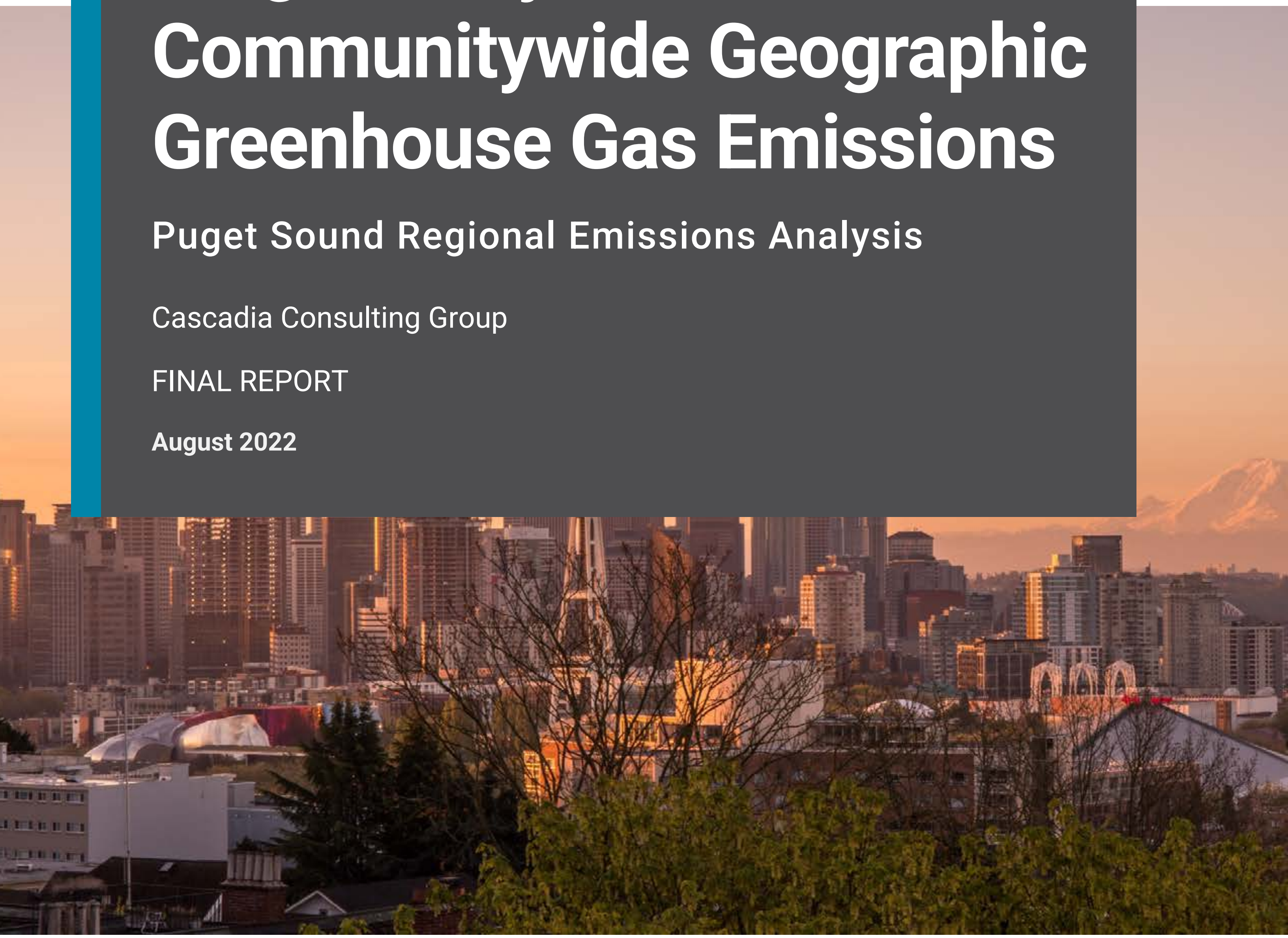
King County Communitywide Geographic Greenhouse Gas Emissions

Puget Sound Regional Emissions Analysis

Cascadia Consulting Group

FINAL REPORT

August 2022



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Executive Summary

To avoid the most serious impacts of climate change, major reductions in greenhouse gas (GHG) emissions are necessary. Quantifying and understanding sources of GHGs, trends over time, and developing scenarios to achieve GHG reduction targets are fundamental steps toward reducing GHG emissions and tracking progress toward emission reduction targets. King County 2020 Strategic Climate Action Plan (SCAP) [1] outlines a suite of strategies and actions designed to reduce emissions and meet local GHG reduction targets. In early 2022, as part of updates to King County Countywide Planning Policies [2], King County and the 39 cities in the County strengthened shared GHG emissions reduction targets to 50% below 2007 levels by 2030; 75% below 2007 levels by 2040; and 95% below 2007 levels and net carbon neutral by 2050.

This report provides a comprehensive **2019 and 2020 update of the county's communitywide geographic GHG emissions**. This update includes the following additional analyses:

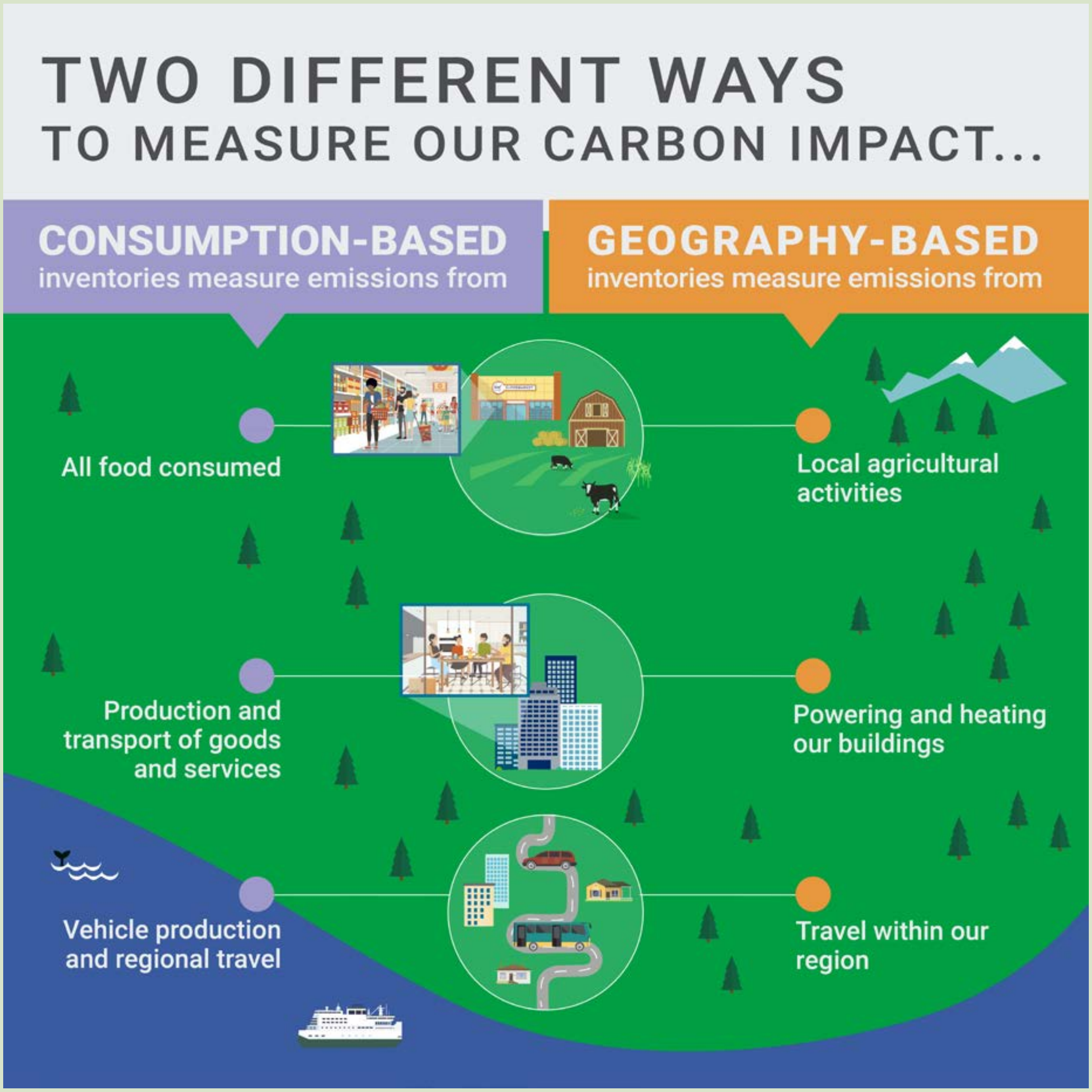
- A **progress update** of historical trends and progress toward the County's GHG emission reduction goals.
- A **contribution analysis** update to explore drivers of changes in emissions between 2015 and 2019.
- A **wedge analysis** to compare a "no action future" emissions scenario with scenarios with emissions reduction actions and policies that combined will achieve adopted targets.

[1] King County 2020 Strategic Climate Action Plan. https://your.kingcounty.gov/dnrp/climate/documents/scap-2020-approved/2020-king-county-strategic-climate-action-plan.pdf

[2] King County Countywide Planning Policies. https://kingcounty.gov/depts/executive/performance-strategy-budget/regional-planning/CPPs.aspx

What is a communitywide geographic GHG emissions inventory?

A communitywide geographic GHG emissions inventory quantifies the annual emissions produced within community boundaries due to community activities, such as on-road transportation and energy consumption. A geographic emissions inventory does not account for upstream emissions from goods and services consumed within the community, such as food or furniture.



Geographic Inventory Findings

- This report provides updated data for both 2019 and 2020. However, because 2020 marked the beginning of the global COVID-19 pandemic, 2020 should not be interpreted as an indicator of long-term emissions sources or trends.
- In 2019 and 2020, King County's residents, businesses, employees, and visitors produced 27.1 million and 22.9 million metric tons of CO_2 equivalent ($MTCO_2e$), respectively (Figure 1).
- This equates to roughly 12.18 and 10.10 $MTCO_2e$ per capita in 2019 and 2020, respectively.
- Total GHG emissions in 2019 increased 3% compared to the last inventory year (2017) and increased 11% compared to the 2007 baseline inventory year (Figure 2).
- Total GHG emissions in 2020 decreased 13% compared to the last inventory year (2017) and decreased 6% compared to the baseline inventory year (2007). [3]
- Per-capita GHG emissions have declined over time (-7% and -23% in 2019 and 2020, respectively, compared to the 2007 baseline year; Figure 2). [4]
- The largest GHG emissions sources continue to be building electricity (~25%), onroad transportation (~25%), and building natural gas (~15%) (Figure 4).

[3] Emissions for 2007 were extrapolated by service population from 2008 inventory values.
[4] Per capita emissions for 2007 are assumed to be equivalent to 2008 inventory values.

Figure 1. Sources of geographic-based greenhouse gas emissions in 2019.

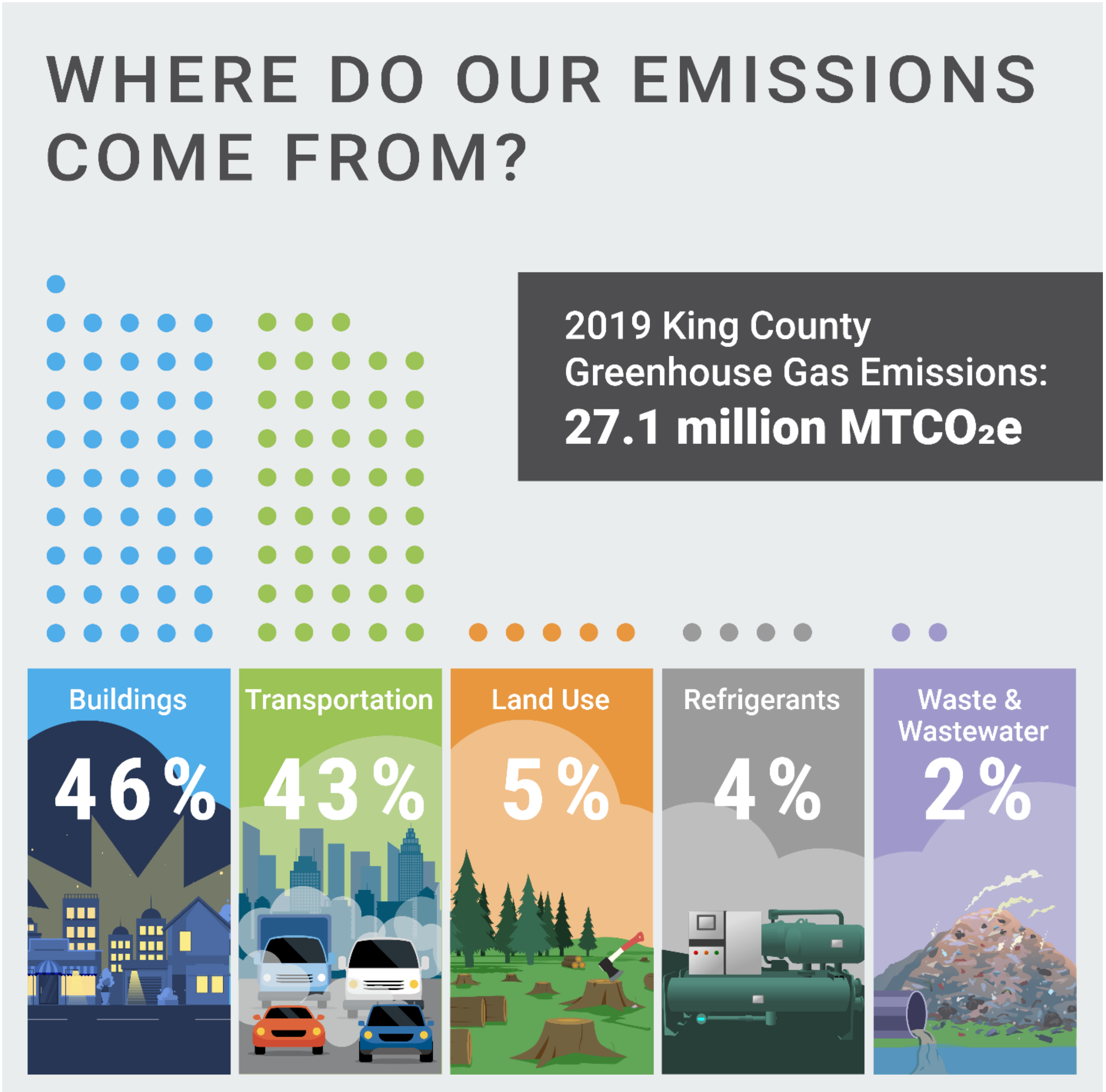


Figure 2. Total greenhouse gas emissions trends over time, by sector.

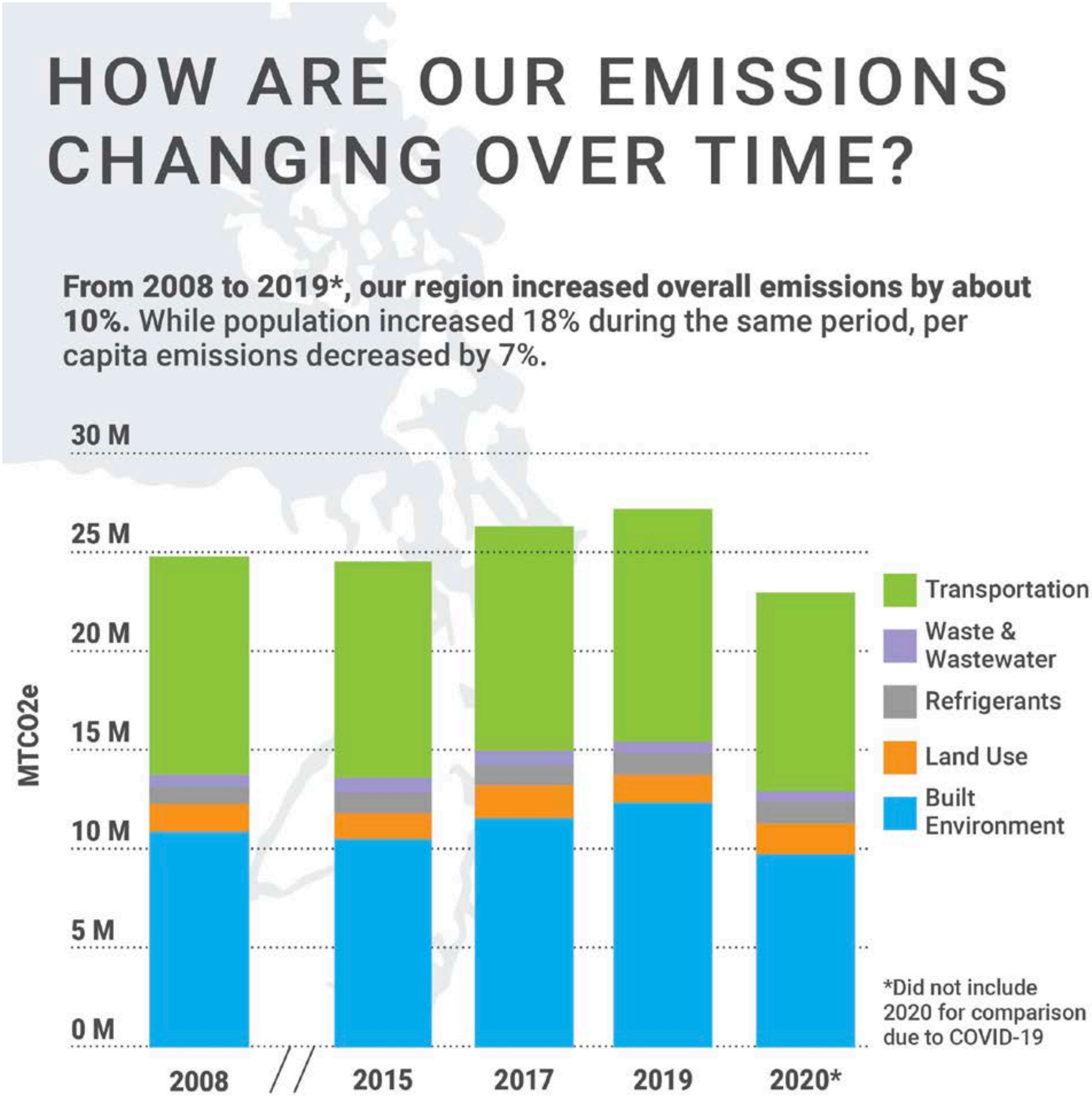
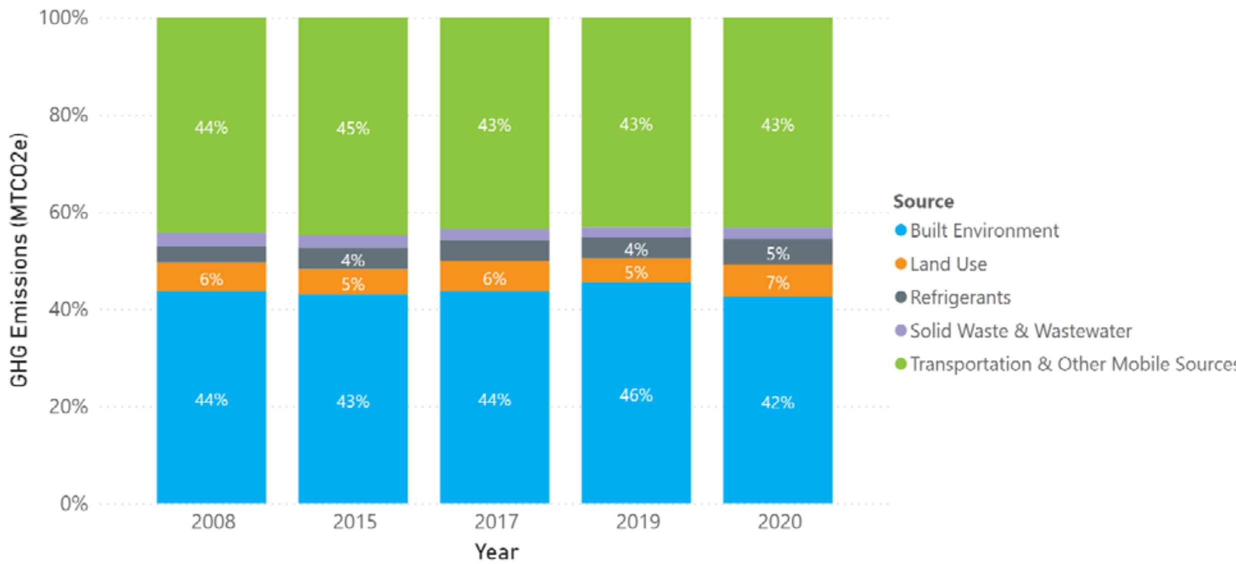


Figure 3. Relative contributions of greenhouse gas emissions, by sector.



