_SA_Direct_Coefficients_yyyy.accdb*
- *CBEI_US_Direct_Coefficients_yyyy.accdb*

Accessory functions are provided, as well, by the following Excel workbook, which receives intermediate results from queries made available in CBEI_Data.accdb:

- *SAyyyy CBEI Use and Disposal.xlsx*

Output from the system is provided by a series of queries made available in *CBEI_Data.accdb* and which feed into the following Excel workbooks:

- *SAyyyy CBEI Results.xlsx*
- *SAyyyy CBEI Modeler Results.xlsx*

System Structure

The components of the system listed above must reside in the same subdirectory for the system to operate correctly.

A subdirectory of this directory, named *CBEI UserReports*, must be present as well. It serves as a repository for snapshots of the Excel browser files which receive their data from the queries in *CBEI_Data.accdb*.

Parameterization

System parameters are maintained in Table: *tblParam* (in *CBEI.accdb*), in order to make the system as flexible as possible.

System Linkage

In order for the system to work correctly, it must have its various components relinked whenever the system is installed, moved or copied. This process is invoked by the first button on the *Main Menu* in the controller program, labeled *Refresh Data Connections*. The macro invoked by this button is *Init_Relink,* which performs the following sequence of actions*:*

- Relinking all Access databases
    - *m_Initialize_RelinkAllDBsToLocalDirectory:* Relinks all tables in all Access databases in the system to the set of files in the current system directory, i.e. the same directory in which CBEI.accdb resides.
- Resetting data connections in all Excel workbooks in the system to Access queries in current system directory
    - *XL_ResetDataConnectionToAccess:* This function resets the target of Access Data Connections within Excel workbooks to the relevant Access database in the current system directory, and does this, in Macro: Init_Relink, for the following:
        - The Use and Disposal workbook, designated above as SAyyyy CBEI Use and Disposal.xls, (and, more specifically, in the parameter table)
    - *m_XLBrowser_ResetConnections:* This macro resets all the data connections from the Complete Emissions Browser (in Excel) to their sources in CBEI_Data.accdb (Access)
    - *m_XLBrowser_ResetConnections:* This macro resets all the data connections from the Complete Emissions Browser (in Excel) to their source in CBEI_Data.accdb (Access)
    - *m_XLModelerBrowser_ResetConnections:* This macro resets all the data connections from the Demand Modeler Browser (in Excel) to their sources in CBEI_Data.accdb (Access)

Enabling Macros

If the directory, or directory tree, within which the system resides is not designated as a Secure Location (via the Trust Center in Access), it will be necessary to enable macros manually each time one starts the system. If this is the case, the system will prompt the user to press, at startup, the required button to enable macros. This is necessary to do for proper functioning of the CBEI system.

Startup

At startup, once macros have been enabled, the rest of Macro: *autoexec* runs and it displays the Main Menu (Form: *frmMainMenu*).

Main Menu

The form, *frmMainMenu*, is the hub of the user-interface for the system.

Button: "Perform Emissions Calculations" invokes Form: *frmEmissionsCalculations*, which provides methods for performing the main calculation streams.

Emissions Processing

The system does Emissions Processing in two basic modes:

- Complete Emissions Processing
- Demand Modeler Processing

In order for each of these to take place, two preliminary operations are performed, invoked when the *Perform Emissions Calculations* button on the *Main Menu* is pressed and before the *Emissions Processing Menu* is displayed:

- Initialization of Matrix Arrays
- Standard Emissions Processing

Initialization of Matrix Arrays

Two large matrices are used repeatedly in calculations and are loaded preliminarily into memory from their static storage in Access tables in order to optimize processing time.

Macro: *m_Initialize_Matrix_Arrays* carries out this process and does it in three steps:

- Function: *initializeMatrixArrays*
    - Creates the variable *numSectors* from the *NumberOfSectors* value in the parameter table

- Dimensions the array *Type_I_SAxx_Matrix* to *numSectors* x *numSectors*
- Dimensions the array *Type_I_USxx_Matrix* to *numSectors* x *numSectors*

- Function: *initialize_Matrix* loads Table: *tbl_Type_I_SAxx*, which stores the Study Area matrix, into the memory array named *Type_I_SAxx_Matrix*
- Function: *initialize_Matrix* loads Table: *tbl_Type_I_USxx*, which stores the US matrix, into the memory array named *Type_I_USxx_Matrix*

Standard Emissions Processing: Overview

Standard Emissions Processing performs several calculations that are required for Complete Emissions and Demand Modeler processing. Notably, these are:

- Setting up the phase tables
- Calculating the GDP ratios which are multiplicative factors used to calculate demand values for an Emissions Study year which may be different from an EmissionsData year
- Calculating values for and storing them in Table: *tblIMPLAN_Adjusted*, which represents the values stored in Table: *tblIMPLAN_Raw* multiplied times the GDP ratios.
- Calculating and storing the values for emissions Coefficients in Table: *tblCoefficients_Standard*.

