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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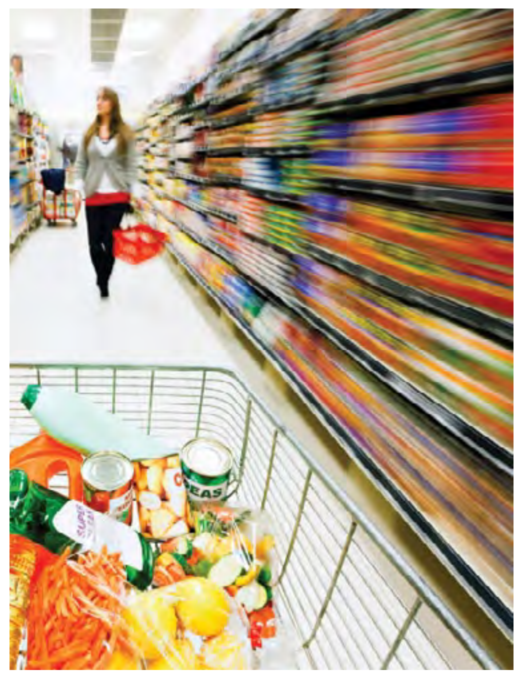

King County

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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 $MTCO_2e$) 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 percent less than the average Washington State resident (15.5 $MTCO_2e$) and about half the average U.S. resident (23.4 $MTCO_2e$).** 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 $MTCO_2e$ per person. Cars and trucks were the largest source of transportation emissions at 4.7 $MTCO_2e$ per person, but emissions from air travel were also significant at 1.2 $MTCO_2e$ per person.
- **Heating and cooling both residential and commercial buildings was the second biggest source of emissions**, representing 4.3 $MTCO_2e$ 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.

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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.

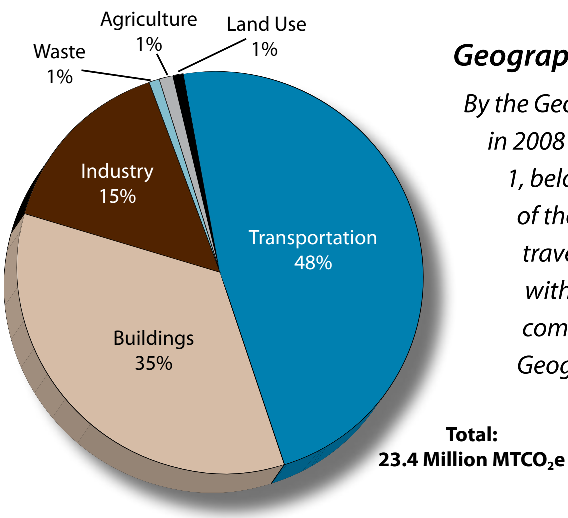
5 ICLEI – Local Governments for Sustainability has been developing a community GHG emissions protocol it intends to promote nationally.

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**

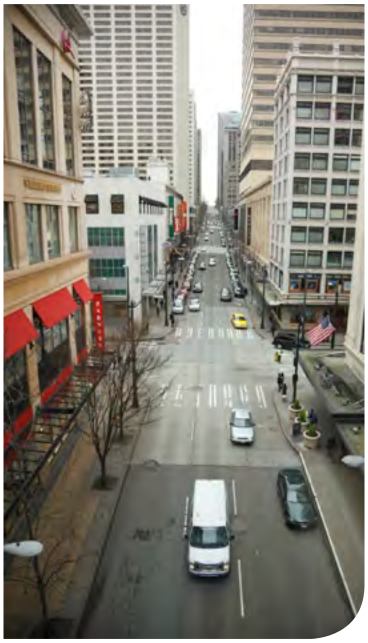
a Emissions per person for the U.S. based on SEI analysis of the U.S. inventory for 2008 (U.S. EPA 2011), with a few adjustments made to facilitate comparisons. For example, the official national inventory does not include international air travel, but these emissions were added back in for the purpose 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 $MTCO_2e$, or 12.6 $MTCO_2e$ 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 $MTCO_2e$ to 3.1 $MTCO_2e$ 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 $MTCO_2e$ /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$_2$e), "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$_2$e), 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*