Contribution Analysis Findings

A contribution analysis allows jurisdictions to discover the main drivers behind changes in emissions between two inventories separated in time. This updated contribution analysis for 2015–2019 emissions explores the drivers behind the changes in King County's geographic emissions between these years. The 2015 emissions inventory has been updated using the latest methodology, so 2015 values may differ from those previously reported.

In 2015, total emissions in King County were 24.5 million $MTCO_2e$, and in 2019, total emissions were 27.1 million $MTCO_2e$, an 11% increase (+2.6 million $MTCO_2e$) from 2015. Figure 4 shows some of the drivers that resulted in increases and decreases of emissions over this period. Some key findings include:

- The most substantial drivers for an increase in emissions were population growth, higher GHG emissions electricity provided by Puget Sound Energy; and increased aviation emissions.
- Increased efficiency of passenger vehicles (decreased emissions per mile) was the largest contributor to decreasing emissions.
- More efficient electricity use by households and commercial entities also contributed significantly to decreasing emissions.
- Other smaller contributors to the growth in emissions included a colder winter in 2019, growth in employment, and increased industrial energy use.

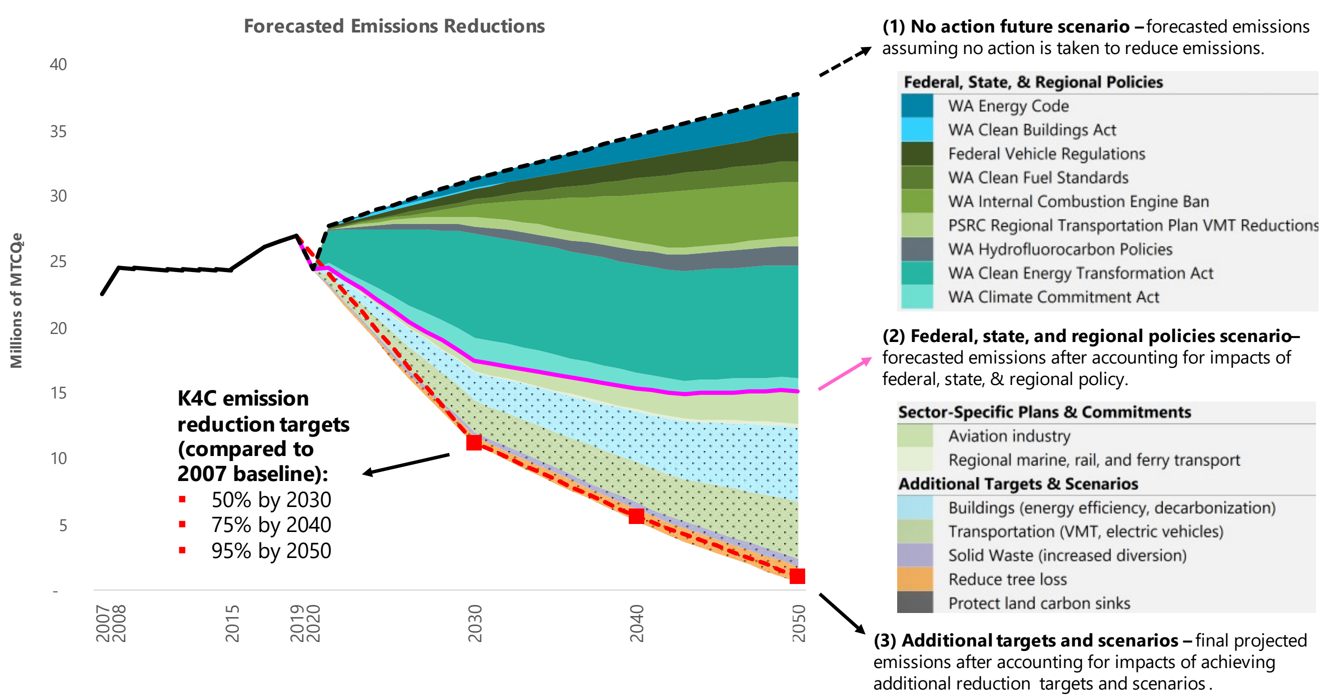
Figure 4. Top contributions to change between the 2015 and 2019 GHG inventories.

Wedge Analysis Findings

The wedge analysis forecasts King County's emissions from 2020 through 2050 under the following three scenarios: 1) no action future; 2) federal, state, and regional policies; and 3) additional targets. The additional targets scenario includes adopted King County targets and additional scenarios created for this analysis to achieve overarching emissions reduction goals set in the Strategic Climate Action Plan (SCAP). As depicted in Figure 5, action by industries, governments, businesses, and individuals will be needed to achieve the King County-Cities Climate Collaboration (K4C) targets to reach 50%, 75%, and 95% emissions reductions by 2030, 2040, and 2050, respectively. The wedge analysis revealed the following projections compared to 2007 baseline greenhouse gas emissions levels:

- Under a **no-action future**, we estimate that King County GHG emissions will increase 68% by 2050.
- We estimate that **existing federal, state, and regional policies** will reduce King County's GHG emissions by one third (33%) by 2050.
- The estimated collective impact of the federal, state, and regional policies combined with **additional targets** is a 50% reduction by 2030, 75% reduction by 2040, and 95% reduction by 2050.

Figure 5. Forecasted emissions and reductions under three scenarios.



Acronyms

ACS	American Community Survey
BAU	Business as usual
BOD	Biochemical oxygen demand (a metric of the effectiveness of wastewater treatment plants)
CO_2e	Carbon dioxide equivalent
ECA	Emission Control Area
eGRID	Emissions & Generation Resource Integrated Database
EIA	United States Energy Information Association
EPA	United States Environmental Protection Agency
FLIGHT	Facility Level Information on Greenhouse gases Tool
GHG	Greenhouse gas (limited to CO_2, CH_4, N_2O, and fugitive gases in this inventory)
HFCs	Hydrofluorocarbons
ICLEI	Local Governments for Sustainability
kWh	Kilowatt-hour
LTO	Landing and takeoff
MOVES	Motor Vehicle Emission Simulator model (developed by EPA to quantify emissions from mobile sources)
MSW	Municipal solid waste
$MTCO_2e$	Metric tons of carbon dioxide equivalent
ODS	Ozone-depleting substances
PSE	Puget Sound Energy
PSEI	Puget Sound Maritime Air Emissions Inventory
PSRC	Puget Sound Regional Council
SCL	Seattle City Light
SPU	Seattle Public Utilities
USDA	United States Department of Agriculture
WARM	Waste Reduction Model (model developed by EPA to quantify solid waste emissions)
VMT	Vehicle Miles Travelled

Glossary of Terms

Afforestation	The act or process of establishing trees or a forest, especially on land not previously forested.
Carbon sequestration	The process of capturing and storing atmospheric carbon dioxide, often through organic forms such as trees and soils.
Enteric fermentation	Part of the digestive process in ruminant animals such as cattle, sheep, goats, and buffalo that emits methane, a potent greenhouse gas.
Fugitive emissions	Emissions of greenhouse gases that are not produced intentionally by a stack or vent and can include leaks from industrial plants and pipelines. Fugitive emissions may be caused by the production, processing, transmission, storage, and use of fuel (IPCC, 2006).
Greenhouse gas (GHG)	A gas that absorbs and emits radiant energy within the thermal infrared range, causing the greenhouse effect. Primary greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases (e.g., HFCs).
Ozone-depleting substances	Compounds that contribute to stratospheric ozone depletion, such as chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). Many of these compounds have recently been substituted with hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs), which are not ozone depleting, but are potent greenhouse gases.
Switchgear insulation	The environment within switchgears that are used in electricity transmission systems. Sulfur hexafluoride (SF6), a potent greenhouse gas, is often used in switchgears due to its excellent insulation properties.
Upstream or “lifecycle” GHG emissions	Greenhouse gas (GHG) emissions associated with the production, processing, transmission, storage, and distribution of goods and services, beginning with the extraction of raw materials and ending with the delivery of the goods and services to the site of use.

Introduction

GHG inventories allow communities to account for sources and quantities of GHG emissions generated by community activities. The **geographic inventory** estimates the annual GHG emissions released within community boundaries plus those associated with certain activities, such as electricity consumption and waste disposal.

The **geographic inventory** estimates GHG emissions produced by activities of the King County community, including emissions resulting from community energy use; wastewater and solid waste processing; and land use practices. It includes both "in-boundary" emission *sources*—any physical process inside the jurisdictional boundary that releases GHG emissions—and activities resulting in GHG emissions. For example, it includes emissions associated with the in-county *production* of food and goods, regardless of where those goods are consumed, such as from a manufacturer located within King County that produces goods for export.

This inventory report includes new communitywide geographic inventories for 2019 and 2020, as well as updated 2008, 2015, and 2017 inventories to reflect methodology improvements conducted for the 2019 and 2020 inventories.

Roadmap of this Report

This report is organized into the following sections:

- **Where Do King County Emissions Come From?** Describes methodologies and results for the geographic-plus inventory.
- **What's Driving King County Emissions Trends?** Explores drivers of King County emission trends.
- **How Can We Meet Local Climate Goals?** Includes a "wedge analysis" that shows estimated emissions reductions from existing policies and additional reductions needed to meet countywide climate goals.
- **Appendix A. Inventory Methodology** provides a detailed summary of the geographic inventory methodology, including key data sources and assumptions.

Where Do King County Emissions Come From?

Geographic Inventory Approach

The 2019 and 2020 King County GHG emissions inventories were prepared in accordance with the *U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions* and the *Global Protocol for Community Scale Greenhouse Gas Emission Inventories*. Inventory data was gathered for the 2019 and 2020 calendar years and accounts for emissions from the activities of King County residents, businesses, employees, and visitors undertaken within or originating from within the county limits. This inventory does not include "upstream" GHG emissions related to the consumption of goods and services; those sources are estimated in the Consumption Inventory, which is complementary to this inventory.

Geographic Inventory Sectors & What's Included

Sector	What's Included	Sector	What's Included
Transportation	Driving within county limits, flights from county travelers, maritime/rail travel, non-road vehicle and equipment use	**Building Energy**	Residential, commercial, and industrial electricity and natural gas use and associated loss and leakage, residential fuel oil and propane, and industrial processes
Solid Waste & Wastewater	Solid waste generation and disposal and wastewater processes	**Refrigerants**	Substitution of ozone-depleting substances and switchgear insulation
Land Use	Agriculture and tree cover loss	**Sequestration**	Solid waste disposal sequestration and sequestration from trees and forests

What is a communitywide geographic GHG emissions inventory?

A communitywide geographic GHG emissions inventory quantifies the annual emissions produced within community boundaries due to community activities, such as on-road transportation and energy consumption. A geographic emissions inventory does not account for upstream emissions from goods and services consumed within the community, such as food or furniture.

This is different from King County's consumption-based inventory, which provides an inventory of the GHG emissions associated with consumption of food and goods within the community, regardless of where the goods were produced. For example, the consumption-based inventory would not include GHG emissions associated with the production of goods from a local manufacturer that are consumed entirely outside the community, but would include GHG emissions associated with the production of goods manufactured in another community but consumed within King County. Thus, the consumption-based inventory accounts for different, but related sources of emissions associated with community activities.

The geographic and consumption-based inventories provide insights about different GHG emission footprints of a community. For example, a community may consume electricity generated from low-emission sources, but also consume goods produced in another community with high-emission energy. The two inventories can account for these differences to paint a comprehensive picture of community emissions.

Inventory Summary

- In 2019 and 2020, King County's residents, businesses, employees, and visitors produced 27.1 million and 22.9 million metric tons of CO_2 equivalent ($MTCO_2e$), respectively (Figure 6; Figure 7).
- This equates to roughly 12.18 and 10.10 $MTCO_2e$ per capita in 2019 and 2020, respectively (Table 2).
- Total GHG emissions in 2019 increased 3% compared to the last inventory year (2017) and increased 11% compared to the baseline inventory year (2007; Figure 8).
- Total GHG emissions in 2020 decreased 13% compared to the last inventory year (2017) and decreased 6% compared to the baseline inventory year (2007; Figure 8). [5]
- Per-capita GHG emissions have declined over time (-7% and -23% in 2019 and 2020, respectively, compared to the 2007 baseline year) (Figure 9). [6]
- The largest GHG emissions sources continue to be building electricity (~25%), onroad transportation (~25%), and building natural gas (~15%).

Comparing to a 2007 vs. 2008 Baseline

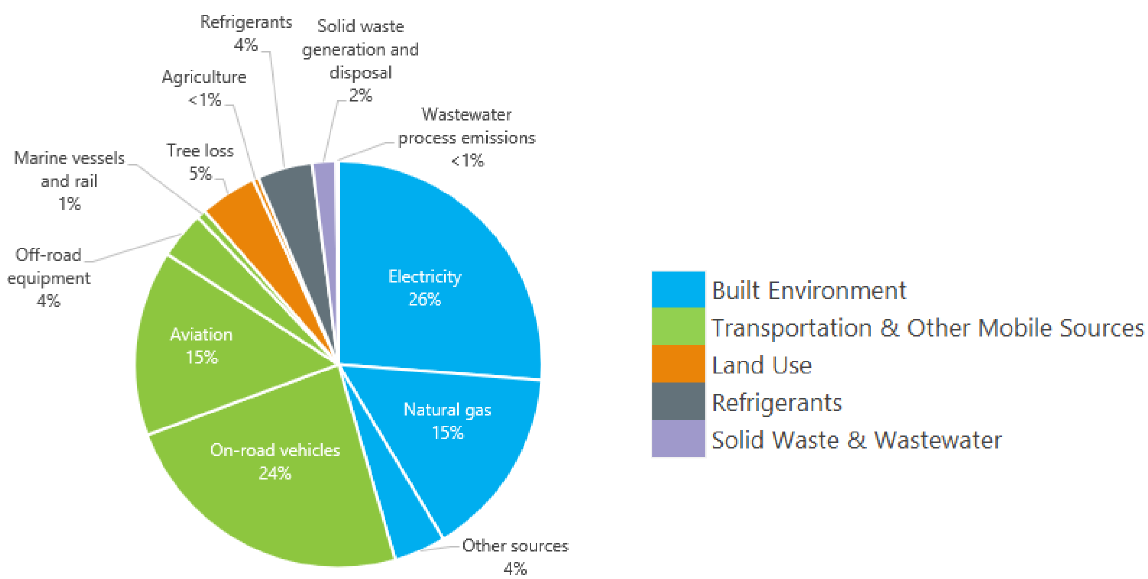
While King County established 2007 as the baseline inventory year for setting GHG emission reduction targets, the closest comprehensive GHG inventory for the county was conducted in 2008.

To account for this difference, 2008 inventory estimates were backcasted to 2007 based on changes in population and employment between the two years.

For this analysis, we often compare to 2007 when assessing progress toward overall countywide GHG emission reduction targets. Comparisons to 2008 are made when assessing trends in individual sectors (e.g., transportation, buildings) and when depicting progress graphically (e.g., Figure 9).

Figure 6. Sources of greenhouse gas emissions for King County in 2019.

Total = 27.1 million $MTCO_2e$



[5] Emissions for 2007 were extrapolated by service population from 2008 inventory values.
[6] Per capita emissions for 2007 are assumed to be equivalent to 2008 inventory values.

Figure 7. Sources of greenhouse gas emissions for King County in 2020.

Total = 22.9 million $MTCO_2e$

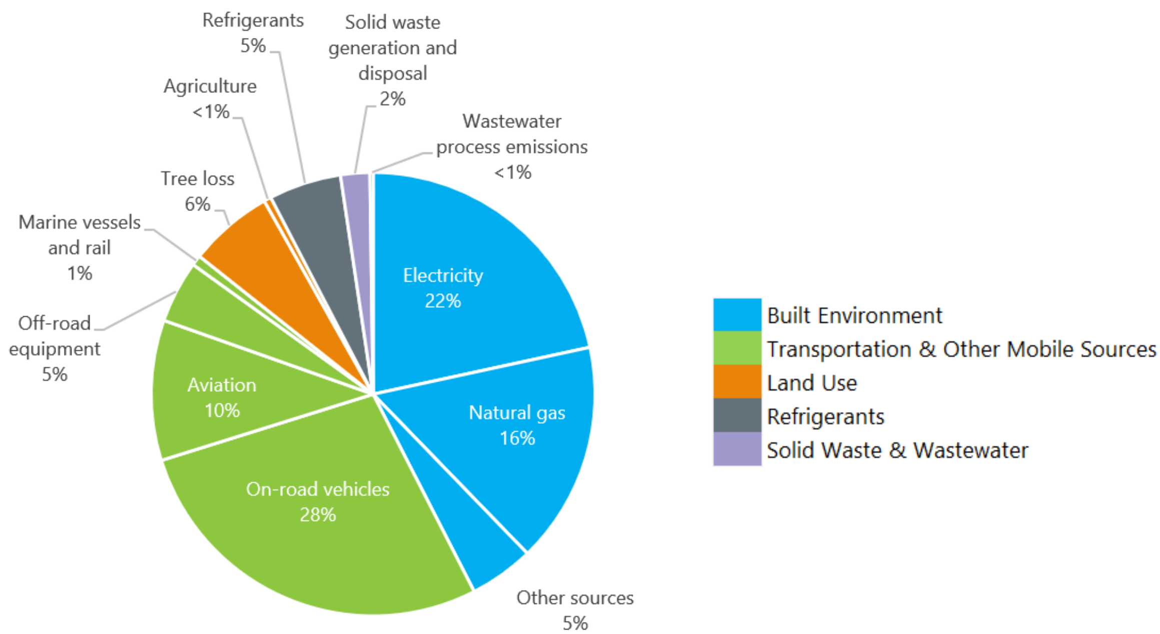


Figure 8. Greenhouse gas emissions trends over time by sector for King County.

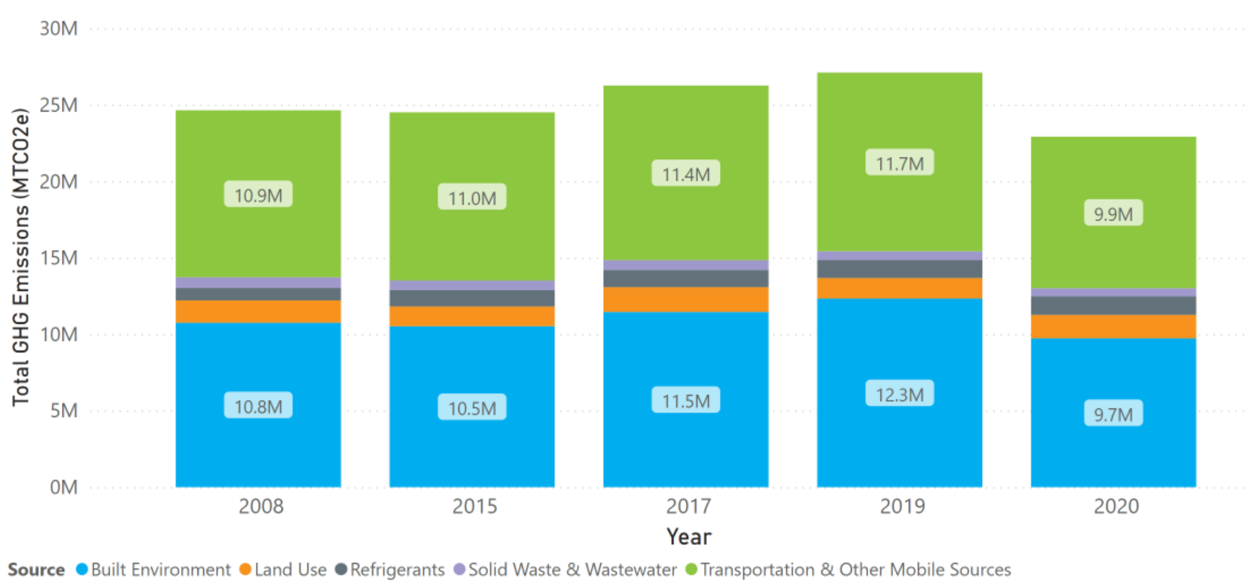


Figure 9. Per-capita greenhouse gas emissions trends over time, by sector.