As well, Standard Emissions Processing produces results in Table: *tblFinalDemand_Standard* and Table: *tblEmissions_Standard*, which represent aggregate calculations based on the input data.

Standard Emissions Processing: Details

Main driver: Macro *m_AllCalculatedResults_Standard_Update.* This routine calls all the necessary steps in sequence:

- Macro *m_tblPhase_*_Update* sets up the phase tables, which contain lists of sectors corresponding to each of the three phases that form part of standard processing.
- Macro *m_tblCBEIParam_Calc_Update* initializes various system variables, notably the GDP ratio between the study year and the data year.

- Macro *m_tblIMPLAN_Adjusted_Standard_Update* creates, from the raw IMPLAN data, a secondary "adjusted" table which represents a calculation based on the GDP ratios.

- Macro *m_tblFinalDemand_Standard_Update* is the first major piece of Standard processing, and the one that takes the longest time to execute. It involves loading tblFinalDemand_Standard, which is derived from a series of calculations which load the work table, tblFinalDemand. Multiple of the resultant vectors in tblFinalDemand are generated by a matrix multiplication that loads Leontieff matrices, stored in the tables *tbl_Type_I_SAxx* and *tbl_Type_I_USxx*, and derives a product from them and a series of demand vectors stored in tblFinalDemand. That series of calculations is executed by the Macro *m_tblFinalDemand_Update*, which, as an example calls Macro *m_tblFinalDemand_GD_10000_SA_Update* which performs the species of matrix multiplication in question by invoking the VBA function *arrayMMult_Store,* which one can find in Module: *Main*.

- Macro *m_tblCoefficients_Update* updates tblCoefficients, through a series of subsidiary macros and queries, and, to this end, uses vectors derived from CBEI_SA_Direct_Coefficients_2008.accdb and CBEI_US_Direct_Coefficients_2008.accdb. To retrieve those vectors – delivered as queries from those databases, this macro makes use of a series of routines, evident, for example, in Macro *m_tblCoefficients_Dcoef_SA_Update,* which constructs a query to the relevant target database depending on the current path of the system. (See, for example, the function, also in Module: *Main*, *qryCoefficients_Dcoef_SA_Construct)* which creates the appropriate query code for this retrieval function and uses it, in the context of the macro, to load a vector array in tblCoefficients, which is then used in subsequent calculations.

- Macro *m_tblEmissions_Standard_Update* calls Macro *m_tblEmissions_Update* and performs the final calculations of the first three phases of emissions based on the results thus far calculated and stored in *tblFinalDemand* and *tblCoefficients*. These results are stored in the work table *tblEmssions*, and finally stored in *tblEmissions_Standard*.

Complete Emissions Processing

Complete Emissions Processing involves a similar set of routines to Standard Processing, with the following exceptions:

- Calculations for each sector of *tblEmissions_LCA_Complete* (which is the final result of the process) is derived by isolating each row of the original IMPLAN data (found in *tblIMPLAN_Adjusted*) and running , iteratively, the entire series of calculations for tblFinalDemand and tblEmissions.

This process is driven by the Macro *m_tblEmissions_LCA_Complete_Update* , which invokes the VBA function *LCAComplete_CalcAndStore_AllSector)* (in Module: *Main*) which, in turn, commands the process which isolates each row of *tblIMPLAN_Adjusted* and stores the final results, ultimately, in *tblEmissions_LCA_Complete.*

The Complete Emissions Process is very execution intensive (running a sequence of about a million different calculations) and are best run on a local (not a networked) directory on a fast machine.

- The last two phases, for emissions related to use and disposal, are calculated as follows. Macro *m_tblUseAndDisposal_Update* creates vectors that go into tblUseAndDisposal, and which are retrieved by the Excel program *CBEI Use and Disposal.xlsx.*
- In order that the Excel program is updated with the values from Access, Macro: *m_tblUseAndDisposal_Update* then executes a VBA function (found in Module: *Main*) *XL_RefreshLocalWorkbook* which does this through an automation interface between Access and Excel.
- Macro: *m_tblEmissions_5Phase_Update* performs a series of routines that use results derived from the calculations in the Excel workbook in combination with subtotals (corresponding to sector subcategories) to produce the results for the use and disposal phases, which are stored in the table *tblEmissions_5Phase*. A routine which tailors specialized instances, Macro: *m_tblEmissions_5Phase_Tailor* ,is run subsequently to modify the results in *tblEmissions_5Phase*.
- Output to the Excel reporting module is summarized through a series of queries, among them *qry__OUTPUT_Emissions_3Phase_Standard* and *qry__OUTPUT_Emissions_5Phase_Standard.*

Demand Modeler

The Demand Modeler process is very similar to the Complete Emissions process, with the provision for enabling the user to fill in sample data for final demand. That process of filling in can be done through the form *frmLCAModeler* which calls the form *frmLCAModeler_Input*.