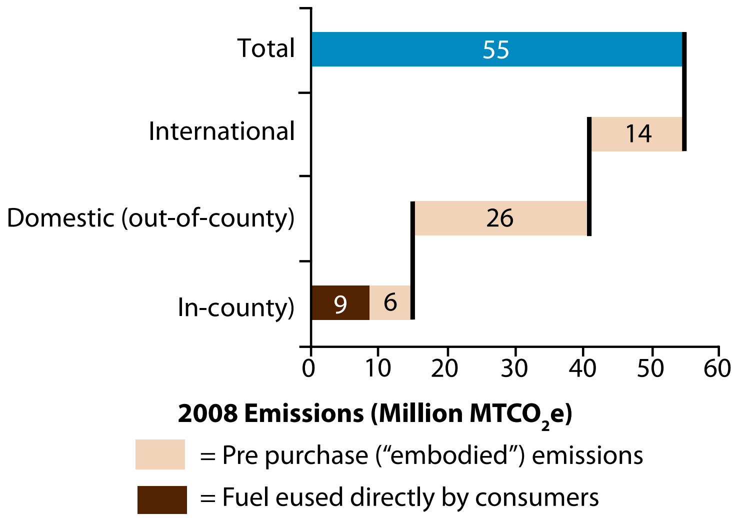
This section describes King County's *Consumption-based* GHG inventory. The key difference of this method from the *Geographic-plus* method is that here we count the emissions associated with producing all products and services consumed in King County, regardless of whether they are produced locally, 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;

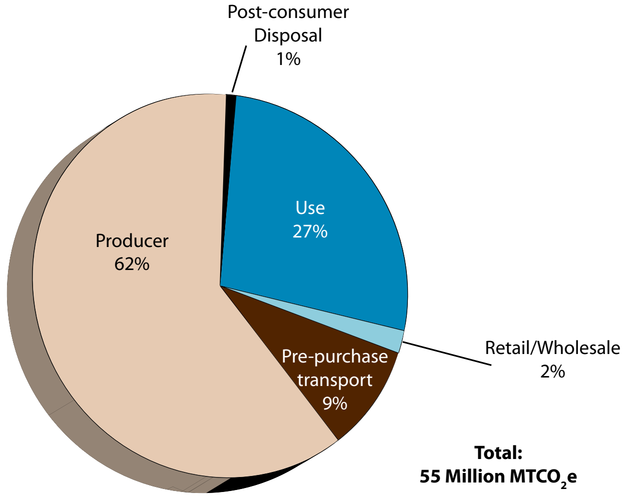
4. **Use:** using a good, such as a personal vehicle, home heating system;

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 $MTCO_2e$.[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.

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".

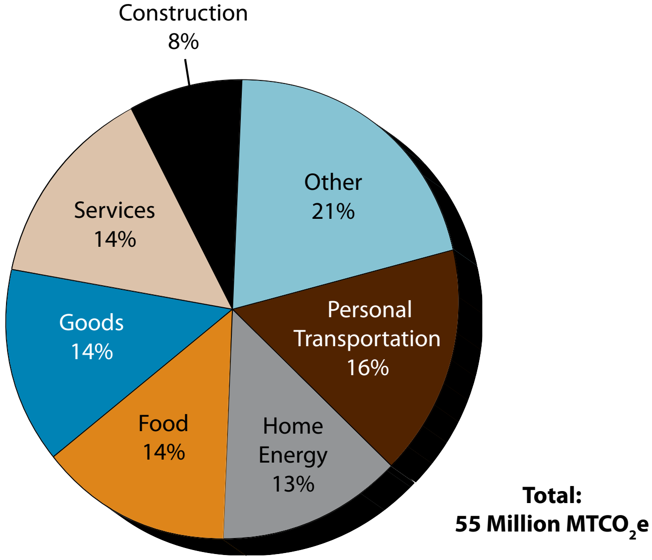
a The Consumption-based methodology includes "final demand" and associated emissions from government spending and business capital investment in addition to consumer spending. For most categories, consumer (household) demand is responsible for 85 percent or more of the emissions. Categories where government 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