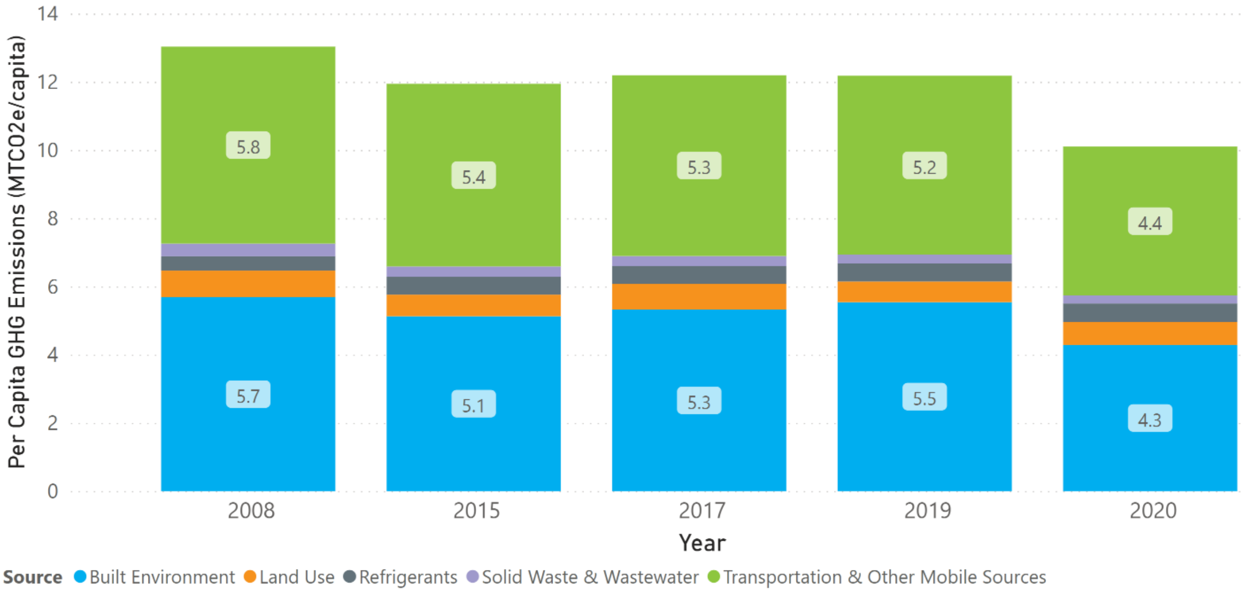
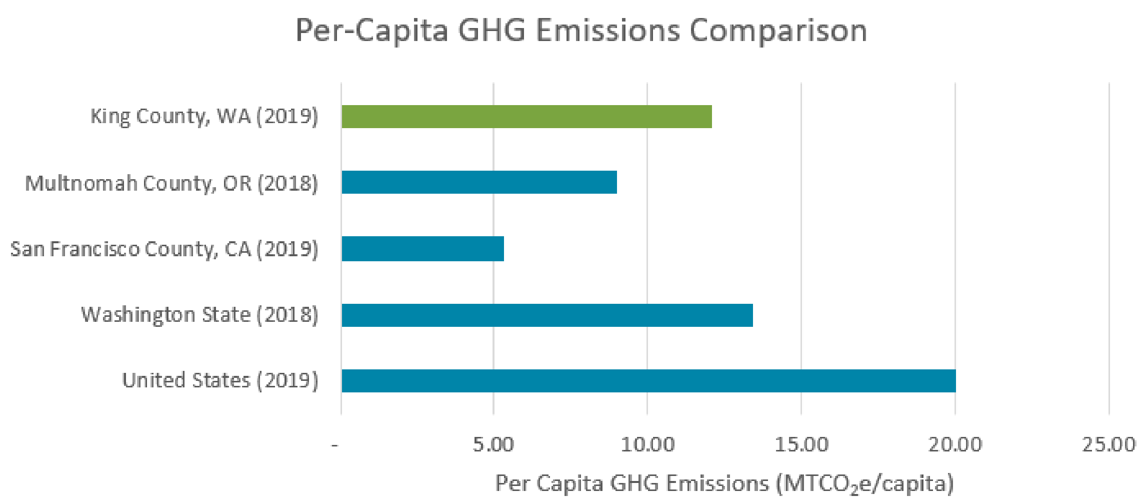
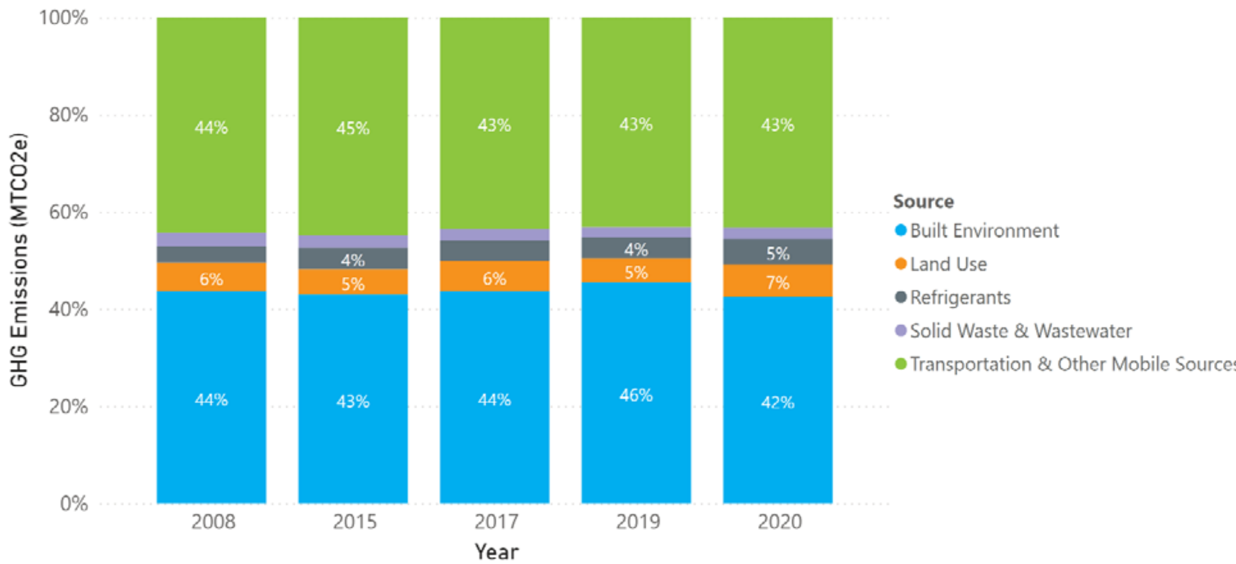


Figure 10. Comparison of per-capita GHG emissions from all sectors across jurisdictions. [7]



[7] Included emissions sources vary by jurisdiction.

Figure 11. Relative contributions of greenhouse gas emissions, by sector.



What's behind the dip in 2020 emissions?

Overall GHG emissions in 2020 declined approximately 15% compared to just a year earlier in 2019—a drastic reduction in just one year. Because 2020 marked the beginning of the global COVID-19 pandemic, this reduction should not be interpreted as an indicator of long-term emissions sources or trends. However, understanding the details behind observed emissions for the year can help inform future climate action.

The following factors help explain the dip in 2020 emissions.

- **Aviation activity:** Commercial flight activity plummeted in 2020 due to the COVID-19 pandemic, causing a dip in aviation-related emissions. SeaTac airport data indicates a 40% reduction in aviation fuel use in 2020 compared to 2019.
- **Puget Sound Energy electricity fuel mix:** Puget Sound Energy provided much cleaner electricity in 2020; the carbon intensity of their electricity dropped 25% from 0.53 in 2019 to 0.40 $MTCO_2e$/MWh in 2020.
- **Commercial electricity & natural gas consumption:** While residential electricity consumption remained relatively constant, commercial electricity and natural gas consumption both declined by 13% between 2019 and 2020. Residential natural gas consumption also declined slightly (-3%).
- **Industrial operations:** Emissions from industrial processes declined across the board in 2020 compared to 2019, including electricity use (-33%), natural gas use (-23%), and direct process emissions (-2%).

Table 1. Communitywide geographic GHG emissions, by sector and year ($MTCO_2e$).

GHG Emissions by Sector ($MTCO_2e$)	2007	2008	2015	2017	2019
Built Environment	**10,630,439**	**10,756,118**	**10,524,224**	**11,457,932**	**12,336,188**
Electricity	**5,553,621**	**5,619,279**	**5,967,172**	**6,191,688**	**7,109,886**
Residential	2,368,786	2,396,791	2,515,936	2,683,137	2,859,396
Commercial	2,607,271	2,638,096	2,859,828	2,924,863	3,608,823
Industrial	577,564	584,392	591,408	583,688	641,667
Natural gas	**3,710,124**	**3,753,987**	**3,393,382**	**4,138,621**	**4,110,659**
Residential	1,899,367	1,921,822	1,650,087	2,042,153	1,967,193
Commercial	1,222,211	1,236,661	1,207,842	1,395,615	1,441,544
Industrial	588,546	595,504	535,453	700,853	701,922
Other sources	**1,366,694**	**1,382,852**	**1,163,670**	**1,127,623**	**1,115,643**
Fuel oil	588,235	595,189	443,744	385,203	334,738
Residential propane	86,474	87,496	66,124	97,194	112,522
Industrial processes	691,986	700,167	653,802	645,226	668,383
Transportation and Other Mobile Sources	**10,792,079**	**10,919,669**	**10,993,618**	**11,414,156**	**11,683,116**
On-road vehicles	**6,509,824**	**6,586,787**	**6,530,791**	**6,515,027**	**6,470,836**
Passenger vehicles	5,357,064	5,420,398	5,308,712	5,296,436	5,119,314
Freight and service vehicles	1,040,345	1,052,645	1,082,908	1,070,169	1,201,724
Transit vehicles	112,415	113,744	139,171	148,422	149,798
Aviation	**2,903,729**	**2,938,059**	**3,333,154**	**3,727,683**	**3,998,546**
Off-road equipment	**1,156,361**	**1,170,032**	**945,773**	**972,911**	**1,016,406**
Marine & rail	**222,164**	**224,791**	**183,900**	**198,535**	**197,328**
Solid Waste & Wastewater	**687,165**	**695,289**	**622,644**	**639,764**	**564,503**
Solid waste generation & disposal	**642,455**	**650,050**	**573,741**	**589,729**	**513,096**
Landfill	608,618	615,813	516,049	508,469	465,699
Compost	33,837	34,237	57,692	81,260	47,397
Wastewater process emissions	**44,710**	**45,239**	**48,903**	**50,035**	**51,407**
Refrigerants	**805,743**	**815,269**	**1,080,542**	**1,129,693**	**1,185,036**
Refrigerants	**805,743**	**815,269**	**1,080,542**	**1,129,693**	**1,185,036**
Land Use	**1,442,495**	**1,459,549**	**1,291,978**	**1,620,893**	**1,341,477**
Agriculture	**147,802**	**149,549**	**131,978**	**120,893**	**121,477**
Tree loss	**1,294,693**	**1,310,000**	**1,160,000**	**1,500,000**	**1,220,000**
Total Emissions	**24,357,920**	**24,645,894**	**24,513,006**	**26,262,438**	**27,110,320**
Subset: Basic Activities	16,348,318	16,541,598	16,374,818	17,336,678	18,106,086

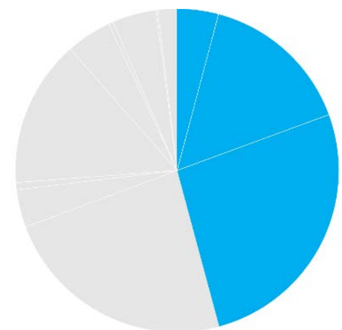
Table 2. Per-capita geographic GHG emissions, by year ($MTCO_2e$).

GHG Emissions by Sector ($MTCO_2e$)	2007	2008	2015	2017	2019	2020
Built Environment	**5.7**	**5.7**	**5.1**	**5.3**	**5.5**	**4.3**
Electricity	**3.0**	**3.0**	**2.9**	**2.9**	**3.2**	**2.2**
Residential	1.3	1.3	1.2	1.2	1.3	1.0
Commercial	1.4	1.4	1.4	1.4	1.6	1.0
Industrial	0.3	0.3	0.3	0.3	0.3	0.2
Natural gas	**2.0**	**2.0**	**1.7**	**1.9**	**1.8**	**1.6**
Residential	1.0	1.0	0.8	0.9	0.9	0.8
Commercial	0.7	0.7	0.6	0.6	0.6	0.6
Industrial	0.3	0.3	0.3	0.3	0.3	0.2
Other sources	**0.7**	**0.7**	**0.6**	**0.5**	**0.5**	**0.5**
Fuel oil	0.3	0.3	0.2	0.2	0.2	0.1
Residential propane	0.0	0.0	0.0	0.0	0.1	0.0
Industrial processes	0.4	0.4	0.3	0.3	0.3	0.3
Transportation and Other Mobile Sourc	**5.8**	**5.8**	**5.4**	**5.3**	**5.2**	**4.4**
On-road vehicles	**3.5**	**3.5**	**3.2**	**3.0**	**2.9**	**2.8**
Passenger vehicles	2.9	2.9	2.6	2.5	2.3	2.2
Freight and service vehicles	0.6	0.6	0.5	0.5	0.5	0.5
Transit vehicles	0.1	0.1	0.1	0.1	0.1	0.1
Aviation	**1.6**	**1.6**	**1.6**	**1.7**	**1.8**	**1.0**
Off-road equipment	**0.6**	**0.6**	**0.5**	**0.5**	**0.5**	**0.5**
Marine & rail	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
Solid Waste & Wastewater	**0.4**	**0.4**	**0.3**	**0.3**	**0.3**	**0.2**
Solid waste generation & disposal	**0.3**	**0.3**	**0.3**	**0.3**	**0.2**	**0.2**
Landfill	0.3	0.3	0.3	0.2	0.2	0.2
Compost	0.0	0.0	0.0	0.0	0.0	0.0
Wastewater process emissions	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Refrigerants	**0.4**	**0.4**	**0.5**	**0.5**	**0.5**	**0.5**
Refrigerants	**0.4**	**0.4**	**0.5**	**0.5**	**0.532**	**0.5**
Land Use	**0.8**	**0.8**	**0.6**	**0.8**	**0.6**	**0.7**
Agriculture	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
Tree loss	**0.7**	**0.7**	**0.6**	**0.7**	**0.5**	**0.6**
Total Emissions	**13.0**	**13.0**	**11.9**	**12.2**	**12.2**	**10.1**
Subset: Basic Activities	8.7	8.7	8.0	8.0	8.1	6.8

Inventory Findings, By Sector

Built Environment

Summary



- In 2019 and 2020, the built environment accounted for 46% and 42% of communitywide emissions, respectively.
- Emissions from electricity and natural gas accounted for most of those emissions and 26% and 15% of *all* emissions in 2019, respectively.
- Built environment emissions in 2019 increased 15% since 2008.
- Built environment emissions in 2020 decreased 9% since 2008. Primary contributors to this change include changes in electricity and natural gas consumption and a lower carbon intensity (emissions per unit of energy produced) of PSE's fuel mix in 2020.
- Industrial process emissions account for 2% of total communitywide emisions in 2019 and 3% of total emissions in 2020; 2019 and 2020 emissions have decreased 5% and 7% since 2008, respectively, but have increased slightly since 2017.

Electricity

King County's electricity is delivered through two energy providers: Seattle City Light (SCL) and Puget Sound Energy (PSE). Electricity accounted for 26% and 22% of King County's total communitywide GHG emissions in 2019 and 2020, respectively. **Electricity emissions in 2019 increased** 27% since 2008. Electricity emissions in **2020 decreased** 12% compared to 2008. These changes in electricity emissions can be attributed to changes in electricity consumption (Figure 13) and the carbon intensity of utility electricity fuel sources (Figure 14); for example, commercial electricity consumption and PSE's carbon intensity both declined substantially between 2019 and 2020.

Figure 12. Electricity emissions trends, by sector.

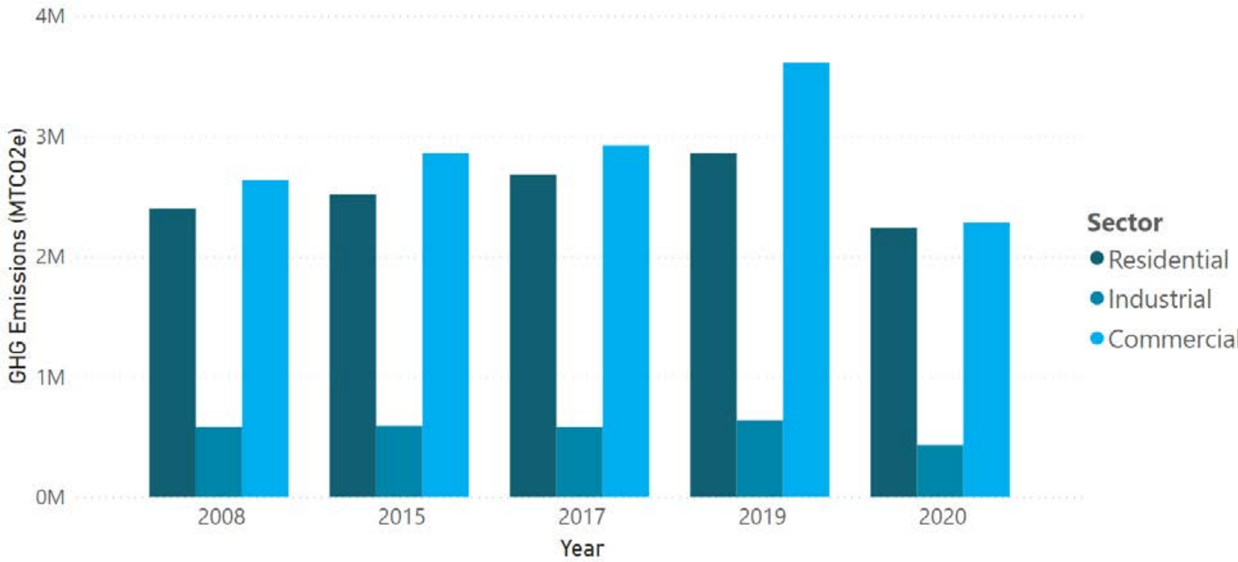


Figure 13. Electricity consumption trends, by sector.