Macro *m_tblEmissions_LCA_Modeler_Update* is the main routine for the Demand Modeler. It runs through a very similar set of steps to the routine which runs the Complete Emissions process, except that, instead of running the processes based on each line of the *tblIMPLAN_Adjusted*, it uses instead, each line of the final demand data input by the user, in *tblDemand_LCAModeler*. The main macro calls a VBA function, *LCAModeler_CalcAndStore_AllSector)* which, akin to the version for the Complete Emissions process, runs through the full calculation process iteratively. Results are stored in *tblEmissions_LCAModeler*.

Modeler results are transmitted to the Excel reporting interface through the queries qry__*OUTPUT_Emissions_3Phase_LCA_Complete* and *qry__OUTPUT_Emissions_3Phase_LCA_Modeler.*

Again, the Demand Modeler processes do not generate 5-phase output.

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Appendix: CBEI Sectors, Sub-Categories, and Categories

Category	Subcategory	#	Sector Name
Appliances, HVAC	Heating and cooling appliances	215	Heating equipment (except warm air furnaces)
Appliances, HVAC	Heating and cooling appliances	216	Air conditioning, refrigeration, and warm air heating equipment
Appliances, other	Lighting fixtures and bulbs	259	Electric lamp bulbs and parts
Appliances, other	Lighting fixtures and bulbs	260	Lighting fixtures
Appliances, other	Ranges and microwaves	262	Household cooking appliances
Appliances, other	Refrigerators and freezers	263	Household refrigerators and home freezers
Appliances, other	Washers and dryers	264	Household laundry equipment
Appliances, other	Other appliances	261	Small electrical appliances
Appliances, other	Other appliances	265	Other major household appliances
Clothing	Clothing	86	Knit apparel
Clothing	Clothing	87	Cut and sewn apparel from contractors
Clothing	Clothing	88	Mens and boys cut and sewn apparel
Clothing	Clothing	89	Womens and girls cut and sewn apparel
Clothing	Clothing	90	Other cut and sew apparel
Clothing	Clothing	91	Apparel accessories and other apparel
Clothing	Clothing	93	Footwear
Concrete, cement and lime	Concrete, cement and lime	160	Cement
Concrete, cement and lime	Concrete, cement and lime	161	Ready-mix concrete
Concrete, cement and lime	Concrete, cement and lime	162	Concrete pipes, bricks, and blocks
Concrete, cement and lime	Concrete, cement and lime	163	Other concrete products
Concrete, cement and lime	Concrete, cement and lime	164	Lime and gypsum products
Construction	Non-residential construction	34	Newly constructed nonresidential commercial and health care structures
Construction	Non-residential construction	35	Newly constructed nonresidential manufacturing structures
Construction	Non-residential construction	36	Other newly constructed nonresidential structures
Construction	Non-residential construction	39	Maintained and repaired nonresidential structures
Construction	Prefabricated buildings	101	Manufactured homes (mobile homes)
Construction	Prefabricated buildings	102	Prefabricated wood buildings
Construction	Prefabricated buildings	186	Plates and fabricated structural products
Construction	Residential construction and remodeling	37	Newly constructed residential permanent site single- and multi-family structures
Construction	Residential construction and remodeling	38	Other newly constructed residential structures
Construction	Residential construction and remodeling	40	Maintained and repaired residential structures
Electronics	Computer service and equipment	234	Electronic computers
Electronics	Computer service and equipment	235	Computer storage devices
Electronics	Computer service and equipment	236	Computer terminals and other computer peripheral equipment
Electronics	Computer service and equipment	257	Software, blank audio and video media, mass reproduction
Electronics	Computer service and equipment	352	Data processing- hosting- ISP- web search portals
Electronics	Computer service and equipment	371	Custom computer programming services
Electronics	Computer service and equipment	372	Computer systems design services
Electronics	Computer service and equipment	373	Other computer related services, including facilities management
Electronics	Other electronics	212	Photographic and photocopying equipment
Electronics	Other electronics	237	Telephone apparatus
Electronics	Other electronics	238	Broadcast and wireless communications equipment
Electronics	Other electronics	239	Other communications equipment
Electronics	Other electronics	240	Audio and video equipment
Food and beverages	Beverages	66	Coffee and tea
Food and beverages	Beverages	70	Soft drinks and manufactured ice
Food and beverages	Beverages	71	Beer, ale, malt liquor and nonalcoholic beer
Food and beverages	Beverages	72	Wine and brandies
Food and beverages	Beverages	73	Distilled liquors except brandies
Food and beverages	Condiments, oils and sweeteners	1	Oilseeds
Food and beverages	Condiments, oils and sweeteners	44	Corn sweeteners, corn oils, and corn starches
Food and beverages	Condiments, oils and sweeteners	45	Soybean oil and cakes and other oilseed products
Food and beverages	Condiments, oils and sweeteners	46	Shortening and margarine and other fats and oils products