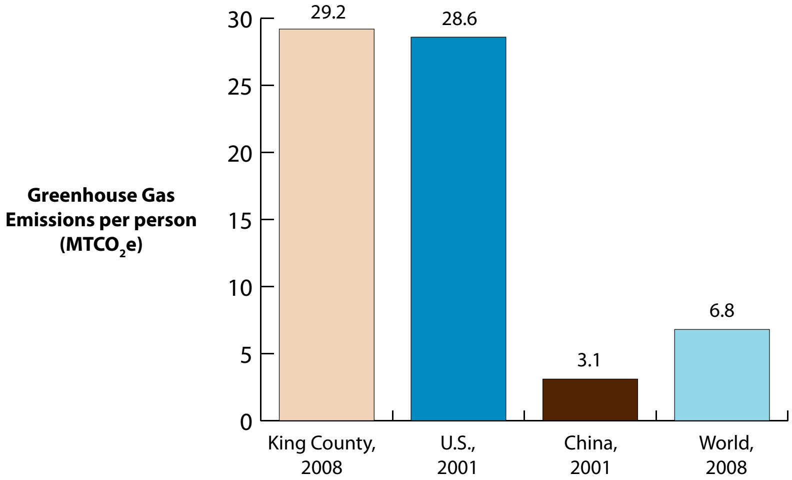


Comparison with Other World Regions

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.

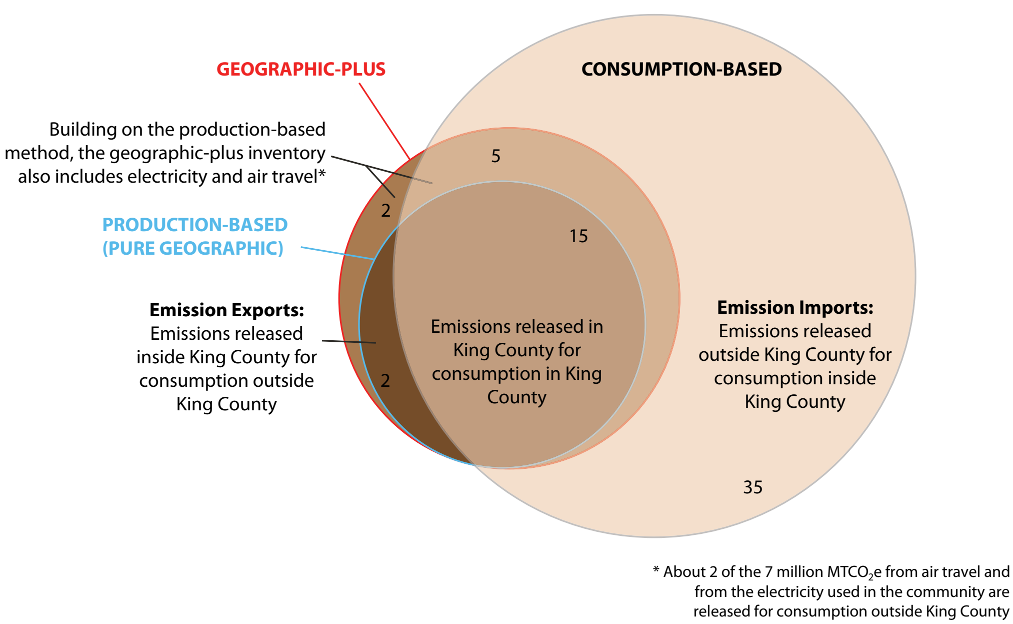
- **The emissions *intensity* of producing different goods and services can vary dramatically.** Looking at emissions per dollar can help inform how to shift to lower-GHG consumption patterns. The emissions intensity of consumption varies by more than a factor of ten, from over 2 kg CO_2e per dollar (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 $MTCO_2$e 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 $MTCO_2$e). But as described previously, the *Consumption-based Inventory* excludes emissions associated with in-county production for consumption elsewhere (about 2 million $MTCO_2$e). About 15 million $MTCO_2$e 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 $MTCO_2$e, 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 $MTCO_2$e 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.

