2020 Community Greenhouse Gas Emissions Inventory

Seattle

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Dear Friends and Partners,

Seattle, like many cities across the country, conducts regular greenhouse gas emissions inventories to measure the scope and scale of our climate pollution and help identify where the opportunities are for the greatest future impact. While our reports are conducted on a regular basis, this year's 2020 inventory report is anything but normal, as it captures for the first time the unprecedented change and disruption the COVID-19 pandemic brought to people's lives.

In March of 2020, Seattle, like much of the nation and world, went into lockdown to prevent the rapid spread of the deadly COVID-19 virus. Offices and buildings in our downtown core and throughout the city shuttered and went vacant as people remained at home, and all non-essential personal and public transportation came to a halt. The corresponding measurements show a dramatic – but not unexpected – decrease in transportation emissions (24.5%) and a decrease in commercial building emissions (5%).

Despite this seemingly positive step in reducing emissions, we must view this year's inventory in the context of the COVID-19 pandemic. Fossil fuel extraction and consumption is still the single-largest contributor to climate change, harmful air pollution, and environmental degradation, all of which disproportionately impact Seattle's Black, Indigenous, and Communities of Color (BIPOC). We must not accept these disparities as something we are powerless to address.

Under the framework of the newly released One Seattle Climate Justice Agenda, we have seen unprecedented investments to support policies and programs aimed at building an equitable clean energy economy, ensuring a just transition away from fossil fuels, and building healthy and climate resilient communities.

I am grateful and excited to see what comes next with our Green New Deal for Seattle, and we're moving forward with policies to reduce emissions from commercial buildings and help low-to-middle income residents transition from dirty oil to clean heat pumps, as well as embracing new transportation policies that prioritize transit and the electrification of vehicles that move people, goods, and services throughout our City.

We know the road ahead will be a long and arduous journey, but we're ready to come together as One Seattle to do the work to center community in efforts and scale what we know works and take advantage of unprecedented opportunity with new federal, state, and local funding to reduce emissions and adapt to current climate impacts. I thank you for your support and more to come!

Sincerely,

Jessyn Farrell, Director
Seattle Office of Sustainability & Environment

Introduction and Context

The Role of a Greenhouse Gas Inventory in Equity-Centered Climate Action

Tracking greenhouse gas (GHG) emissions across the buildings, transportation, industrial, and waste sectors helps the City develop effective programs and policies designed to reduce climate impacts. This GHG emissions inventory reports on the sources and magnitude of Seattle's core GHG emissions and provides short- and long-term trends so the City of Seattle and its residents are better able to take informed actions to combat the climate crisis.

Seattle's climate leadership has resulted in progressive energy efficiency policies and a robust public transit network which has in turn helped achieve one of the lowest per-capita emissions rates relative to North American peer cities. Our early climate investments started us off in the right direction to reduce emissions, however, as our population and economy continue to grow, we need a greater degree of reductions primarily from eliminating fossil fuel use through electrifying our buildings and vehicles to achieve our climate goals.

Centering Climate Justice

Climate change is a racial justice issue at its core. Seattle's increasing consumption of fossil gas harms our Black, Indigenous, and People of Color (BIPOC) communities who unequally bear the burden of climate change, air pollution, and environmental degradation. While this GHG inventory provides a broad understanding of how our emissions are trending, it is not detailed enough in scope or depth to use as the primary source for making decisions that center racial equity. To address this gap, Seattle is working on developing a Climate Portal which aims to house more frequent and granular indicators of emissions in our neighborhoods.

Research indicates that BIPOC communities in the U.S are more concerned than whites about climate change[1], yet historically, environmental decisions on policy, communications and programming have been made by those with race and class privilege. It is therefore imperative that we center this context and prioritize partnering with BIPOC communities to shape equitable climate policy for the City when analyzing the results of this inventory.