Category	Subcategory	#	Sector Name
Food and beverages	Condiments, oils and sweeteners	48	Raw and refined sugar from sugar cane
Food and beverages	Condiments, oils and sweeteners	49	Refined sugar from sugar beets
Food and beverages	Condiments, oils and sweeteners	67	Flavoring syrups and concentrates
Food and beverages	Condiments, oils and sweeteners	68	Seasonings and dressings
Food and beverages	Dairy	12	Dairy cattle and milk products
Food and beverages	Dairy	55	Fluid milk and butter
Food and beverages	Dairy	56	Cheese
Food and beverages	Dairy	57	Dry, condensed, and evaporated dairy products
Food and beverages	Dairy	58	Ice cream and frozen desserts
Food and beverages	Fresh fruit, nuts and vegetables	3	Vegetables and melons
Food and beverages	Fresh fruit, nuts and vegetables	4	Fruit
Food and beverages	Fresh fruit, nuts and vegetables	5	Tree nuts
Food and beverages	Frozen food	53	Frozen foods
Food and beverages	Grains, baked goods, cereals, roasted nuts, nut butters	2	Grains
Food and beverages	Grains, baked goods, cereals, roasted nuts, nut butters	43	Flour and malt
Food and beverages	Grains, baked goods, cereals, roasted nuts, nut butters	47	Breakfast cereal products
Food and beverages	Grains, baked goods, cereals, roasted nuts, nut butters	51	Chocolate confectioneries from purchased chocolate
Food and beverages	Grains, baked goods, cereals, roasted nuts, nut butters	52	Nonchocolate confectioneries
Food and beverages	Grains, baked goods, cereals, roasted nuts, nut butters	62	Bread and bakery products
Food and beverages	Grains, baked goods, cereals, roasted nuts, nut butters	63	Cookies, crackers, and pasta
Food and beverages	Grains, baked goods, cereals, roasted nuts, nut butters	64	Tortillas
Food and beverages	Grains, baked goods, cereals, roasted nuts, nut butters	65	Snack foods including nuts, seeds and grains, and chips
Food and beverages	Poultry and eggs	13	Poultry and egg products
Food and beverages	Poultry and eggs	60	Processed poultry meat products
Food and beverages	Processed fruit, nuts and vegetables	54	Canned, pickled and dried fruits and vegetables
Food and beverages	Red meat	11	Cattle from ranches and farms
Food and beverages	Red meat	59	Processed animal (except poultry) meat and rendered byproducts
Food and beverages	Restaurants	413	Restaurant, bar, and drinking place services
Food and beverages	Seafood	17	Fish
Food and beverages	Seafood	61	Seafood products
Food and beverages	Other food and agriculture	7	Tobacco
Food and beverages	Other food and agriculture	8	Cotton
Food and beverages	Other food and agriculture	9	Sugarcane and sugar beets
Food and beverages	Other food and agriculture	10	All other crop farming products
Food and beverages	Other food and agriculture	14	Animal products, except cattle, poultry and eggs
Food and beverages	Other food and agriculture	18	Wild game products, pelts, and furs
Food and beverages	Other food and agriculture	19	Agriculture and forestry support services
Food and beverages	Other food and agriculture	41	Dog and cat food
Food and beverages	Other food and agriculture	42	Other animal food
Food and beverages	Other food and agriculture	50	Chocolate cacao products and chocolate confectioneries
Food and beverages	Other food and agriculture	69	All other manufactured food products
Food and beverages	Other food and agriculture	74	Cigarettes, cigars, smoking and chewing tobacco, and reconstituted tobacco
Forest products	Paper and cardboard	105	Paper from pulp
Forest products	Paper and cardboard	106	Paperboard from pulp
Forest products	Paper and cardboard	107	Paperboard containers
Forest products	Paper and cardboard	108	Coated and laminated paper, packaging paper and plastics film
Forest products	Paper and cardboard	109	All other paper bag and coated and treated paper