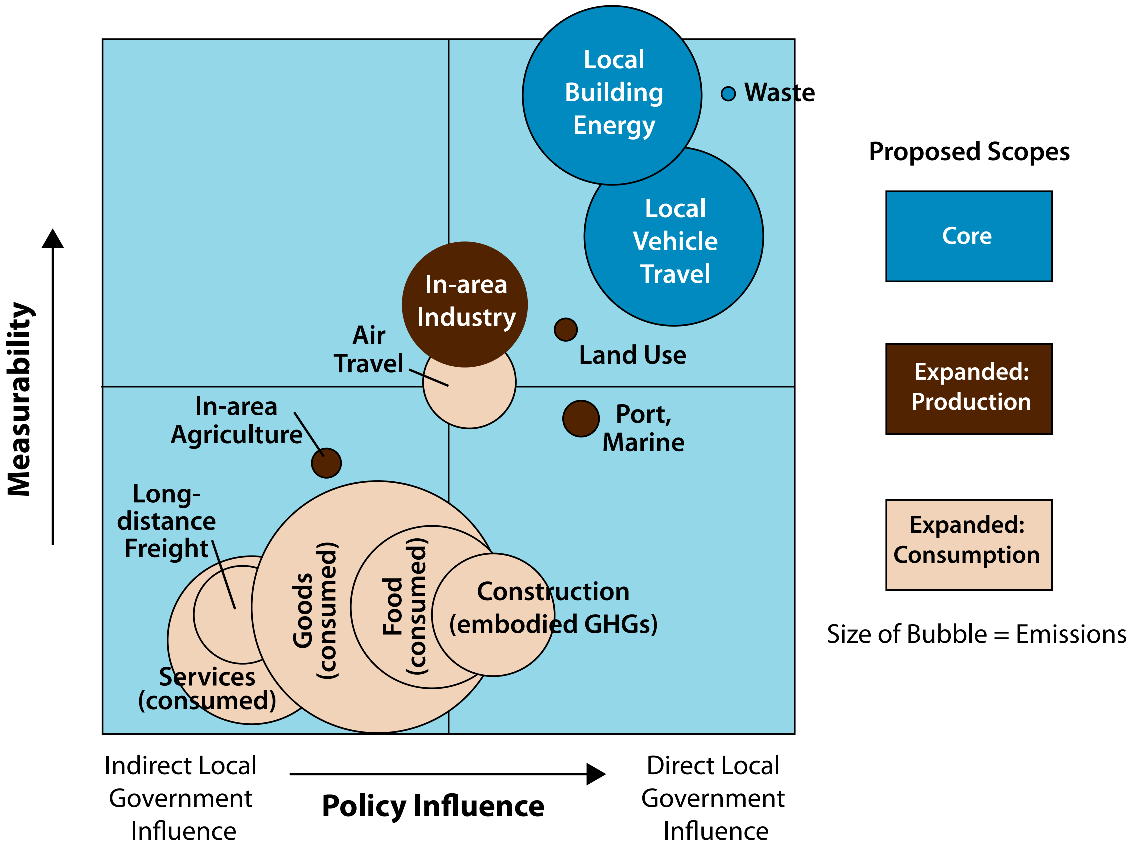
Table 9. Criteria Used to Assess Emissions Sources and Develop GHG Tracking Framework

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.

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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