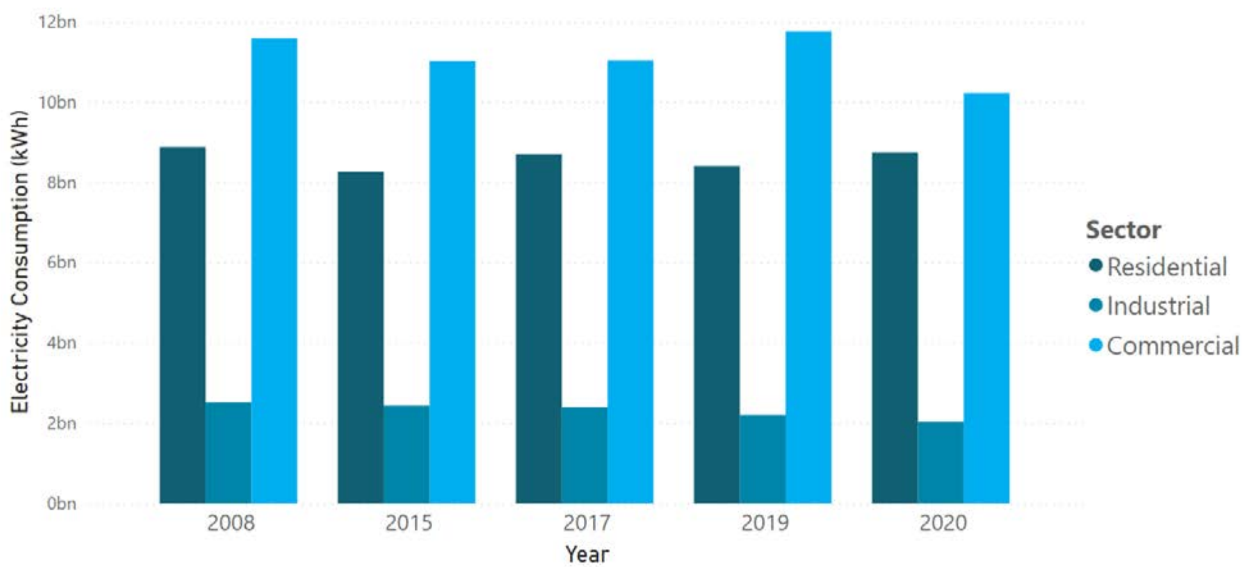
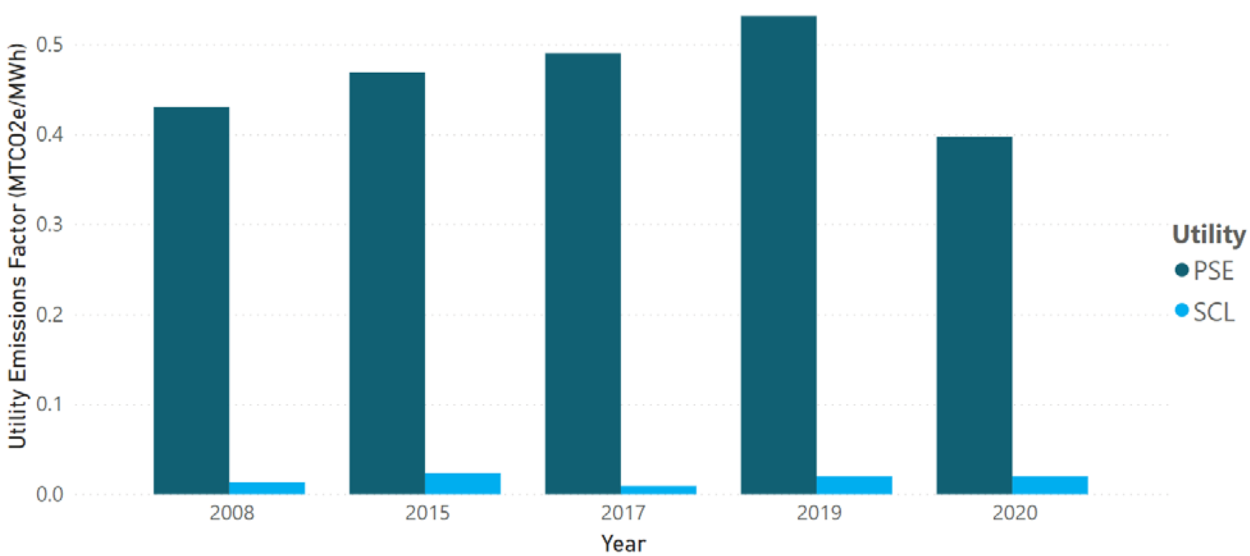


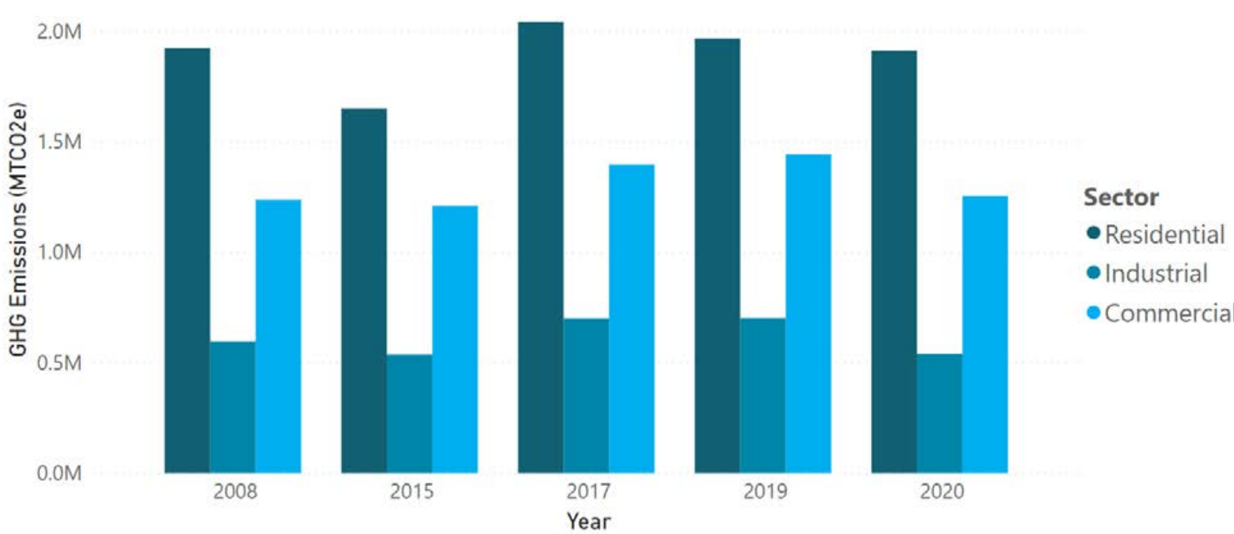
Figure 14. Electricity carbon intensities for King County electricity utilities.



Natural Gas

King County's natural gas is delivered by Puget Sound Energy (PSE). **Natural gas accounted for 15% and 16% of King County's total communitywide GHG emissions** in 2019 and 2020, respectively. Natural gas emissions in 2019 increased 10% since 2008. Natural gas emissions in 2020 were lower than those in 2019, mostly driven by a decrease in industrial and commercial natural gas use (Figure 15).

Figure 15. Natural gas emissions trends, by sector.



Other Sources

Other sources of emissions from buildings and energy include emissions from **residential, commercial, and industrial fuel oil; residential propane; and industrial processes**. These other sources account for 4% of the 2019 inventory and 5% of the 2020 inventory.

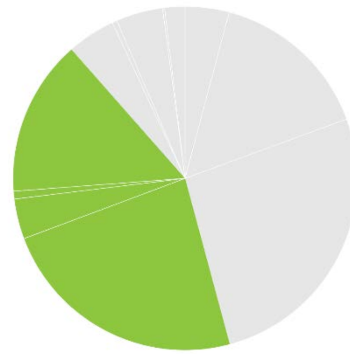
Fuel oil emissions in 2019 and 2020 decreased 44% from 2008, driven by a decrease in the overall consumption of fuel oil in Washington state.

Residential propane emissions, however, increased in both 2019 and 2020 (+29% and +4%, respectively, compared to 2008). Emissions from residential propane are very small, accounting for less than 1% of all King County emissions.

Industrial process emissions in both 2019 and 2020 decreased compared to 2008 (-5% and -7%, respectively). These trends were driven partially by a steady annual decrease—56% in 2017 and 2019—in the baseline emissions of the County's third highest emitting facility. Emissions in 2020 from the County's second-highest emitter also decreased from baseline levels.

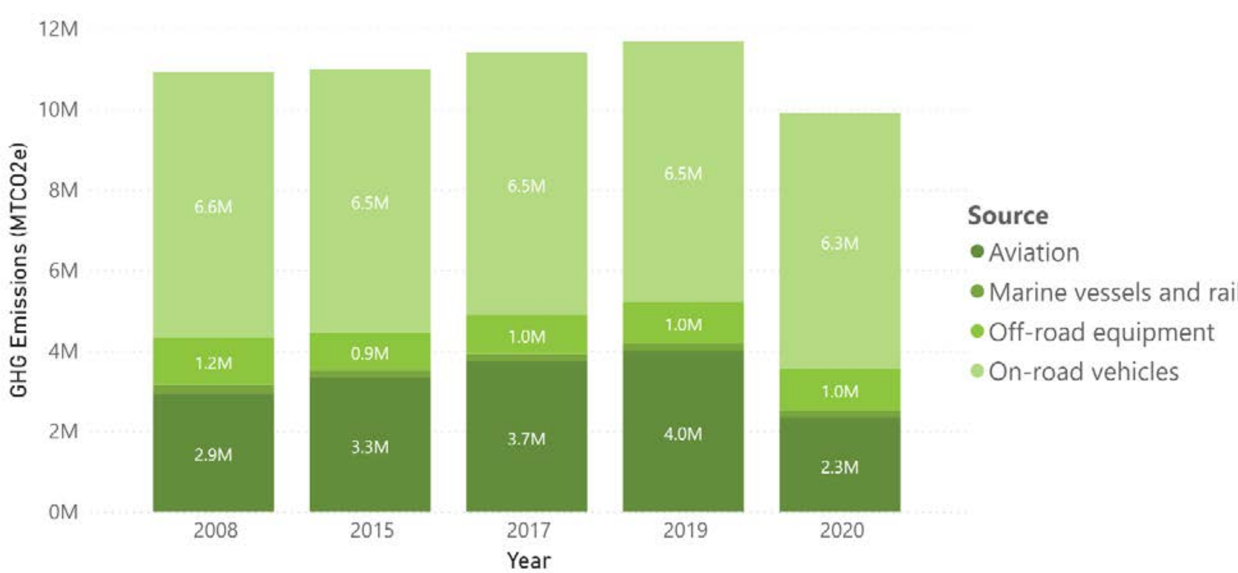
Transportation

Summary



- In both 2019 and 2020, transportation accounted for 43% of communitywide emissions.
- Emissions from onroad passenger and freight travel accounted for most of those emissions and 24% and 28% of *all* emissions in 2019 and 2020, respectively (Figure 16).
- Total and per-capita onroad passenger vehicle transportation emissions in 2019 are estimated to have decreased 6% and 20% since 2008, respectively. Emissions from freight and service vehicle transportation have increased 14% in total, but decreased 3% per capita, since 2008.
- Transportation emissions in 2019 increased 7% since 2008. Contributors to this change include population and economic growth, vehicle fuel efficiency improvements, and reductions in VMT/capita.
- In 2020, transportation emissions decreased 9% from 2008, largely driven by a decrease in flights due to COVID-19.
- Aviation emissions in 2019 accounted for 15% of total communitywide emissions and have increased 36% since 2008.

Figure 16. Transportation emissions trends, by sector.

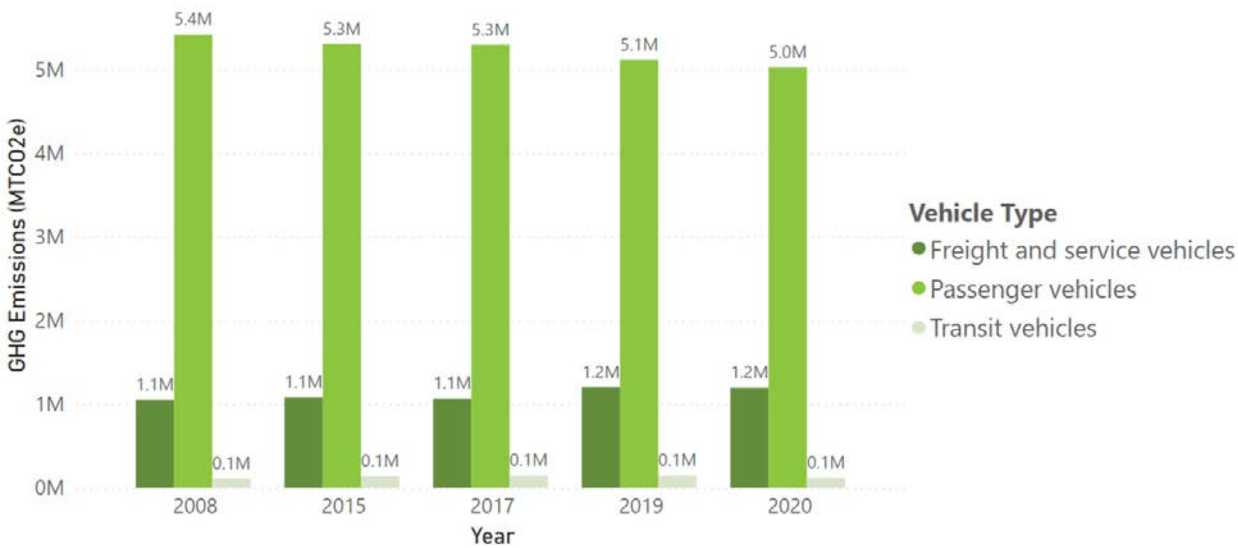


Onroad Transportation

Onroad transportation emissions include those from passenger vehicles, freight trucks, and transit vehicles within the county boundary. **Onroad tranportation activities accounted for 24% and 28% of King**

County's total communitywide GHG emissions in 2019 and 2020, respectively. Total onroad emissions in 2019 and 2020 decreased 2% and 4%, respectively, since 2008. These trends are driven by vehicle fuel economy improvements and reductions in per-person vehicle miles traveled (Figure 17).

Figure 17. Onroad transportation emissions trends, by sector.



Aviation Emissions

Aviation emissions come from fuel burned to power commercial aircraft. Attributing aviation emissions to a particular geography is challenging because aviation fuel is often burned outside the geographic boundary of the county. To better quantify the full magnitude of GHG emissions associated with air travel to and from King County, four separate approaches were used as part of this project to quantify the impact of this sector:

- A **LTO analysis**, estimating only emissions that occur within King County.
- A **passenger-based approach**, looking at all aviation fuel sold in the Puget Sound region and attributable to King County residents or visitors.
- **All fuels** sold at airports located within King County.
- A **consumption-based approach**, estimating aviation emissions from King County residents that may occur anywhere in the world.

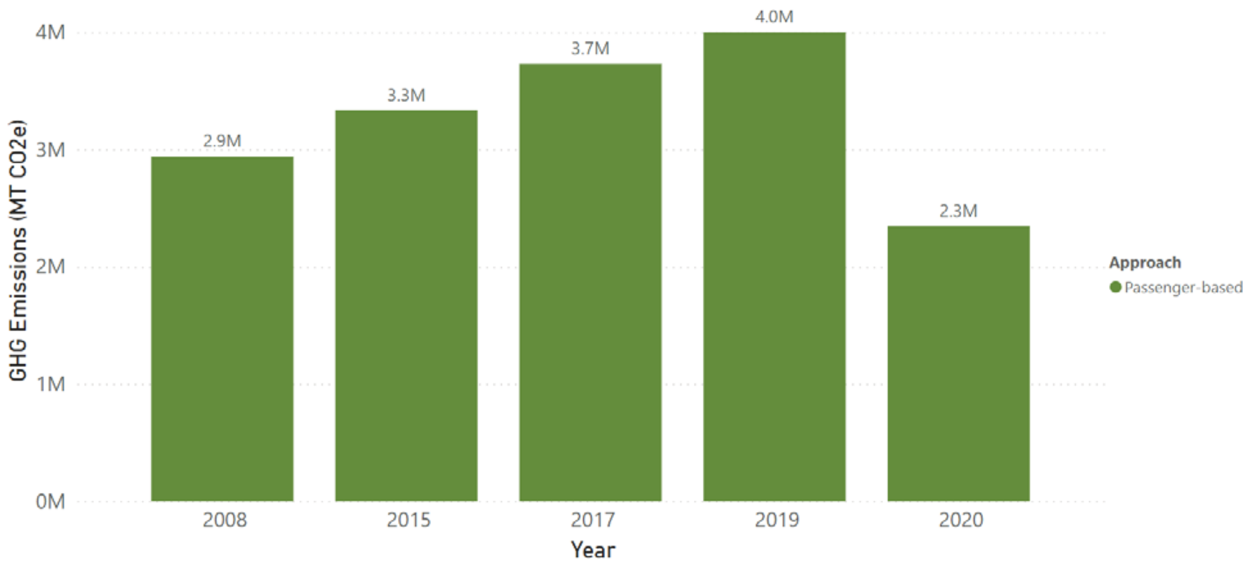
A summary of GHG emissions for each methodology is included in Table 3 below.

Table 3. County aviation sector GHG emissions for the 2019 calendar year.

Approach	Description	Per Capita ($MTCO_2e$)	Total ($MTCO_2e$)
Landing and takeoff only	**Locally generated emissions associated with airplane takeoff and landing** (incomplete, historic method recommended by local government GHG protocols, 10% of "all fuels" approach)	0.3	678,000 (~2% of total King County geographic inventory)
Passenger-based	**Total attributable to King County residents, employees, and visitors** (71% of "All Fuels"; remainder included in Snohomish, Pierce, and Kitsap County inventories; total included in geographic inventory)	1.78	3,999,000 (total proposed for geographic "wedge analysis", ~15% of total geographic inventory)
All fuels	**All fuels sold at SeaTac and KCIA/Boeing Field** (no matter the user)	3.0	6,783,000 (~25% of King County geographic inventory)
Consumption-based	**Personal air travel by King County residents** (emissions occur worldwide; excludes some work travel; excludes travel associated with residents that live outside King County; uses lifecycle GHG coefficient)	0.76	1,700,000 (included in consumption inventory and wedge analysis, ~4% of total)

Using the passenger-based approach, aviation is estimated to have accounted for 15% and 10% of King County's total communitywide GHG emissions in 2019 and 2020, respectively. Findings using this method are presented in the summary graphics for this inventory because they more comprehensively reflect the full GHG emissions associated with air travel due to County resident and business activities. In 2019, aviation emissions increased 36% from 2008, driven by a combination of population and economic growth. In 2020, aviation emissions decreased 20% from 2008 due to travel impacts from the COVID-19 pandemic (Figure 18).

Figure 18. Aviation emissions trends using the passenger-based estimation method.



Other Sources

The remaining 11% of transportation emissions are from **marine vessels, freight and passenger rail, and non-road vehicles and equipment**.

The non-road vehicles and equipment categories included in this inventory are recreational, construction, industrial, lawn/garden, agriculture, commercial, logging, airport support, oil field, pleasure craft, and railroad. Emissions from non-road vehicles and equipment decreased in both 2019 and 2020 compared to 2008 (-13% and -11%, respectively).

Overall, emissions from marine vessels and rail have decreased since 2008 (-12% and 23% for 2019 and 2020, respectively). This category includes emissions from ferries, freight and passenger rail, and maritime OGV (ocean-going vessel—shipping).

Emissions from ferries have increased since 2008 (+39% and +24% in 2019 and 2020, respectively).

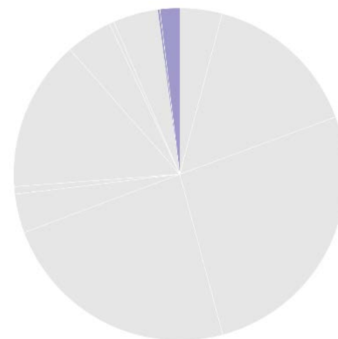
Freight and passenger rail emissions have declined since 2008 (-17% for both 2019 and 2020).

Emissions from maritime ocean-going vessels have decreased over time (-27% and -47% since 2008 for 2019 and 2020, respectively).

Drivers of these trends include the North American Emission Control Area (ECA), which came into effect in 2015 and requires vessels to use sustainable fuels near the coast, and an increase in the use of shore power. Also, there have been fewer vessel activity in recent years, including no cruise ship activity in 2020 due to the COVID-19 pandemic.

Solid Waste & Wastewater

Summary



- In 2019 and 2020, solid waste & wastewater accounted for 2% of communitywide emissions.
- Emissions from landfill accounted for most of those emissions and just under 2% of *all* emissions, respectively.
- Solid waste emissions in 2019 and 2020 decreased compared to 2008 (-22% and -26%, respectively). Contributors to this change include an increase in waste diversion and reduction in overall organic waste generation (Figure 16).
- Wastewater emissions in 2019 and 2020 increased 14% since 2008.

Solid Waste

Solid waste emissions include those from landfilling and commercial composting of solid waste. Emissions are released during the transport of waste and methane is released when organic waste is broken down under anaerobic conditions (a lack of oxygen) often found in landfills. Many landfills capture the majority of methane that is released, but some methane is leaked and released into the atmosphere. Commercial composting also releases greenhouse gases as the organic material decomposes.

Solid waste activities accounted for 2% of King County's total communitywide GHG emissions in 2019 and 2020. **Overall, solid waste emissions have decreased since 2008 (-22% and -26% in 2019 and 2020, respectively) driven by reductions in tons of waste sent to landfill and increased diversion of organic waste** (Figure 19 and Figure 20).

These estimates do not include the carbon sequestration benefits of solid waste disposal—only GHG emissions.

Figure 19. Solid waste emissions trends, by sector.