Category	Subcategory	#	Sector Name
Forest products	Paper and cardboard	110	Paper and paperboard stationary products
Forest products	Paper and cardboard	112	All other converted paper products
Forest products	Other processed forest products	97	Engineered wood members and trusses
Forest products	Other processed forest products	98	Reconstituted wood products
Forest products	Other processed forest products	99	Wood windows and doors and millwork
Forest products	Other processed forest products	100	Wood containers and pallets
Forest products	Other processed forest products	103	All other miscellaneous wood products
Forest products	Other processed forest products	104	Wood pulp
Forest products	Unprocessed forest products	15	Forest, timber, and forest nursery products
Forest products	Unprocessed forest products	16	Logs and roundwood
Forest products	Unprocessed forest products	95	Dimension lumber and preserved wood products
Forest products	Unprocessed forest products	96	Veneer and plywood
Fuel, utilities, waste	Gasoline, heating fuels, other petroleum products	115	Refined petroleum products
Fuel, utilities, waste	Natural gas distribution	32	Natural gas, and distribution services
Fuel, utilities, waste	Oil and gas extraction	20	Oil and natural gas
Fuel, utilities, waste	Oil and gas extraction	28	Oil and gas wells
Fuel, utilities, waste	Oil and gas extraction	29	Support services for oil and gas operations
Fuel, utilities, waste	Oil and gas extraction	119	All other petroleum and coal products
Fuel, utilities, waste	Oil and gas extraction	120	Petrochemicals
Fuel, utilities, waste	Oil and gas extraction	121	Industrial gas
Fuel, utilities, waste	Power generation and supply	31	Electricity, and distribution services
Fuel, utilities, waste	Waste management	390	Waste management and remediation services
Fuel, utilities, waste	Water- sewage and other systems	33	Water, sewage treatment, and other utility services
Healthcare	Healthcare services	394	Offices of physicians, dentists, and other health practitioners
Healthcare	Healthcare services	395	Home health care services
Healthcare	Healthcare services	396	Medical and diagnostic labs and outpatient and other ambulatory care services
Healthcare	Healthcare services	397	Private hospital services
Healthcare	Healthcare services	398	Nursing and residential care services
Healthcare	Medicines and other healthcare supplies	132	Medicines and botanicals
Healthcare	Medicines and other healthcare supplies	133	Pharmaceutical preparations
Healthcare	Medicines and other healthcare supplies	134	In-vitro diagnostic substances
Healthcare	Medicines and other healthcare supplies	135	Biological products (except diagnostic)
Healthcare	Medicines and other healthcare supplies	305	Surgical and medical instrument, laboratory and medical instruments
Healthcare	Medicines and other healthcare supplies	306	Surgical appliances and supplies
Healthcare	Medicines and other healthcare supplies	307	Dental equipment and supplies
Healthcare	Medicines and other healthcare supplies	308	Ophthalmic goods
Healthcare	Medicines and other healthcare supplies	309	Dental laboratories
Home, yard, office	Home furnishings	82	Carpets and rugs
Home, yard, office	Home furnishings	83	Curtains and linens
Home, yard, office	Home furnishings	295	Wood kitchen cabinets and countertops
Home, yard, office	Home furnishings	296	Upholstered household furniture
Home, yard, office	Home furnishings	297	Nonupholstered wood household furniture
Home, yard, office	Home furnishings	298	Metal and other household furniture
Home, yard, office	Home furnishings	303	Mattresses
Home, yard, office	Home furnishings	304	Blinds and shades
Home, yard, office	Household supplies	111	Sanitary paper products
Home, yard, office	Household supplies	138	Soaps and cleaning compounds

Category	Subcategory	#	Sector Name
Home, yard, office	Household supplies	139	Toilet preparations
Home, yard, office	Household supplies	142	Plastics packaging materials and unlaminated films and sheets
Home, yard, office	Household supplies	153	Pottery, ceramics, and plumbing fixtures
Home, yard, office	Household supplies	156	Flat glass
Home, yard, office	Household supplies	157	Other pressed and blown glass and glassware
Home, yard, office	Household supplies	159	Glass products made of purchased glass
Home, yard, office	Household supplies	184	Cutlery, utensils, pots, and pans
Home, yard, office	Household supplies	270	Storage batteries
Home, yard, office	Household supplies	271	Primary batteries
Home, yard, office	Household supplies	310	Jewelry and silverware
Home, yard, office	Household supplies	318	Brooms, brushes, and mops
Home, yard, office	Lawn and garden	6	Greenhouse, nursery, and floriculture products
Home, yard, office	Lawn and garden	130	Fertilizer
Home, yard, office	Lawn and garden	131	Pesticides and other agricultural chemicals
Home, yard, office	Lawn and garden	204	Lawn and garden equipment
Home, yard, office	Media and office supplies (except paper)	313	Office supplies (except paper)
Home, yard, office	Media and office supplies (except paper)	341	Newspapers
Home, yard, office	Media and office supplies (except paper)	342	Periodicals
Home, yard, office	Media and office supplies (except paper)	343	Books
Home, yard, office	Media and office supplies (except paper)	344	Directories and mailing lists
Home, yard, office	Media and office supplies (except paper)	345	Software
Home, yard, office	Media and office supplies (except paper)	346	Motion pictures and videos
Home, yard, office	Media and office supplies (except paper)	347	Sound recordings
Retailer and wholesale	Retailers	320	Retail Services - Motor vehicle and parts
Retailer and wholesale	Retailers	321	Retail Services - Furniture and home furnishings
Retailer and wholesale	Retailers	322	Retail Services - Electronics and appliances
Retailer and wholesale	Retailers	323	Retail Services - Building material and garden supply
Retailer and wholesale	Retailers	324	Retail Services - Food and beverage
Retailer and wholesale	Retailers	325	Retail Services - Health and personal care
Retailer and wholesale	Retailers	326	Retail Services - Gasoline stations
Retailer and wholesale	Retailers	327	Retail Services - Clothing and clothing accessories
Retailer and wholesale	Retailers	328	Retail Services - Sporting goods, hobby, book and music
Retailer and wholesale	Retailers	329	Retail Services - General merchandise
Retailer and wholesale	Retailers	330	Retail Services - Miscellaneous
Retailer and wholesale	Retailers	331	Retail Services - Nonstore, direct and electronic sales
Retailer and wholesale	Wholesale	319	Wholesale trade distribution services
Services	Banks, financial, legal, real estate, insurance	354	Monetary authorities and depository credit intermediation services
Services	Banks, financial, legal, real estate, insurance	355	Nondepository credit intermediation and related services
Services	Banks, financial, legal, real estate, insurance	356	Securities, commodity contracts, investments, and related services
Services	Banks, financial, legal, real estate, insurance	357	Insurance
Services	Banks, financial, legal, real estate, insurance	358	Insurance agencies, brokerages, and related services
Services	Banks, financial, legal, real estate, insurance	359	Funds, trusts, and other financial services
Services	Banks, financial, legal, real estate, insurance	360	Real estate buying and selling, leasing, managing, and related services