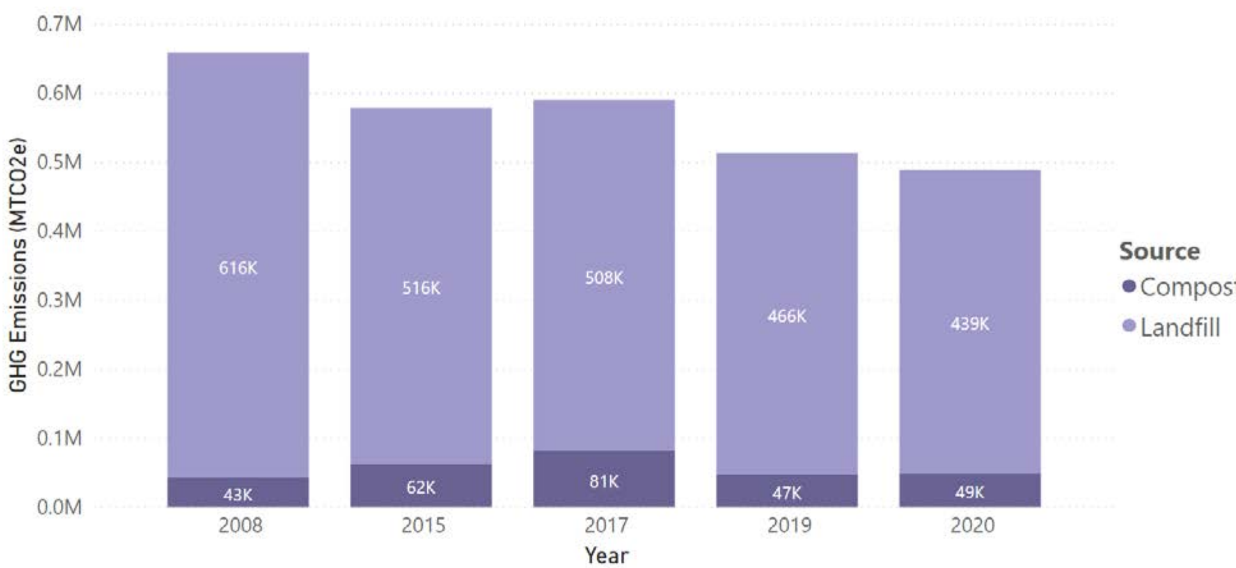
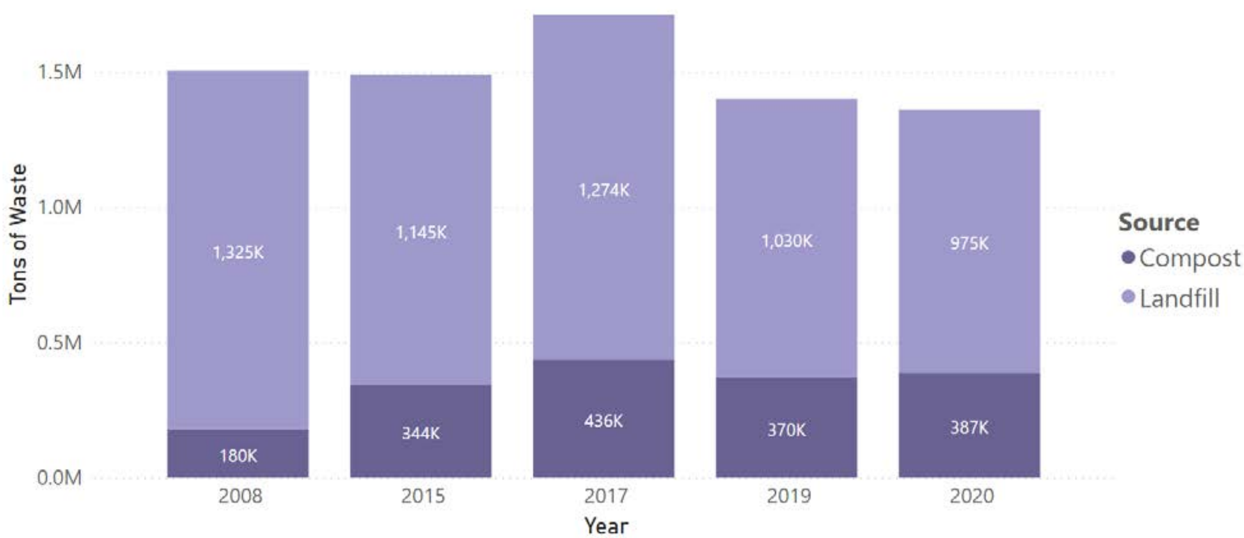


Figure 20. Solid waste tonnage trends, by sector.



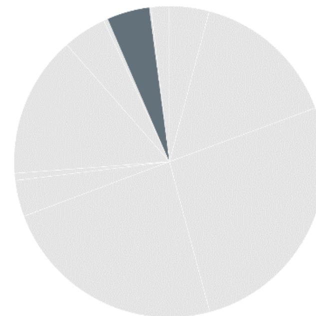
Wastewater

GHG emissions from the wastewater sector stem from the biological processing of organic wastewater products in both wastewater treatment plants and septic systems. Wastewater treatment plants also indirectly produce GHG emissions through energy use to power the wastewater treatment processes—those emissions are accounted for in the commercial electricity sector.

GHG emissions King County's emissions from wastewater have **increased over time** (+14% since 2008). This increase is tied primarily to a growing population. King County supplies biosolids as fertilizer for several Washington operations, which likely reduces the need for artificial fertilizer. The GHG benefits associated with biosolid fertilizer applicationfall outside the scope of this inventory.

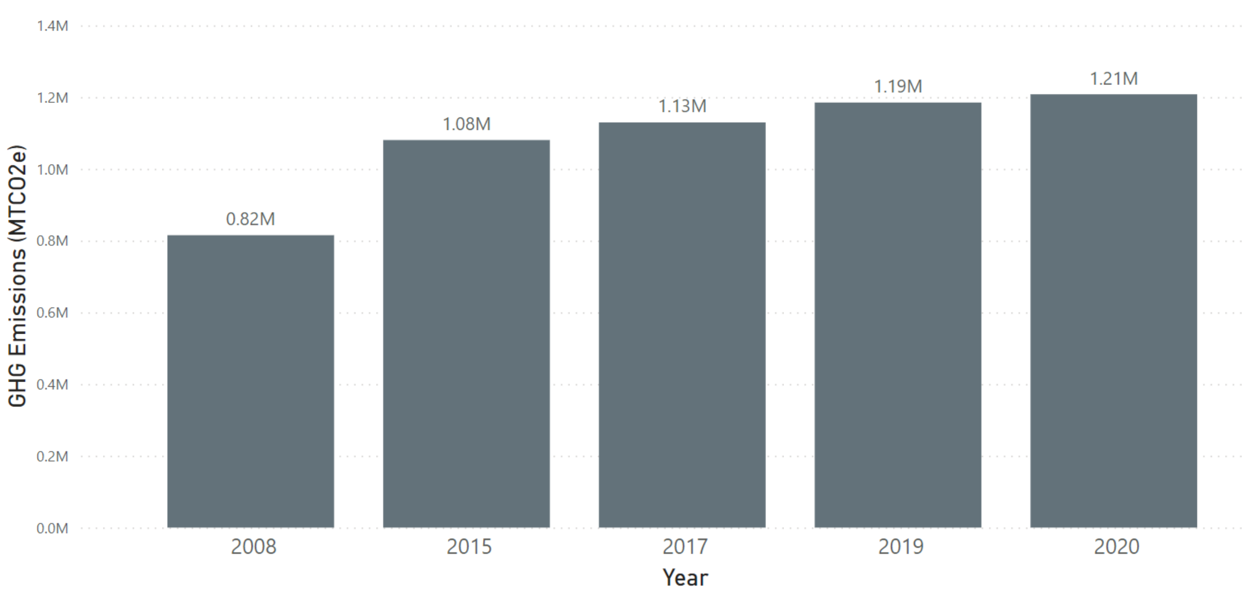
Refrigerants

Summary



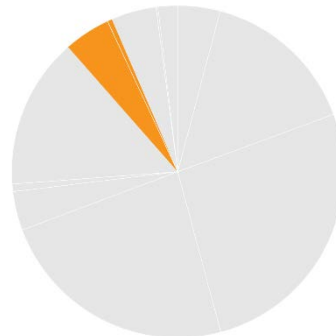
- Refrigerant emissions stem primarily from the release of hydrofluorocarbons (HFCs), which are a substitution for ozone depleting substances (ODSs). HFCs, which are greenhouse gases, are mainly used for air conditioning and refrigeration equipment (USEPA, 2014).
- In 2019 and 2020, refrigerants accounted for 4% and 5% of communitywide emissions, respectively.
- Refrigerant emissions have increased over time (+5% and +7% in 2019 and 2020, respectively, since 2008).
- The majority of refrigerant emissions in this inventory are estimated by downscaling national-level refrigerant emission data to the local level based on population. Therefore, trends in this source are a product of both national-level refrigerant trends and local population growth.
- In addition to downscaled national-level refrigerant emissions, this inventory includes fugitive SF_6 emissions from Seattle City Light.

Figure 21. Refrigerant emissions trends.



Land Use

Summary



- Land use emissions stem from agriculture and tree cover loss.
- In 2019 and 2020, land use accounted for 5% and 7% of communitywide emissions, respectively.
- Land use emissions have fluctuated over time (-8% and +5% in 2019 and 2020, respectively, compared to 2008).
- One contributor to this change is a decrease in the number of cattle since 2008.

Agriculture

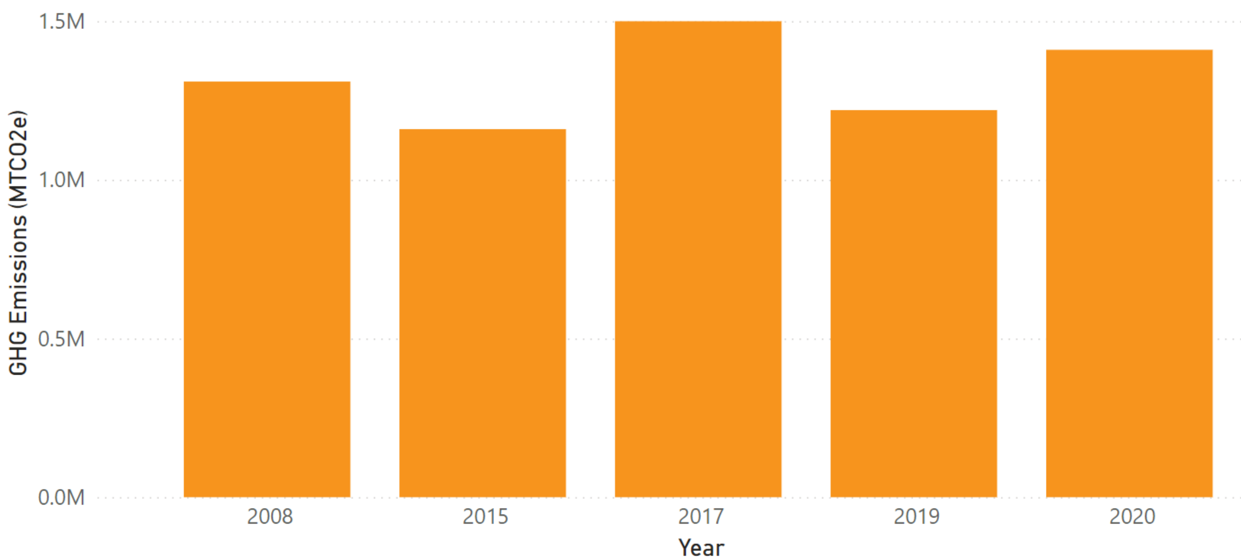
Agriculture accounts for about 1% of GHG emissions in King County, and this relative contribution has remained steady over time. Emissions are primarily derived from the release of methane and nitrous oxide associated with livestock digestion (enteric fermentation) and manure management. **Emissions from livestock and manure management** in 2019 and 2020 **decreased** 21% compared to 2008, likely due to a decrease in the number of beef and dairy cattle, which release more methane than other farm animals. Nitrous oxide emissions from soil have increased 16% from 2008 due to a larger number of cropland acres in King County and a higher rate of emissions per acre nationwide. Because the Census of Agriculture is only released once every five years, the 2017, 2019, and 2020 agricultural emissions values are assumed to be constant.

Tree Loss

Deforestation and tree cover loss by other sources accounted for an estimated 5% and 6% of King County's total communitywide GHG emissions in 2019 and 2020, respectively. Forests store carbon in tree trunks, roots, leaves, branches, and soil, so when tree cover is lost, that carbon is released into the atmosphere. Overall, **tree cover loss emissions vary annually** (-8% and +5% in 2019 and 2020, respectively, compared to 2008). In addition to deforestation due to development, tree cover loss can be driven by a number of factors, including harvesting, fire, disease, or storm damage.

These estimates do not include the carbon sequestration benefits of existing forests or tree planting (afforestation) but represent only the GHG emissions.

Figure 22. Tree loss emissions trends.



Carbon Sequestration

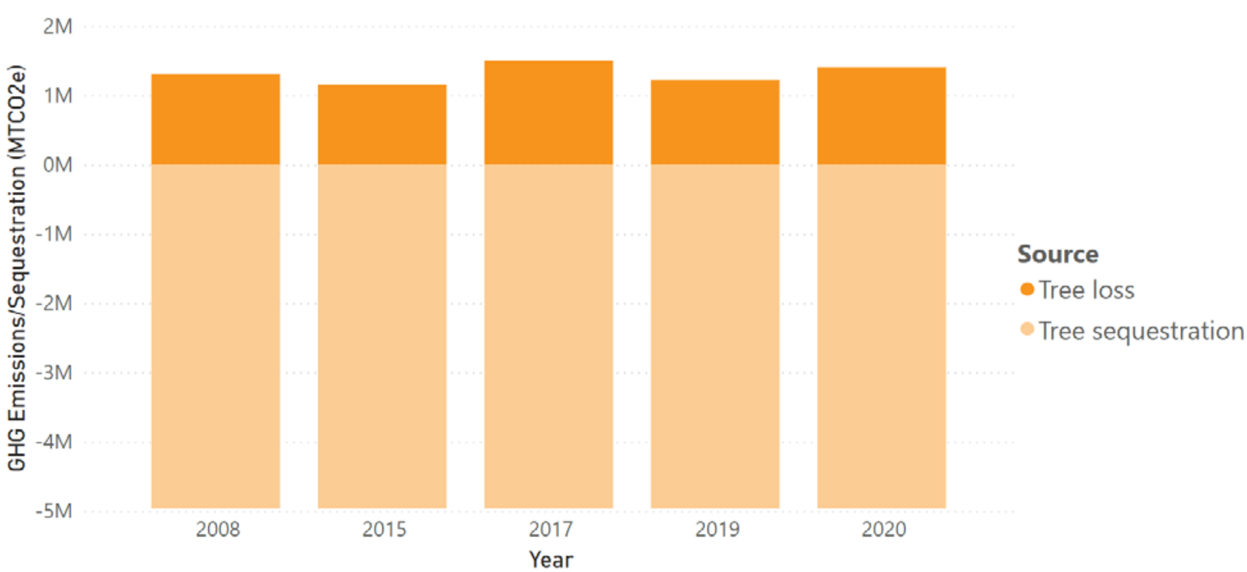
Summary

- Carbon sequestration (removal of CO_2 from the atmosphere) stems from trees removing carbon from the atmosphere and solid waste disposal.
- Total gross carbon sequestration from these sources totals 5.39 million and 5.37 million $MTCO_2e$ in 2019 and 2020, respectively.
- Contributors to changes in sequestration include net tree loss from development and forest degradation/deforestation and changes in the tons and composition of organic waste that is landfilled and composted.
- For this inventory, carbon sequestration from trees and forests was averaged over a twenty year period, so annual values do not vary. [8]

Tree Sequestration

Trees and forests in King County **sequester around 4.96 million $MTCO_2e$ per year**. Sequestration estimates are based on a variety of factors, such as the forest type, ecozone, forest age, and number of years of sequestration. Carbon removals were averaged over a twenty-year period because sequestration data was not available as a time series; therefore, sequestration values are the same across years.

Figure 23. Net forest sequestration trends.



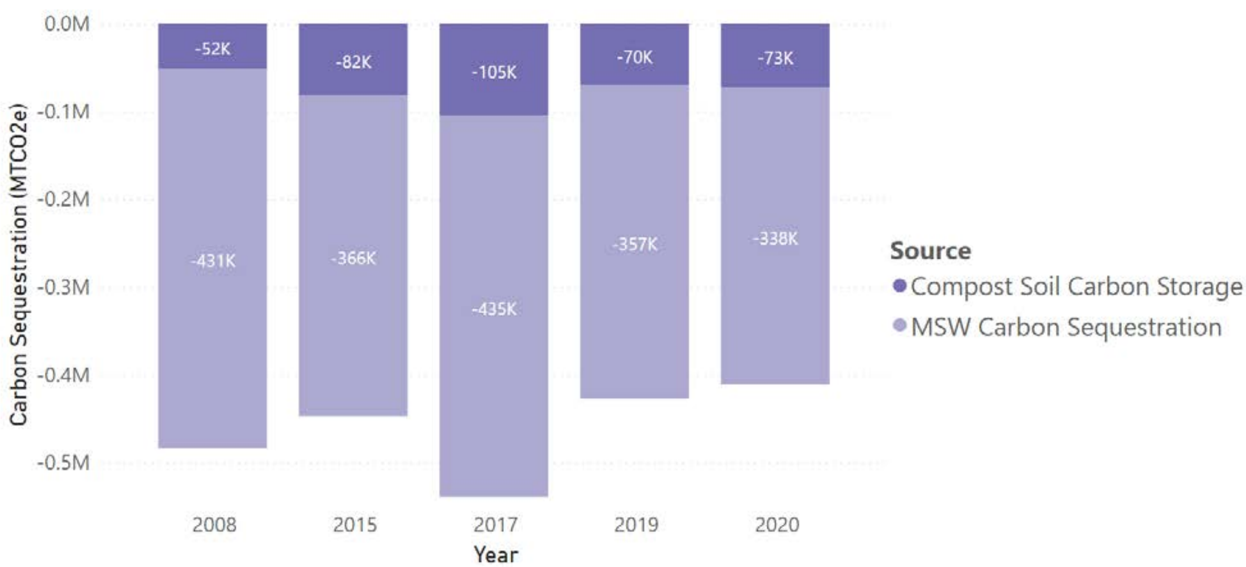
[8] Due to data limitations from the tool utilized for the inventory, World Resource Institute's Global Forest Watch (https://www.wri.org/initiatives/global-forest-watch).

Solid Waste Sequestration

Sequestration from solid waste disposal stems from sequestration of carbon-containing waste products in both landfills and composting systems (e.g., through soil amendments). When organic materials are sent to the landfill, a portion of the carbon that would naturally decompose does not; therefore, aerobic decomposition and the associated emissions are prevented.

Solid waste disposal sequestered approximately 427,000 and 411,000 MTCO2e in 2019 and 2020, respectively. Solid waste sequestration has declined over time due to reductions in overall waste generation and increased diversion rates. This geographic-focused analysis does not account for the upstream, lifecycle GHG savings associated with waste diversion.

Figure 24. Landfilling and composting sequestration trends.



What's Driving King County Emissions Trends?

Contribution Analysis Introduction

A contribution analysis allows jurisdictions to discover the reasons for changes in emissions between two inventories separated in time. This updated contribution analysis for 2015 to 2019 emissions was conducted using the tool available from ICLEI USA. [9]

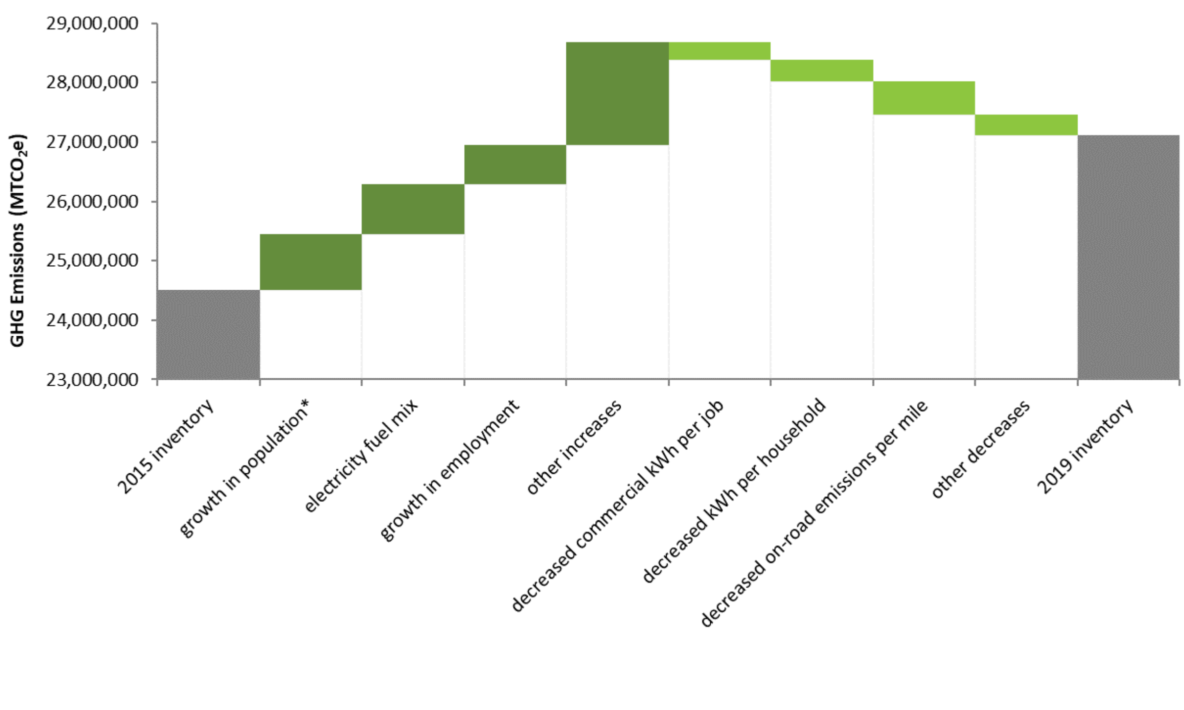
Results

In 2015, total emissions were 24.5 million $MTCO_2e$. In 2019, total emissions were 27.1 million $MTCO_2e$, a 11% increase (+2.6 million $MTCO_2e$) from the 2015 value.

Figure 25 below provides a summary of the three largest factors increasing emissions and the three largest factors decreasing emissions. The remaining increases and decreases are combined and categorized as "other increases" and "other decreases."

Emissions increases are primarily driven by growth in population and the electricity fuel mix. Increased efficiency of passenger vehicles (decreased emissions per mile) was the largest contributor to decreasing emissions. More efficient electricity use by households and commercial entities also contributed significantly to decreasing emissions.

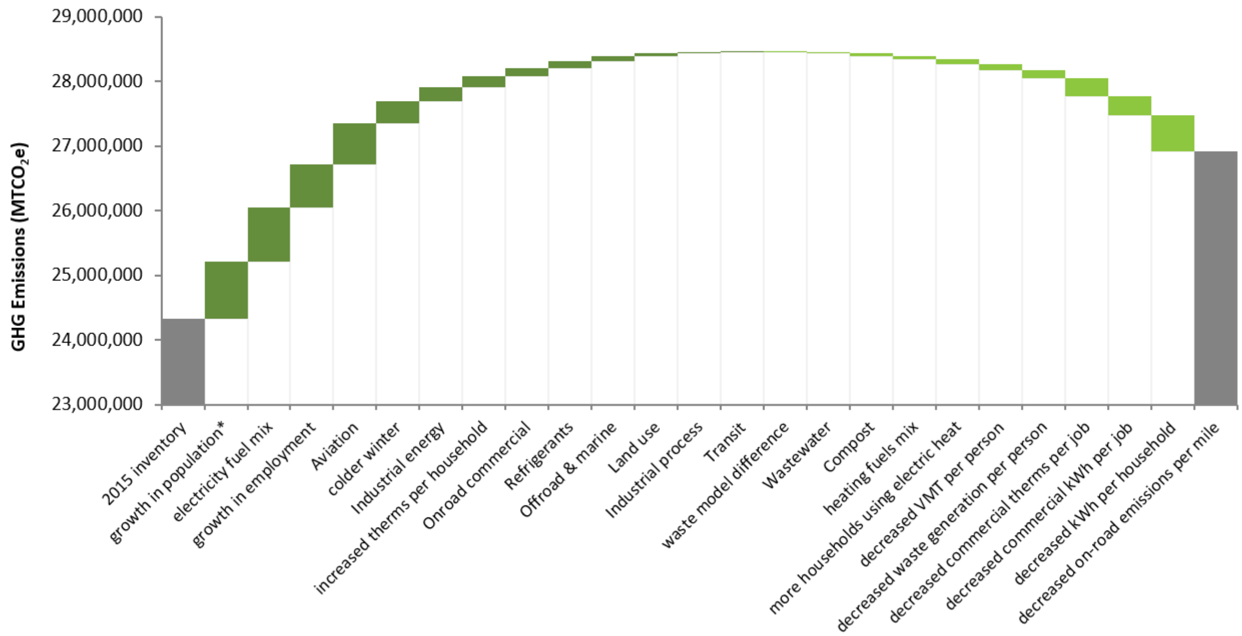
Figure 25. Top contributions to change between the 2015 and 2019 GHG inventories.



[9] Available at https://icleiusa.org/ghg-contribution-analysis/.

Figure 26 shows a detailed breakdown of the factors contributing to increases and decreases, as listed below.

Figure 26. Detailed contributions to change between the 2015 and 2019 GHG inventories.



Increases

Population (+932,150 $MTCO_2e$) includes the impacts of increased housing, increased driving, and increased solid waste generation driven by King County's growing population. King County's population increased 10% from 2.05 million in 2015 to 2.52 million in 2019.

Electricity fuel mix (+838,279 $MTCO_2e$) is the impact of shifting electricity generation sources.

Employment (+665,987 $MTCO_2e$) increases with growth in business activity in King County and drives increased consumption of energy for heating, cooling, lighting, and other building energy. King County's employment increased 15% from ~913,000 in 2015 to ~1,051,000 jobs in 2019.

Aviation (+665,392 $MTCO_2e$) is the impact of increased activity at SeaTac commercial airport. This sector is not subject to decomposition, so the bar shows the total change in emissions, driven in part by population and economic growth.

Colder winter (+333,931 $MTCO_2e$) is the increased demand for heating fuels and electricity because of colder winter weather.

Industrial energy use (+204,410 $MTCO_2e$) represents the emissions incerase from combined industrial electricity, natural gas, and other fuel usage.

Increased natural gas use per household (+130,853 $MTCO_2e$) is the net remaining change after accounting for weather, and for the percent of households shifting from fuels to electricity for heating.

This change is likely influenced by multiple positive and negative factors, including consumer behavior, changes in average home size, and changes to building and equipment efficiency.

Onroad commercial vehicles (+118,816 $MTCO_2e$) is the total change in emissions from this source, which was not subject to further decomposition.

Refrigerants (+104,494 $MTCO_2e$) this increase was driven primarily by increased use of HFCs in refrigeration/air conditioning systems, fire suppressants, and foam manufacture. This data is based on national averages and King County's population and may not reflect local changes.

Offroad and marine (+84,061 $MTCO_2e$) is the total change in emissions from these forms of transportation, which also includes change in commercial rail emissions. They are not subject to decomposition, so the bar shows the total change in their emissions, driven in part by population, economic growth, and additional, minor factors. Offroad equipment data comes from the EPA MOVES model which downscales national data and may not reflect local changes.

Land use (+49,499 $MTCO_2e$) is the total change in emissions from land use practices, including agriculture and tree loss.

Industrial process (+14,579 $MTCO_2e$) is the total change in emissions from industrial sources; it does not include industrial electricity or natural gas emissions.

Transit (+10,627 $MTCO_2e$) is the total change in emissions from public transit.

Waste model difference (+3,204 $MTCO_2e$) is the difference between the change in solid waste disposal emissions as modeled in the inventories, and the change as modeled within the contribution analysis tool.

Wastewater treatment (+2,504 $MTCO_2e$) is the total change in emissions from this source.

Decreases

Improved vehicle efficiency (-557,297 $MTCO_2e$) is the reduction in emissions associated with reduced gasoline consumption in newer vehicles meeting more stringent federal standards.

Decreased electricity use (kWh) per household (-370,675 $MTCO_2e$) represents the changes in behavior and building stock resulting in reduced residential electricity usage. This is the net remaining change after accounting for weather and transition of building heating from fossil fuels to electricity.

Decreased commercial kWh/job (-288,508 $MTCO_2e$) is the net remaining change after accounting for weather. This change is likely influenced by multiple positive and negative factors, including occupant behavior and building equipment and controls.

Decreased commercial therms per job (-120,476 $MTCO_2e$) is the net remaining change after accounting for weather. This change is likely influenced by multiple positive and negative factors, including occupant behavior and building equipment and controls.

Decreased waste generation per person (-81,785 $MTCO_2e$) is the impact of less waste per person sent to landfill.

Decreased car trips per person (-55,100 $MTCO_2e$) represents the change in driver behavior leading to less gasoline use per person.

More households using electric heat (-45,920 $MTCO_2e$) decreases emissions because of the efficiency of heat pumps and the relatively clean electricity supply in the region.

Heating fuels mix (-31,417 $MTCO_2e$) is a shift of residential and commercial uses from fuel oil to relatively cleaner energy sources.

Composting (-10,295 $MTCO_2e$) is the net change in emissions from commercial composting.

How Can We Meet Our Climate Goals?

Wedge Analysis Introduction

The wedge analysis, which includes all geographic-based King County community-scale emissions sources, forecasts emissions from 2020 through 2050 under the following three scenarios: 1) no action future; 2) federal, state, and regional policies; and 3) additional targets and scenarios. The actions in the additional targets and scenarios approach were developed to help illustrate a plausible scenario to achieve the emissions reduction goals formally adopted by King County and the 39 cities in King County as part of 2021 updates to Countywide Planning Policies. [10] The third scenarios includes a combination of existing adopted King County targets and additional scenarios explored in this analysis.

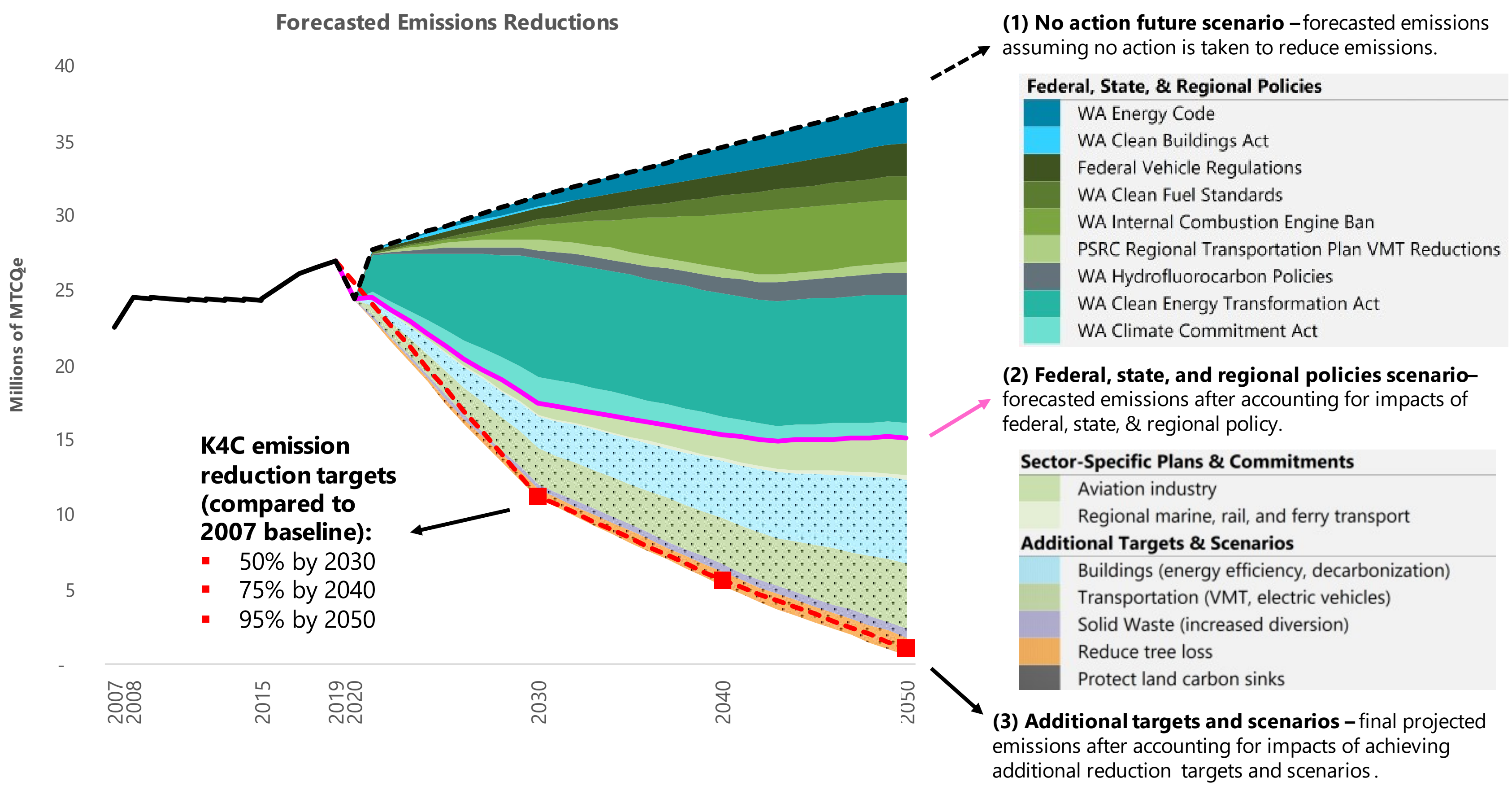
Results

As depicted in Figure 27, action by industries, governments, businesses, and individuals will all be needed to achieve the King County-Cities Climate Collaboration (K4C) targets to reach 50%, 75%, and 95% emissions reductions by 2030, 2040, and 2050, respectively, compared to a 2007 baseline. Specifically, compared to the baseline, the wedge analysis revealed the following:

- Under a **no-action future**, King County GHG emissions will increase 68% by 2050;
- **Existing federal, state, and regional policies** will reduce King County's GHG emissions by one third (33%) by 2050; and
- The estimated collective impact of the federal, state, and regional policies combined with **additional targets and scenarios** is a 50% reduction by 2030, 75% reduction by 2040, and 95% reduction by 2050. The assumptions used for this analysis are listed in Table 5.

[10] https://kingcounty.gov/depts/executive/performance-strategy-budget/regional-planning/CPPs.aspx

Figure 27. Forecasted emissions reductions under three scenarios.



No-Action Future Scenario

The "no-action future" scenario modeled King County's geographic emissions assuming no federal, state, or regional emissions reduction policies or actions. Depending on the emissions sector, changes in emissions were assumed to correlate directly with the projected population, job, and service population (population + jobs) estimates in Table 4.

Table 4. Variables used to estimate GHG emissions under no-action future scenario. [11]

% Change Compared to 2019			
	2030	**2040**	**2050**
Population	+12%	+23%	+34%
Jobs	+19%	+34%	+49%
Service Population	+15%	+27%	+40%

Federal, State, & Regional Policies Scenario

The "federal, state, & regional policies scenario" modeled King County's geographic emissions accounting for the estimated impacts of existing climate, energy, and transportation policies starting in 2019. The model sequentially models the emission reduction of each policy to eliminate the risk of "double counting" emission reductions. Therefore, the order by which policies were modeled influences their associated reductions. However, overall anticipated emissions reductions from identified policies is consistent regardless of the policy sequencing. The federal, state, & regional policies scenario resulted in a 33% emissions reduction by 2050 compared to 2007 baseline levels.

The following federal, state, & regional policies were included in this scenario in the order presented for each sector, along with their interpretation and assumptions as they relate to the wedge analysis:

WA Energy Code (SB 5854)

Interpretation: SB 5854 requires residential and nonresidential construction permitted under the 2031 state energy code to achieve a 70% reduction in annual net energy consumption (compared to a 2006 baseline). State energy codes will be adopted from 2013-2031 to incrementally move towards achieving the 70% reduction by 2031.

Modeling Assumptions: New construction in 2031 and beyond will consume 70% less energy than the 2006 baseline. Used King County's 2008 energy consumption rate as a proxy for 2006 baseline. Assumed this baseline applies to all jurisdictions. Using 2019 energy consumption rates, modeled a straight-line reduction in energy consumption rate from 2019 to 2031 to achieve the 70% reduction from baseline (in new buildings only). Assume that any additional energy consumption under BAU compared to 2019 is from "new buildings."

[11] Source: Puget Sound Regional Council

All new commercial buildings must use electric heat pumps for space heating and electric water heating for 50% of water (reflects updates to the 2021 WA State Energy Code).

- Assume commercial water heating accounts for 9% of building energy use; assume space heating accounts for 23% of building energy use (total = 32%; Source: EIA 2015).
- Assume 75% of current commercial buildings use fossil fuel space/water heating.

WA Clean Buildings Act (HB 1257)

Interpretation: Requires all new and existing commercial buildings over 50,000 square feet to reduce their energy use intensity by 15%, compared to the 2009–2018 average.

- Buildings greater than 220,000 square feet must comply by June 1, 2026
- Buildings greater than 90,000 square feet must comply by June 1, 2027
- Buildings greater than 50,000 square feet must comply by June 1, 2028

Modeling Assumptions: Using 2019 county level commercial energy consumption data, calculated energy consumed per sq ft of commercial building space to arrive at average energy use intensity (EUI: energy consumed per sq ft). Used as proxy for 2009-2018 baseline. Modeled a straight-line reduction in energy use intensity (up to 15%) for Bins 1–3 below for 2020 through respective compliance dates. Assume 15% reduction through 2050.

- Bin 1: >220K sq ft
- Bin 2: > 90K sq ft
- Bin 3: > 50K sq ft
- Bin 4: 50K sq ft and under (rule does not apply)

Federal Vehicle Regulations (CAFE)

Interpretation: Corporate Average Fuel Economy (CAFE) standards are regulated by the DOT and supported by the EPA, calculates average fuel economy levels for manufacturers and sets related GHG standards. Passenger Cars and Light Trucks require an industry-wide fleet average of approximately 49 mpg for passenger cars and light trucks in model year 2026, increasing fuel efficiency 8% annually for model years 2024–2025 and 10% annually for model year 2026. This also will also increase the estimated fleetwide average by nearly 10 miles per gallon for model year 2026, relative to model year 2021.

Modeling Assumptions: Based on PSRC Vision 2050 modeling, assumed the following changes in vehicle emissions intensity (g CO_2e/mile):

- Light duty vehicles: 33% reduction from 2018 to 2050.
- Heavy duty vehicles: 26% reduction from 2018 to 2050.

WA Clean Fuel Standard (HB 1091)

Interpretation: The Clean Fuel Standard requires a 20% reduction in the carbon intensity of transportation fuels by 2038, compared to a 2017 baseline level. Reductions in carbon intensity may be achieved through cleaner fuels or by purchasing clean fuel credits from cleaner producers such as those providing electricity as fuel. Boats, trains, aircraft, and military vehicles & equipment are excluded.

Modeling Assumptions: Model assumes the 2019 transportation fuel emissions factors are applicable for 2017–2023 (2017 is policy baseline year). Overall, policy calls for 20% reduction in carbon intensity of transportation fuels by 2038.

EV/fuel contributions: Since there are concerns with WA's short-term ability to scale up low carbon fuels, for 2030 the split of clean fuel/EV is closer to 35%/65%, compared to 50%/50% by 2038.

Therefore, compared to baseline, we modeled the following for fuel carbon intensities:

- 3.5% reduction in per-gallon gasoline & diesel vehicle (passenger, heavy duty, transit) emissions from cleaner fuels (NOT EVs) by 2030.
- 10% reduction in per-gallon gasoline & diesel vehicle (passenger, heavy duty, transit) emissions from cleaner fuels (NOT EVs) by 2040.
- Maintain 10% reduction levels to 2050.

Given ICE ban, compared to baseline, we will model the following for EV use:

- 6.5% transition of gasoline/diesel passenger vehicles to EV by 2030.
- 10% transition of gasoline/diesel passenger vehicles to EV by 2040.
- Maintain 10% reduction levels to 2050.