Category	Subcategory	#	Sector Name
Services	Banks, financial, legal, real estate, insurance	367	Legal services
Services	Banks, financial, legal, real estate, insurance	368	Accounting, tax preparation, bookkeeping, and payroll services
Services	Building services	388	Services to buildings and dwellings
Services	Education and day care	391	Elementary and secondary education from private schools
Services	Education and day care	392	Education from private junior colleges, colleges, universities, and professional schools
Services	Education and day care	393	Other private educational services
Services	Education and day care	399	Child day care services
Services	Hotels, motels, entertainment, media	348	Radio and television entertainment
Services	Hotels, motels, entertainment, media	349	Cable and other subscription services
Services	Hotels, motels, entertainment, media	350	Internet publishing and broadcasting services
Services	Hotels, motels, entertainment, media	351	Telecommunications
Services	Hotels, motels, entertainment, media	364	Video tape and disc rental services
Services	Hotels, motels, entertainment, media	402	Performing arts
Services	Hotels, motels, entertainment, media	403	Spectator sports
Services	Hotels, motels, entertainment, media	404	Promotional services for performing arts and sports and public figures
Services	Hotels, motels, entertainment, media	405	Independent artists, writers, and performers
Services	Hotels, motels, entertainment, media	406	Museum, heritage, zoo, and recreational services
Services	Hotels, motels, entertainment, media	408	Bowling activities
Services	Hotels, motels, entertainment, media	409	Amusement parks, arcades, and gambling recreation
Services	Hotels, motels, entertainment, media	410	Other amusements and recreation
Services	Hotels, motels, entertainment, media	411	Hotels and motel services, including casino hotels
Services	Hotels, motels, entertainment, media	412	Other accommodation services
Services	Other services	114	Printing support services
Services	Other services	339	Couriers and messengers services
Services	Other services	340	Warehousing and storage services
Services	Other services	353	Other information services
Services	Other services	363	General and consumer goods rental services except video tapes and discs
Services	Other services	365	Commercial and industrial machinery and equipment rental and leasing services
Services	Other services	366	Leasing of nonfinancial intangible assets
Services	Other services	369	Architectural, engineering, and related services
Services	Other services	370	Specialized design services
Services	Other services	374	Management, scientific, and technical consulting services
Services	Other services	375	Environmental and other technical consulting services
Services	Other services	376	Scientific research and development services
Services	Other services	377	Advertising and related services
Services	Other services	378	Photographic services
Services	Other services	379	Veterinary services
Services	Other services	380	All other miscellaneous professional, scientific, and technical services
Services	Other services	381	Management of companies and enterprises
Services	Other services	382	Employment services
Services	Other services	383	Travel arrangement and reservation services
Services	Other services	384	Office administrative services
Services	Other services	385	Facilities support services
Services	Other services	386	Business support services
Services	Other services	387	Investigation and security services
Services	Other services	389	Other support services
Services	Other services	400	Individual and family services
Services	Other services	401	Community food, housing, and other relief services, including rehabilitation services
Services	Other services	407	Fitness and recreational sports center services
Services	Other services	416	Electronic and precision equipment repairs and maintenance
Services	Other services	418	Personal and household goods repairs and maintenance