WA Internal Combustion Engine Ban (SB 5974)

Interpretation: Establishes a target that, "all publicly owned and privately owned passenger and light duty vehicles of model year 2030 or later that are sold, purchased, or registered in Washington state be electric vehicles."

Modeling Assumptions: As part of Move Ahead Washington program, WA would ban sale of gasoline/diesel ICE passenger vehicles starting in 2030. For ICE ban, assuming a 15-year vehicle turnover rate, with the following proportion of new sales EV (a conservative estimate given that the ICE ban is currently a goal and lacks a clear accountability mechanism):

- 25% by 2026.
- 65% by 2030.
- 100% by 2035.
- Maintained by 100% thereafter.

PSRC Regional Transportation Plan VMT Reductions

Interpretation: The Regional Transportation Plan (RTP) is a long-term transportation plan for the central Puget Sound region and is designed to implement the region's growth plan, VISION 2050, outlining investments the region is making in transit, rail, ferry, streets and highways, freight, bicycle and pedestrian facilities, and other systems.

Modeling Assumptions: Assume future passenger vehicle VMT reductions will reflect estimations from the RTP model.

WA Hydrofluorocarbon Policies (HB 1112 & HB 1050)

Interpretation: HB 1112 requires that new equipment be manufactured without HFCs or using refrigerants with a lower global warming potential (GWP) in a phased approach through 2024. Equipment covered by the law are being phased in each year, starting with 2020, and penalties apply for non-compliance. In 2021, HB 1050 applied Clean Air Act provisions for ozone depleting substances to HFCs and extended restrictions on higher GWP HFCs to new equipment such as ice rinks and stationary air conditioning.

Modeling Assumptions: Aligned model assumptions with state modeling.

WA Clean Energy Transformation Act (CETA)

Interpretation: CETA applies to all electric utilities serving retail customers in Washington and sets specific milestones: By 2025, utilities must eliminate coal-fired electricity from their state portfolios; By 2030, utilities must be greenhouse gas neutral, with flexibility to use limited amounts of electricity from natural gas if it is offset by other actions; By 2045, utilities must supply Washington customers with electricity that is 100% renewable or non-emitting, with no provision for offsets.

Modeling Assumptions: Electricity will be GHG neutral (electricity emissions factor equals zero) in 2030 and beyond with a straight-line emissions factor reduction from 2019 to 2030. For utilities that rely on coal for electricity generation, additionally model straight-line reduction to 0% coal by 12/31/2025. Assume coal is replaced by renewables. This action impacts electricity emissions factors (reduces emissions per unit of energy consumed).

WA Climate Commitment Act (E2SSB 5126)

Interpretation: The Climate Commitment Act (known as Cap and Invest) places an economy-wide cap on carbon to meet state GHG reduction targets and remain consistent with best available science, while minimizing the use of offsets to meet those targets. Every polluting facility covered under the program needs to hold one allowance for every ton of greenhouse gas that it emits. Based on an environmental justice review, 35–40% of investments must be made in overburdened communities to reduce health disparities and create environmental benefits, with an additional 10% allocated for tribal programs and projects.

Modeling Assumptions: State estimates that CCA will account for 26.2 million $MTCO_2e$ in statewide reductions by 2030. 2018 total emissions = 99.57 million $MTCO_2e$. Thus, the state anticipates that CCA will reduce total WA emissions 26% compared to current (2018) levels.

Key regulated CCA sectors relevant to the geographic inventory include:

- Natural gas (however, this sector will receive directly-allocated no-cost allowances).
- Industrial processes (however, Emissions-Intensive Trade-Exposed facilities will received directly-allocated no-cost allowances).
- Transportation fuels (however, already covered to some extent by Clean Fuels Standard).

Therefore, assume the following for CCA:

- Assume CETA addresses emissions reductions in electricity sector.
- Apply -10% emissions factor adjustment to natural gas (assuming increase in hydrogen or RNG in fuel mix) to 2030.
- Apply -15% emissions reduction estimate (consider applying a reduction factor) to industrial process emissions to 2030.
- Apply -23.5% fuel emissions factor reduction estimate (consider applying a reduction factor) to transportation emissions to 2030 and -30% to 2040 (includes reductions from CFS).

Additional Targets and Scenarios

Additional regional and local targets and scenarios were modeled to build on the federal, state, and regional policies described above. Some targets are established King County goals and some were developed for this analysis to help illustrate a plausible scenario through which King County achieve its emissions reduction goals. These additional emission reductions could be achieved through both local and regional action, including use of available funding streams such as from the state and federal government (e.g., Inflation Reduction Act and Infrastructure Investment and Jobs Act).

This project does not define or make binding recommendations for which additional targets and scenarios should be pursued to achieve overall GHG targets. However, it does provide a set of plausible additional scenarios that cumulatively would achieve emissions reductions of 50% by 2030, 75% by 2040, and 95% by 2050, compared to a 2007 baseline. These scenarios were provided based on staff and consultant subject matter expertise but are only one possible path, of many, forward. Table 5 shows this set of scenarios modeled. In addition to this scenario, an Excel-based wedge analysis tool is available to explore emissions reductions under other scenarios and jurisdictions. Specifically, inputs depicted in Table 5 can be adjusted to assess resulting emissions trends for each target year (2030, 2040, and 2050).

Table 5. Additional scenarios modeled.

	2025	2030	2035	2040	2045	2050
Electrify new buildings (% fossil fuel use converted to elect.)		100%		100%		100%
Reduce energy use in existing buildings (% reduction in energy use)		25%		35%		45%
Electrify existing buildings (% fossil fuel use converted to elect.)		20%		50%		100%*
Increase local solar (total new MW)		100			250	
Reduce industrial emissions (% reduction in emissions)		10%		50%		80%
Reduce passenger vehicle travel (% reduction in VMT)		20%				28%
Electrify passenger vehicles (% new vehicles sold that are EV)			100%			
Electrify freight/service vehicles (% new vehicles sold that are EV)		25%	50%**	75%		100%
Decarbonize offroad equipment (% reduction in emissions)		50%		75%		95%
Decarbonize aviation fuels (% reduction in fuel carbon intensity)		20%		55%		95%
Reduce air travel (% reduction in aviation fuel use)		20%		23%		25%
Divert C&D materials (% of C&D waste diverted)**	85%	85%		85%		85%
Divert other recyclable and compostable materials (% reduction in waste to landfill)		50%		75%		95%
Reduce tree loss (% reduction in tree loss)		50%		75%		100%
Protect land carbon sinks (% of current sinks protected)		100%		100%		100%

** current King County target = 80% | ** current King County target = 35%*

Adopted KC target | *Scenario for this analysis* | *Deviation from adopted KC target*

Remaining Emissions

In 2030, the largest sources of emissions under the "additional targets and scenarios" will be on-road vehicles, aviation, and natural gas, representing about 26%, 25%, and 21% of 2030 emissions, respectively. By 2050, the largest sources of emissions will be natural gas (16%), aviation (15%), refrigerants (15%), and on-road vehicles (12%). %). It is estimated that electricity will produce zero emissions by 2030 and that emissions from tree loss will be zero by 2050. The federal, state, and regional policies combined with additional targets bring King County's emissions reductions compared to a 2007 baseline to 50% by 2030, 75% by 2040, and 95% by 2050.

Figure 28. Emissions in 2019, 2030, 2040, and 2050, compared to future targets.

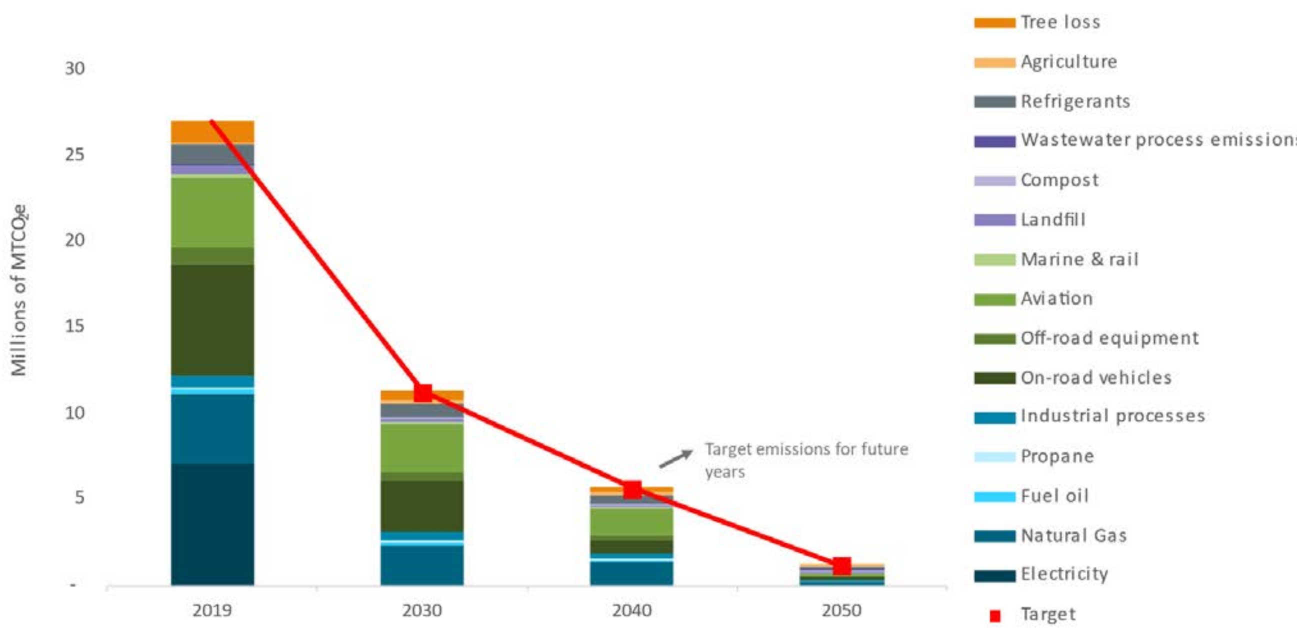
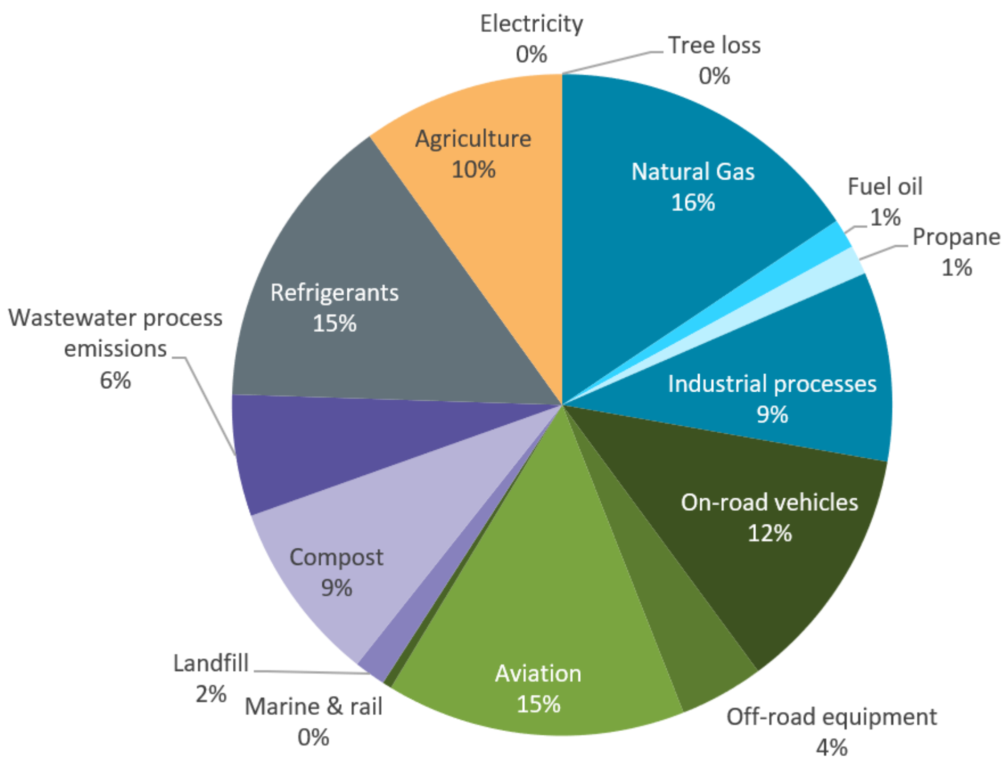


Figure 29. Remaining 2050 emissions under the additional targets scenario.

Total = 1,226,010 $MTCO_2e$



When all feasible emissions reductions are achieved, carbon removals could be considered to achieve long-term net carbon neutrality goals. Currently, we estimate that County lands sequester approximately 4,960,000 $MTCO_2e$ per year.

Appendix A. Inventory Methodology

Approach & Data Sources

Conducting the inventory involved identifying and applying activity data and emissions factors, summarized in Table 6 and detailed in the following sections:

- **Activity data** quantify levels of activity that generate GHG emissions, such as miles traveled and kWh of electricity consumed.
- **Emission factors** translate activity levels into emissions (e.g., $MTCO_2e$ per kWh).

Table 6. Key approaches and data sources for 2019 and 2020 geographic inventories.

Sector	Activity	Emissions Factors
Transportation		
On-road vehicles	Modeled vehicle miles traveled by passenger and service/freight vehicles (PSRC, 2022)	Modeled emissions from VMT, vehicle makeup, and speed assumptions in the MOVES model (PSRC, 2022)
Aviation	SeaTac and Boeing Field fuel data	EPA emissions factors for jet fuel and aviation gas (USEPA, 2021)
Non-road vehicles and equipment	Emissions from non-road vehicles (USEPA, 2020)	
Freight and passenger rail	Emissions from Puget Sound Maritime Air Emissions Inventory (PSEI), attributed by tons of cargo (Starcrest Consulting, 2018)	
Marine vessels	Emissions from Puget Sound Maritime Air Emissions Inventory (PSEI), attributed by vessel calls (Starcrest Consulting, 2018) Ferry fuel consumption estimates by route	Ferry emission factors from Ports Emissions Inventory Guidance: Methodologies for Estimating Port-related and Goods Movement Mobile Source Emissions (USEPA, 2020) EPA emissions factors for ferry fuels (USEPA, 2021)
Building Energy		
Electricity	Electricity consumption (SCL and PSE)	Utility-specific emissions factors (Puget Sound Energy, 2021) (The Climate Registry, 2021)
Natural Gas	Natural gas consumption (PSE)	Utility-specific emissions factor (Puget Sound Energy, 2021)
Fuel oil	Washington state fuel sales (EIA, 2019)	EPA emissions factors for distillate fuel oil no.1 (USEPA, 2021)

Sector	Activity	Emissions Factors
Residential propane	Western region fuel sales (EIA, 2021)	EPA emissions factors for propane (USEPA, 2021)
Industrial processes	Facility emissions collected by the EPA FLIGHT tool (USEPA FLIGHT, 2019)	
Solid Waste & Wastewater		
Solid waste generation & disposal	Annual tons disposed and composted, as reported by King County staff and waste characterization studies	EPA WARM v15 model
Wastewater process emissions	Treatment process and population data provided by wastewater treatment plants and in public records	U.S Community Protocol methodology and emissions calculations for wastewater treatment plants (ICLEI, 2013)
Refrigerants		
Substitution of ozone-depleting substances (ODS)	Nationally reported fugitive gas emissions, scaled by population (USEPA, 2021)	
Switchgear insulation (SF_6)	SF_6 emissions (The Climate Registry, 2021)	
Land Use		
Agriculture	Acres of cropland and number of livestock (USDA, 2019)	Emissions per animal or per acre (USDA, 2019) (USEPA, 2021) (ICLEI, 2013)
Tree cover loss	Acres of tree cover loss (Global Forest Watch, 2021)	Emissions due to tree cover loss (Global Forest Watch, 2021)
Sequestration		
Solid waste disposal	Landfill carbon sequestration	EPA WARM v15 model
Forest sequestration	$MTCO_2e$ sequestered by forest (Global Forest Watch, 2021)	

Built Environment

Electricity & Natural Gas

Emissions from electricity and natural gas were determined by the **kWh and therms consumed** within King County for the inventory years multiplied by the **utility- and year-specific emissions factors**.

Using Puget Sound Energy's annual reported CO_2, CH_4, N_2O, and SF_6 emissions, total kWh generated and purchased, and total natural gas supply, gas-specific emissions factors were calculated for each inventory year and applied to the total energy consumption (Puget Sound Energy, 2021). Seattle City Light's 2019 emissions factor was reported by The Climate Registry and used for both 2019 and 2020 (The Climate Registry, 2021). A contact at Seattle City Light provided a more specific emissions factor for 2019, broken down by CO_2, CH_4, and N_2O. The 2020 emissions factor is expected to be published in 2022.

Energy consumption data was procured directly from PSE and SCL for 2019 and 2020 for residential, commercial, and industrial sectors, including transport customers within those sectors.

Emissions from electricity and natural gas transmission and distribution (T&D) were also accounted for in these inventories. Emissions from electricity loss were calculated by multiplying the energy consumed by the grid loss factor from eGRID (USEPA, 2021), which follows the U.S. Community Protocol outlined by ICLEI (ICLEI, 2013). Emissions from natural gas leakage were calculated using the emissions factor provided by ClearPath, ICLEI's greenhouse gas inventory software platform (ICLEI, 2021).

Other Sources

Fuel Oil & Propane

Residential heating fuel and propane emissions were calculated using EIA state and national residential propane and heating oil sales data. King County's portion of total fuel sales were determined using ACS home heating fuel data.

Commercial and industrial fuel oil emissions were calculated using EIA industrial and commercial fuel oil sales data downscaled by the portion of industrial and commercial employees in King County. Employment data was collected from the Employment Security Department of Washington State, which provides the data on the number of employees across industries. Commercial and industrial propane sales data was not available and was thus omitted from the inventory.

Propane and fuel oil emissions were both calculated using EPA emissions factors (USEPA, 2021).

Industrial Process

Industrial process emissions were collected from the EPA Facility Level Information on Greenhouse gases Tool (FLIGHT), which collects GHG emissions reported by large facilities in King County. FLIGHT data on industrial emissions from the combustion of natural gas were removed to avoid double counting with industrial natural gas emissions calculated from utility-reported energy data.

Transportation

On-Road Transportation

On-road passenger vehicle and freight emissions were calculated by the Puget Sound Regional Council (PSRC). PSRC applied its activity-based travel model data to the EPA's Motor Vehicle Emission Simulator (MOVES) model to arrive at emissions estimations by vehicle type.

PSRC's activity-based travel model produces vehicle miles traveled (VMT), facility type, and speed estimates for time periods within a typical workday in King County. VMT outputs were provided by vehicle type for passenger vehicles, medium trucks, and heavy trucks. At the time of this inventory, PSRC had developed and calibrated this model for analysis years 2006, 2010, 2014, and 2018.

MOVES estimates from cars, trucks, and non-highway mobile sources under user-defined vehicle types, time periods, geographic areas, vehicle operating characteristics, and road types. The model simulates emissions for various vehicle operating processes, such as running, starts, or hoteling. PSRC's use of the model was run using California LEV II standards, which were adopted by the State of Washington beginning with 2009 model year vehicles. PSRC also used County-specific input files provided by the Washington Department of Ecology that reflect the climate, vehicle mix, and inspection and maintenance requirements specific to each county.

Because the PSRC model was only run for 2006, 2010, 2014, and 2018 PSRC linearly interpolated results from modeled years to estimate emissions in past inventories and for this inventory. Both activity data in VMT and the running, start, and hoteling emissions were scaled linearly in this way.

Transit emissions were calculated by multiplying fuel use for King County Metro and Sound Transit by standard fuel-specific emissions factors from the USEPA.

Aviation

Aviation emissions were based on annual jet fuel and aviation gas usage at SeaTac and Boeing Field (King County International Airport). The landing and takeoff only, passenger-based, and all fuels approaches all are estimated based on fuel consumption from the two major airports in the region, Seattle-Tacoma (SeaTac) and King County International Airport/Boeing Field (KCIA/Boeing Field). In 2019, SeaTac reported using 667,574,189 gallons of jet fuel; KCIA/Boeing Field reported using 22,250,000 gallons of jet fuel and 297,000 gallons of aviation gas. Overall, SeaTac made up 95% of total fuel sales and associated emissions between these two airports.