Category	Subcategory	#	Sector Name
Services	Other services	419	Personal care services
Services	Other services	420	Death care services
Services	Other services	421	Dry-cleaning and laundry services
Services	Other services	422	Other personal services
Services	Other services	423	Services from religious organizations
Services	Other services	424	Grantmaking, giving, and social advocacy services
Services	Other services	425	Civic, social, and professional services
Services	Other services	426	Cooking, housecleaning, gardening, and other services to private households
Services	Other services	427	US Postal delivery services
Transportation services	Car rental, repair and wash	362	Automotive equipment rental and leasing services
Transportation services	Car rental, repair and wash	414	Automotive repair and maintenance services, except car washes
Transportation services	Car rental, repair and wash	415	Car wash services
Transportation services	Transportation services, air	332	Air transportation services
Transportation services	Transportation services, mass transit	336	Mass transit
Transportation services	Transportation services, rail	333	Rail transportation services
Transportation services	Transportation services, truck	335	Truck transportation services
Transportation services	Transportation services, water	334	Water transportation services
Transportation services	Transportation services, other	337	Pipeline transportation services
Transportation services	Transportation services, other	338	Scenic and sightseeing transportation services and support activities for transportation
Vehicles and vehicle parts	Aircraft	284	Aircraft
Vehicles and vehicle parts	Cars and light trucks	276	Automobiles
Vehicles and vehicle parts	Cars and light trucks	277	Light trucks and utility vehicles
Vehicles and vehicle parts	Heavy duty trucks	278	Heavy duty trucks
Vehicles and vehicle parts	Other road vehicles	281	Motor homes
Vehicles and vehicle parts	Other road vehicles	282	Travel trailers and campers
Vehicles and vehicle parts	Other road vehicles	292	Motorcycles, bicycles, and parts
Vehicles and vehicle parts	Railroad rolling stock	289	Railroad rolling stock
Vehicles and vehicle parts	Ships and boats	290	Ships
Vehicles and vehicle parts	Ships and boats	291	Boats
Vehicles and vehicle parts	Vehicle parts	118	Petroleum lubricating oils and greases
Vehicles and vehicle parts	Vehicle parts	150	Tires
Vehicles and vehicle parts	Vehicle parts	279	Motor vehicle bodies
Vehicles and vehicle parts	Vehicle parts	280	Truck trailers
Vehicles and vehicle parts	Vehicle parts	283	Motor vehicle parts
Vehicles and vehicle parts	Vehicle parts	285	Aircraft engines and engine parts
Vehicles and vehicle parts	Vehicle parts	286	Other aircraft parts and auxiliary equipment
Vehicles and vehicle parts	Vehicle parts	288	Propulsion units and parts for space vehicles and guided missiles
Vehicles and vehicle parts	Vehicle parts	294	All other transportation equipment
Other	Other	21	Coal
Other	Other	22	Iron ore
Other	Other	23	Copper, nickel, lead, and zinc
Other	Other	24	Gold, silver, and other metal ore
Other	Other	25	Natural stone
Other	Other	26	Sand, gravel, clay, and ceramic and refractory minerals
Other	Other	27	Other nonmetallic minerals
Other	Other	30	Support services for other mining
Other	Other	75	Fiber filaments, yarn, and thread
Other	Other	76	Broadwoven fabrics and felts
Other	Other	77	Woven and embroidered fabrics
Other	Other	78	Nonwoven fabrics and felts
Other	Other	79	Knitted fabrics
Other	Other	80	Finished textiles and fabrics
Other	Other	81	Coated fabric coating
Other	Other	84	Textile bags and canvas
Other	Other	85	All other textile products

Category	Subcategory	#	Sector Name
Other	Other	92	Tanned and finished leather and hides
Other	Other	94	Other leather and allied products
Other	Other	113	Printed materials
Other	Other	116	Asphalt paving mixtures and blocks
Other	Other	117	Asphalt shingles and coating materials
Other	Other	122	Synthetic dyes and pigments
Other	Other	123	Alkalies and chlorine
Other	Other	124	Carbon black
Other	Other	125	All other basic inorganic chemicals
Other	Other	126	Other basic organic chemicals
Other	Other	127	Plastics materials and resins
Other	Other	128	Synthetic rubber
Other	Other	129	Artificial and synthetic fibers and filaments
Other	Other	136	Paints and coatings
Other	Other	137	Adhesives
Other	Other	140	Printing inks
Other	Other	141	All other chemical products and preparations
Other	Other	143	Unlaminated plastics profile shapes
Other	Other	144	Plastics pipes and pipe fittings
Other	Other	145	Laminated plastics plates, sheets (except packaging), and shapes
Other	Other	146	Polystyrene foam products
Other	Other	147	Urethane and other foam products (except polystyrene)
Other	Other	148	Plastics bottles
Other	Other	149	Other plastics products
Other	Other	151	Rubber and plastics hoses and belts
Other	Other	152	Other rubber products
Other	Other	154	Bricks, tiles, and other structural clay products
Other	Other	155	Clay and nonclay refractory products
Other	Other	158	Glass containers
Other	Other	165	Abrasive products
Other	Other	166	Cut stone and stone products
Other	Other	167	Ground or treated mineral and earth products
Other	Other	168	Mineral wool
Other	Other	169	Miscellaneous nonmetallic mineral products
Other	Other	170	Iron and steel and ferroalloy products
Other	Other	171	Steel products from purchased steel
Other	Other	172	Aluminum products
Other	Other	173	Aluminum alloys
Other	Other	174	Aluminum products from purchased aluminum
Other	Other	175	Copper
Other	Other	176	Nonferrous metals (except copper and aluminum)
Other	Other	177	Rolled, drawn, extruded and alloyed copper
Other	Other	178	Rolled, drawn, extruded and alloyed nonferrous metals (except copper and aluminum)
Other	Other	179	Ferrous metals
Other	Other	180	Nonferrous metals
Other	Other	181	All other forged, stamped, and sintered metals
Other	Other	182	Custom roll formed metals
Other	Other	183	Crowned and stamped metals
Other	Other	185	Handtools
Other	Other	187	Ornamental and architectural metal products
Other	Other	188	Power boilers and heat exchangers
Other	Other	189	Metal tanks (heavy gauge)
Other	Other	190	Metal cans, boxes, and other metal containers (light gauge)
Other	Other	191	Ammunition
Other	Other	192	Arms, ordnance, and accessories
Other	Other	193	Hardware
Other	Other	194	Spring and wire products