Fuel data was limited to these two airports; the other smaller general aviation airports in the region did not provide estimates of fuel usage, despite multiple requests from the project team. However, the included two airports account for most aviation emissions in the region. Nationally, commercial aviation is 82% of aviation emissions, with general aviation and military activity accounting for only 18% of aviation emissions. There are no military aircraft operations based in King County. While specific data was not provided, Auburn Municipal Airport, the busiest general aviation airport in the region, has published estimates [12] of 80,000 gallons of aviation gasoline sold per year, which comes out to only 665 metric tons of CO_2e – a very small amount well within the year-to-year variation of the 6.8 million metric tons of CO_2e resulting from SeaTac fuel sales.

For the passenger-based analysis, SeaTac fuel data was weighted by the percentage of travelers reported to be going to or returning from destinations in King County, based upon SeaTac airport passenger survey data. The survey data, which the Port of Seattle has collected annually since 2000, indicated that about 70% of 2019 SeaTac passengers were “origin passengers” meaning SeaTac was their final departure or arrival airport. Of these passengers, 82% were King County residents or visitors. All remaining SeaTac fuel related GHG emissions from origin passengers were distributed to the other Puget Sound jurisdictions that SeaTac serves based on income weighted population. All King County International Airport (KCIA)/Boeing Field fuel consumption was attributed to King County. Table 7 below details how SeaTac fuel was distributed using this passenger-based approach.

Based on the passenger-based approach, 57.5% of all aviation fuel sold at SeaTac and all of the KCIA/Boeing Field fuel use – and the associated emissions – were attributed to King County residents or visitors, for a total of 4 million $MTCO_2e$.

Total emissions from the passenger-based approach are included in the King County geographic inventory. This approach includes emissions attributable to King County residents, employees, and visitors. Similarly, a portion of the fuel and emissions are also ascribed to the residents, employees, and

[12] https://auburnmunicipalairport.com/community-impact

visitors of surrounding counties in western Washington. This approach excludes the 30% of fuel use and associated emissions from connecting passengers (those who take a connecting flight and do not leave the airport).

While most passengers were going to or from destinations in King County, a sizable number had destinations elsewhere in the region. As such, a comprehensive accounting of aviation fuel, including *"all fuels"* sold at these airports (not just attributable to King County residents or visitors), results in an estimate of 6.8 million $MTCO_2e$.

Table 7. SeaTac fuel distribution using the passenger-based approach.

Entity	Percent of total SeaTac fuel [13]	Total fuel (gallons)
King County residents	~57.5%	384,282,406
Kitsap County residents	~1.5%	10,241,850
Pierce County residents	~4.5%	30,471,072
Snohomish County residents	~5%	33,291,522
Thurston County residents	~1.5%	10,350,230
Connecting passengers	~30%	198,937,108
Total	**100%**	**667,574,189**

Table 8 outlines the annual fuel usage from SeaTac and Boeing Field. No other regional airports were included in this assessment due to data collection challenges. Emissions were calculated using EPA emissions factors (USEPA, 2021).

Table 8. Annual jet fuel and aviation gas usage from SeaTac and Boeing Field.

Year	Airport	Annual fuel consumption *(gallons)*	Percent of annual consumption of fuel *(SeaTac + Boeing)*
Jet Fuel			
2019	SeaTac	667,574,189	97%
2019	Boeing Field	22,250,000	3%
2020	SeaTac	385,312,040	96%
2020	Boeing Field	16,550,000	4%
Aviation Gas *SeaTac stopped using aviation gas in 2015.*			
2019	Boeing Field	297,000	100%
2019	Boeing Field	241,000	100%

Methodology Discussion: Consumption-Based Aviation Emissions

While the geographic based approaches quantify emissions related to aviation sector fuel usage, the consumption-based data is focused on air travel by King County residents for personal trips. These air travel emissions could occur anywhere in the world, for flights from any airport. The estimate is based on dollars spent on flying by King County residents. The consumption inventory also includes air travel emissions associated with goods and services purchased by King County residents, both related to work/business travel and cargo/freight aviation, though these emissions are attributed to purchased goods and services.

[13] Sum does not total 100% due to rounding.

For some individual households, personal air travel for trips is a major source of emissions. This varies significantly between households, largely due to income: air travel is a luxury for most Americans, and only the wealthiest households do substantial flying. According to Gallup survey data, between 1999 and 2015, between 48% and 60% of the US population did not fly in any given year. More recent data from Statista.com suggests that in 2019, 41% of the US had never traveled by air, and another 28% flew only about once per year. The data are limited, but further research from the nonprofit group Possible with support from the International Council for Clean Transportation suggests that a sizeable majority of flights (60% or more) are taken by a small minority of flyers (potentially as little as 12%).

While the consumption-based inventory approach is focused on air travel by residents, aviation emissions from both business travel and cargo are also included in the inventory as part of the embodied emissions of purchased goods and services. Aviation emissions for cargo (transport of goods) can be specifically broken out in the model; for nearly all categories of goods, air transport emissions account for less than 2% of the emissions associated with that category. For the average King County household, about 1.1% of total consumption-based emissions are from air transport of goods. Countywide, this is 44,000 $MTCO_2e$, out of the county's total inventory of 40 million $MTCO_2e$.

In addition to cargo, business/work travel is estimated to make up 12% of passengers and 30% of travel spending. Presently, the consumption-based inventory methodology cannot distinguish business air travel (i.e., passenger work travel, not cargo) separately from overall production emissions.

Methodology Discussion: Emissions Factors

The emission factors used for the geographic and consumption approaches differ. Under the geographic inventory approach, only direct, tailpipe emissions are included (emissions factor of 0.0097503 $MTCO_2e$ /gallon of aviation fuel). Using this tailpipe (also known as combustion based) coefficient is consistent with all other fuel sources included in the geographic inventory.

In contrast to the geographic based inventory, the consumption-based inventory also includes upstream emissions and forcing effects from contrails and high-altitude pollution (emissions factor of 0.001974 $MTCO_2e$/dollar of air travel). The consumption GHG emissions estimate is based on US national average cost per passenger mile data provided by Department of Transportation[i], combined with total US passenger miles traveled by air (DOT[ii]) and commercial aviation emissions (EPA[iii]) to get an estimated 940 g CO_2e per dollar spent. This was then multiplied by a lifecycle emissions multiplier of 2.1 to account for high-altitude radiative forcing effects (+90%) and life-cycle well-to-wheel emissions associated with jet fuel (+20%), based upon best available research provided by the CoolClimate Network at UC Berkeley.

An additional approach to estimate air travel emissions combining elements of the geographic inventory approach and consumption approach would be to add lifecycle emissions associated with high-altitude radiative forcing effects and life-cycle well-to-wheel emissions to the geographic based estimates. This approach would multiple the estimates in the geographic inventory by the lifecycle emissions multiplier of 2.1. Total emissions estimated using this approach would range up to nearly 14.3 million $MTCO_2e$ for 2019 for the “all fuels” approach using the lifecycle emissions coefficient. See additional details in table below.

GHG protocols for local governments recommend use of tailpipe GHG emissions coefficients, which may offer incomplete inventory estimates for certain sources such as aviation emissions. Certain sources such as aviation sector and fossil fuel natural gas GHG emissions have higher lifecycle emissions than those estimated in the geographic based inventory. For example, there is strong evidence that fossil fuel natural gas GHG emissions are significantly higher than tailpipe coefficient-based estimates due to methane leakage during mining, transport, and combustion.

Future GHG inventories by King County should continue to build on the best available science and improving inventory accounting protocols to quantify all sources of emissions as completely and transparently as possible – especially for complex sources such as aviation sector emissions – through estimates such as those provided in this report. Presenting aviation sector emissions in multiple, complementary approaches is meant to provide a more comprehensive picture of the emissions associated with this sector and support action to reduce these emissions.

King County Aviation Sector Tailpipe and Lifecycle GHG Emissions Totals and Comparisons (2019 calendar year)

Approach	2019 Totals Using Tailpipe GHG Emission Coefficient ($MTCO_2e$)	2019 Totals Using Lifecycle GHG Emission Coefficient ($MTCO_2e$)
Landing and takeoff only	678,000	1,423,800
Passenger-based	3,999,000	8,397,900
All fuels	6,783,000	14,244,300
Consumption-based	Not applicable	1,700,000

i. https://www.transportation.gov/policy/aviation-policy/domestic-airline-consumer-airfare-report
ii. https://www.bts.gov/content/us-passenger-miles
iii. https://www.epa.gov/sites/default/files/2021-04/documents/us-ghg-inventory-2021-main-ext.pdf?VersionId=uuA7i8WoMDBOc0M4ln8WVXMgn1GkujvD

Other Sources

Maritime & Rail

To estimate emissions from **ocean-going vessels and freight rail**, we scaled the 2016 Puget Sound Maritime Air Emissions Inventory (Starcrest Consulting, 2018) emissions estimations by 2019 cargo tonnage and vessel calls. King County's portion of ocean-going vessel maneuvering and hotelling emissions are from vessels visiting the ports within the county. Ocean-going vessel transit emissions are from vessels transiting through to either visit the ports within King County or elsewhere. King County rail emissions are from on-terminal switching and line haul and near-port line haul operations within the county. Regional freight emissions transiting through King County were scaled using rail throughput tonnage published in the Washington State Rail Plan (WSDOT, 2020).

Data from Washington State Ferries route statements and annual reports on fuel cost by route and total fuel consumption were used to estimate **ferry** emissions.

Non-Road Vehicles and Equipment

Emissions from **non-road vehicles and equipment** were calculated using EPA MOVES3, a model that estimates emissions from mobile sources (USEPA, 2020). The non-road sectors from the MOVES3 model included in this inventory are recreational, construction, industrial, lawn/garden, agriculture, commercial, logging, airport support, oil field, pleasure craft, and railroad. The model produces CH_4 and CO_2 emissions per sector for gasoline, LPG, CNG, and diesel.

Solid Waste & Wastewater

Solid Waste

Emissions from **generation and disposal of solid waste** were estimated by multiplying the tons generated by material type-specific emissions factors derived from the EPA WARM v15 model (USEPA, 2020). We obtained waste and compost composition data from the 2020 Washington Statewide Waste Characterization Study (Ecology, 2020), or data obtained directly from the County, where available. Seattle waste emissions were calculated separately from King County to account for different landfill management scenarios. We translated these waste composition data into the EPA WARM categories and applied landfill gas capture estimations to estimate methane emissions (we assumed the most aggressive landfill gas capture scenario available in the WARM model for King County landfills and average landfill gas capture for Seattle generated waste).

Wastewater

King County's emissions from **wastewater** come from treatment processes and combustion of waste gas, which produces both methane and nitrous oxide. Emissions were calculated for all three of King County's wastewater treatment plants—West Point, Brightwater, and South Plant—as well as the estimated 86,000 septic systems around the county. Emissions were estimated based on the type of treatment processes at a given plant—such as the use of anaerobic digestion—as well as the size of the population served. Emissions were calculated using equations and emissions factors provided by the U.S. Community Protocol (ICLEI, 2013).

Refrigerants

To estimate emissions from the **substitution of ozone-depleting substances**, national emissions reported by the EPA were scaled by population for King County (USEPA, 2021). Additionally, **SF_6 emissions from switchgear insulation** reported by Seattle City Light were included in the inventory as refrigerants; these annual greenhouse gas reports were accessed through the Climate Registry (The Climate Registry, 2021). SF_6 emissions from other electricity utilities were included in the electricity emissions section, as we assume that these emissions are integrated into overall $MTCO_2e$/kWh emissions factors reported by the utilities.

Land Use

Agriculture

Agricultural emissions were calculated following the methodology from the U.S. Community Protocol, developed by ICLEI. Agricultural emissions stem **from livestock enteric fermentation, manure management, and soil**.

For these calculations, the EPA Inventory Annexes provided values for the following: livestock enteric fermentation emissions factors, distribution of waste management systems, typical animal mass, daily and annual volatile solid production rates, maximum CH_4 producing capacity per pound of manure, methane conversion factors based on manure management system, daily excreted nitrogen rates, nitrous oxide emissions factors, nitrogen lost through volatilization, and nitrogen lost through runoff and leaching. The U.S. Community Protocol Appendix G provided values for volatilization and runoff/leaching emissions factors. Data on the number of animals in King County was sourced from the USDA 2017 Census of Agriculture. The EPA Inventory and Inventory Annexes provided nationwide values for direct and indirect N_2O emissions from soils, and the total U.S. cropland acreage was provided by the 2017 USDA Census of Agriculture. This national data was used to create an emissions factor for soil, which was applied to the acres of cropland in King County.

The USDA publishes the Census of Agriculture every five years, so the animal number values are not directly aligned with inventory years. For this inventory, the 2007 census numbers were used for the 2008 inventory, the 2012 numbers were used for the 2015 inventory, and the 2017 numbers were used for 2017, 2019, and 2020. The 2022 Census of Agriculture currently underway.

Tree Loss

Emissions from tree cover loss were estimated by the **Global Forest Watch**, which was established by the World Resources Institute. Global Forest Watch's online tool estimates **annual tree cover loss** at the county level. Tree cover loss does not necessarily indicate deforestation, as it can result from harvesting, fire, disease, or storm damage (Global Forest Watch, 2021).

This data set defines tree cover as all vegetation that is taller than five meters, with a data resolution of 30 by 30 meters. Emissions estimates include CO_2, NH_4, and N_2O and relevant carbon pools, such as aboveground and belowground biomass, dead wood, and soil. Global Forest Watch uses calculation methods that follow IPCC greenhouse gas inventory guidelines and are described in Harris et al. 2021 (Harris, et al., 2021). Emissions estimates are also influenced by factors such as the driver of disturbance, whether fire was observed before the disturbance event, and if the tree loss occurred on peat (Global Forest Watch, 2021).

Global Forest Watch reports 75% confidence that the tree loss occurred within the year selected for analysis and 97% confidence that the loss occurred within one year before or after the selected year (Global Forest Watch, 2021).

Carbon Sequestration

Solid Waste

U.S. EPA WARM v15 model defines carbon sequestration as removal of carbon (usually in the form of carbon dioxide) from the atmosphere, by plants (through forest carbon sequestration) or by technological means (landfill carbon sequestration).

Tree Sequestration

Carbon sequestration by tree cover was estimated by the **Global Forest Watch**. The online tool estimates metric tons of CO_2e sequestered at the county level. Sequestration estimates are based on **forest type, ecozone, forest age, and number of years of sequestration**. Carbon removals were averaged over a twenty-year period because sequestration data was not available as a time series; therefore, sequestration values are the same across years.

Approach & Data Limitations

Notable limitations of our approach and data sources are summarized below:

- **Land use change emissions and sequestration:** Global Forest Watch provides county-level annual emissions from tree cover loss and an average annual sequestration value. The tool does not provide year-specific sequestration rates or values; the annual sequestration value is an average of sequestration in King County over the time period 2001–2020. Global Forest Watch also does not have data on annual forest cover gain or total forest cover acreage by year (Global Forest Watch, 2021).
- **Propane and fuel oil:** EIA industrial and commercial propane sales data was not available so these emissions were not calculated for this inventory. EIA residential propane data was only avaiable at the regional level, so the analysis required downscaling total sales from the entire western region (Alaska, Arizona, California, Hawaii, Nevada, Oregon, and Washington).
- **Agriculture:** The Census of Agriculture is published by the USDA every five years, so numbers of animals and acres of cropland are the same for the 2017, 2019, and 2020 inventories (USDA, 2019).
- **2020 estimates:** In some cases, 2020 data were not yet available or may not reflect unique COVID-driven conditions. For example, the 2020 Seattle City Light emissions factor was not yet available at the time of this inventory, and the PSRC onroad transportation estimates were based on an extrapolation of a 2018 model run, and so may not reflect year-to-year anomalies.
- **Aviation:** Aviation emissions are attributed based on passenger data from SeaTac. At the time of this inventory, King Count was the only county for which quantiative survey data was available. Therefore, attribution of SeaTac fuel consumption to the other counties is an estimate based on a qualitative summary of survey data.
- **Refrigerants:** Emissions from refrigerants are scaled by national data, so they do not take into account local factors (e.g., milder summers that result in less air conditioning).

Furthermore, not all inventory values are based on locally derived data. Table 9 summarizes some of the limitations and sensitivities of data used in the inventory.

Table 9. Summary of data sensitivity to local conditions for the 2019 geographic inventory.

Sector	Percent of total 2019 emissions	Values are sensitive to local conditions	Values are sensitive to local conditions, with some exceptions	Values are based on scaled regional/state data	Values are based on scaled national data
Transportation	**43%**				
On-road vehicles	24%		✓		
Aviation	15%			✓	
Non-road vehicles and equipment	4%			✓	
Freight and passenger rail	<1%		✓		
Marine vessels	<1%		✓		
Building Energy	**46%**				
Electricity	26%	✓			
Natural gas	15%	✓			
Fuel oil	1%			✓	
Residential propane	<1%			✓	
Industrial processes	2%		✓		
Solid Waste & Wastewater	**2%**				
Solid waste generation & disposal	2%		✓		
Wastewater process emissions	<1%		✓		
Refrigerants	**4%**				
Substitution of ozone-depleting substances (ODS)	4%				✓
Switchgear insulation (SF_6)	<1%	✓			
Land Use	**5%**				
Agriculture	<1%		✓		
Tree cover loss	5%	✓			
Sequestration	N/A				
Solid waste disposal	N/A		✓		
Forest sequestration	N/A	✓			

Methodology Updates

Several methodological differences between the current inventory and previous inventories led to changes in GHG emissions reported (see Table 6). The values reflected in this inventory report for current and previous inventory years (2008, 2015, 2017, 2019, and 2020) have been calculated using the current methodology.

Table 6. Brief methodological outline of previous inventories and the 2019 inventory.

Sector	Methodology for Previous Inventories	Methodology for 2019 Inventory Update
Transportation		
On-road vehicles	PSRC activity-based travel model applied to MOVES model	Same, with additional attribution by vehicle fuel type
Aviation	Jet fuel and aviation fuel usage downscaled through a standard LTO estimate	SeaTac jet fuel usage downscaled to jurisdiction through passenger survey data; Boeing Field jet fuel and aviation gas usage
Non-road vehicles and equipment	MOVES2014 model	MOVES3 model (newest version)
Freight and passenger rail	PSEI inventory	PSEI inventory, scaled to years/jurisdictions by tonnage
Marine vessels	PSEI inventory used for OGV, ferry fuel consumed and latest harbor craft emission factors from EPA guidance.	PSEI inventory, scaled to years/jurisdictions by tonnage and vessel calls. Ferry fuel consumed by route.
Building Energy		
Electricity	kWh consumed and emissions factors based on WA Fuel Mix Disclosure reports	kWh consumed and utility-specific emissions factors calculated or pulled from utility emissions reports
Natural Gas	Therms consumed and EPA natural gas emissions factor	No change
Steam	Steam emissions included	Steam emissions assumed to be already accounted for by commercial and industrial natural gas consumption and industrial processes
Fuel oil	EIA sales data downscaled using ACS house heating data	Methodology remained the same; used ACS 5-year estimates, which are more comprehensive than the previously used 1-year estimates
Residential propane	EIA sales data downscaled using ACS house heating data	Methodology remained the same; used ACS 5-year estimates, which are more comprehensive than the previously used 1-year estimates
Industrial processes	Calculated emissions from individual King County facilities	All facility emissions collected by the EPA FLIGHT tool

Solid Waste & Wastewater		
Solid waste generation & disposal	Applied "custom" modified version of EPA WARM v14 emissions factors to tonnage estimates	Applied more "standard" emission factors from EPA WARM v15 emissions factors to tonnage estimates
Wastewater process emissions	Included biogas emissions, BOD_5 emissions, and septic systems	No change
Refrigerants		
Substitution of ozone-depleting substances (ODS)	National EPA value scaled to region by population	No change
Switchgear insulation (SF_6)	SF_6 emissions from PSE and SCL	PSE SF_6 emissions reflected in PSE emissions factor and not included in refrigerants
Land Use		
Agriculture	Enteric fermentation and manure management from U.S. Community Protocol	Calculations updated to more closely align with the U.S. Community Protocol
Tree cover loss	Permit data and carbon storage assumptions	Global Forest Watch estimates
Sequestration		
Solid waste disposal	Apply tons to WARM v14 emissions factors	No change (applied to WARM v15 emissions factors)
Forest sequestration	Not included	Global Forest Watch estimates

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