Category	Subcategory	#	Sector Name
Other	Other	195	Machined products
Other	Other	196	Turned products and screws, nuts, and bolts
Other	Other	197	Coated, engraved, heat treated products
Other	Other	198	Valves and fittings other than plumbing
Other	Other	199	Plumbing fixture fittings and trims
Other	Other	200	Balls and roller bearings
Other	Other	201	Fabricated pipes and pipe fittings
Other	Other	202	Other fabricated metals
Other	Other	203	Farm machinery and equipment
Other	Other	205	Construction machinery
Other	Other	206	Mining and oil and gas field machinery
Other	Other	207	Other industrial machinery
Other	Other	208	Plastics and rubber industry machinery
Other	Other	209	Semiconductor machinery
Other	Other	210	Vending, commercial, industrial, and office machinery
Other	Other	211	Optical instruments and lens
Other	Other	213	Other commercial and service industry machinery
Other	Other	214	Air purification and ventilation equipment
Other	Other	217	Industrial molds
Other	Other	218	Metal cutting and forming machine tools
Other	Other	219	Special tools, dies, jigs, and fixtures
Other	Other	220	Cutting tools and machine tool accessories
Other	Other	221	Rolling mills and other metalworking machinery
Other	Other	222	Turbines and turbine generator set units
Other	Other	223	Speed changers, industrial high-speed drives, and gears
Other	Other	224	Mechanical power transmission equipment
Other	Other	225	Other engine equipment
Other	Other	226	Pumps and pumping equipment
Other	Other	227	Air and gas compressors
Other	Other	228	Material handling equipment
Other	Other	229	Power-driven handtools
Other	Other	230	Other general purpose machinery
Other	Other	231	Packaging machinery
Other	Other	232	Industrial process furnaces and ovens
Other	Other	233	Fluid power process machinery
Other	Other	241	Electron tubes
Other	Other	242	Bare printed circuit boards
Other	Other	243	Semiconductor and related devices
Other	Other	244	Electronic capacitors, resistors, coils, transformers, and other inductors
Other	Other	245	Electronic connectors
Other	Other	246	Printed circuit assemblies (electronic assemblies)
Other	Other	247	Other electronic components
Other	Other	248	Electromedical and electrotherapeutic apparatus
Other	Other	249	Search, detection, and navigation instruments
Other	Other	250	Automatic environmental controls
Other	Other	251	Industrial process variable instruments
Other	Other	252	Totalizing fluid meters and counting devices
Other	Other	253	Electricity and signal testing instruments
Other	Other	254	Analytical laboratory instruments
Other	Other	255	Irradiation apparatus
Other	Other	256	Watches, clocks, and other measuring and controlling devices
Other	Other	258	Magnetic and optical recording media
Other	Other	266	Power, distribution, and specialty transformers
Other	Other	267	Motor and generators
Other	Other	268	Switchgear and switchboard apparatus
Other	Other	269	Relay and industrial controls
Other	Other	272	Communication and energy wires and cables

Category	Subcategory	#	Sector Name
Other	Other	273	Wiring devices
Other	Other	274	Carbon and graphite products
Other	Other	275	All other miscellaneous electrical equipment and components
Other	Other	287	Guided missiles and space vehicles
Other	Other	293	Military armored vehicles, tanks, and tank components
Other	Other	299	Institutional furniture
Other	Other	300	Office Furniture
Other	Other	301	Custom architectural woodwork and millwork
Other	Other	302	Showcases, partitions, shelving, and lockers
Other	Other	311	Sporting and athletic goods
Other	Other	312	Dolls, toys, and games
Other	Other	314	Signs
Other	Other	315	Gaskets, packing and sealing devices
Other	Other	316	Musical instruments
Other	Other	317	All other miscellaneous manufactured products
Other	Other	361	Imputed rental services of owner-occupied dwellings
Other	Other	417	Commercial and industrial machinery and equipment repairs and maintenance
Other	Other	428	* Not a unique commodity (electricity from fed govt utilities)
Other	Other	429	Products and services of Fed Govt enterprises (except electric utilities)
Other	Other	430	* Not a unique commodity (passenger transit by state & local govt)
Other	Other	431	* Not a unique commodity (electricity from state & local govt utilities)
Other	Other	432	Products and services of State & Local Govt enterprises (except electric utilities)
Other	Other	433	Used and secondhand goods
Other	Other	434	Scrap
Other	Other	435	Rest of the world adjustment
Other	Other	436	Noncomparable foreign imports
Other	Other	437	* Employment and payroll only (state & local govt, non-education)
Other	Other	438	* Employment and payroll only (state & local govt, education)
Other	Other	439	* Employment and payroll only (federal govt, non-military)
Other	Other	440	* Employment and payroll only (federal govt, military)