ICLEI and Scope of Emissions

The International Council for Local Environmental Initiatives (ICLEI) – Local Governments for Sustainability is an international organization of local and regional government organizations that have made a commitment to sustainable development. The ICLEI's USA program was founded in 1991 and created the Cities for Climate Protection, the world's first and largest program supporting cities in climate action planning to reduce GHG emissions measurably and systematically.[2] This GHG inventory follows the national standards set forth by ICLEI – Local Governments for Sustainability USA as outlined in their "U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions", which outlines methodology for community-scale GHG emission inventories. These standards make it easier for the city to compare its emissions with other cities and past inventories.[3]

[1] https://climatecommunication.yale.edu/publications/race-and-climate-change/
[2] http://icleiusa.org/about-us/who-we-are/
[3] ICLEI, Greenhouse Gas Protocols, *U.S. Community Protocol*. http://icleiusa.org/ghg-protocols/

The emission sources covered in the "core emissions inventory" correspond to ICLEI's "local government significant influence" framework. The "expanded emissions inventory" correspond to ICLEI's "community-wide activities" framework and include GHG emissions released within community boundaries and due to community activities, such as energy consumption and waste disposal.

Core Emissions

Sector	Subsector(s)	Categories
Buildings	Residential	Heating Oil, Puget Sound Energy, Seattle City Light
	Commercial	CenTrio Steam, Heating Oil, Puget Sound Energy, Seattle City Light, UW Steam
Transportation	Road: Passenger	Buses, Cars, Light-Duty Trucks
	Road: Trucks	Medium- & Heavy-Duty Trucks
Waste	Residential, Commercial, Self-Haul	All waste materials
Offsets	Residential, Commercial	Seattle City Light

Table 1: 'Core Emissions' categories delineated by sector and subsector

Core emissions include the transportation, buildings, and waste sectors as well as GHG offsets. Core emissions sources are those the city can most directly and significantly impact. Most of the City's climate policies and programs are aimed at reducing our core emissions.

Expanded Emissions

Sector	Subsector(s)	Categories
Buildings	Residential	Yard Equipment
	Commercial	Commercial Equipment
Industry	Energy Use	Industrial Equipment, Heating Oil, Puget Sound Energy, Seattle City Light, King County Wastewater Treatment
	Fugitive Gasses	Gas Infrastructure Leaks, (Sulfur Hexafluoride) SF6 from Switchgear
	Process	Cement, Glass, Steel
Transportation	Air	King County Airport (KCA), Sea-Tac Airport (SEA)
	Marine	Hotelling, Pleasure Craft, State Ferries, Other Boat Traffic
	Rail	Freight Rail, Passenger Rail
Waste	Construction & Demolition	All waste materials
	Wastewater	Fugitive Emissions
Sequestration	Commercial, Residential, Self-Haul	Waste materials with high carbon content[4]
Offsets	Industrial	Seattle City Light

Table 2: 'Expanded Emissions' categories delineated by sector and subsector

[4] Specific high-carbon content materials such as wood scraps and lumber unfortunately still make it into our landfills. Their sequestration of carbon is represented as negative emissions in this category.

Expanded emissions include all core emission sectors as well as additional sectors, subsectors, and categories. The table below identifies the sectors, subsectors, and categories included under core emissions and additional ones included under expanded emissions.

Consumption-based Emissions

Consumption-based inventories account for the emissions associated with the goods and services consumed within the community, no matter where they are produced. This includes embodied emissions associated with production, transportation, use, and disposal of goods, food, and services consumed. Consumption-based emissions inventories help communities understand how consumption of goods and services by their community contributes as a root driver of GHG emissions on a global scale.

For example, while the core and expanded inventories capture the emissions generated by a car while it is being driven in Seattle, they do not capture the emissions generated elsewhere in sourcing the raw materials or assembling the vehicle in a factory. Such emissions likely occurred outside the U.S. or inside this country, but outside of Seattle.

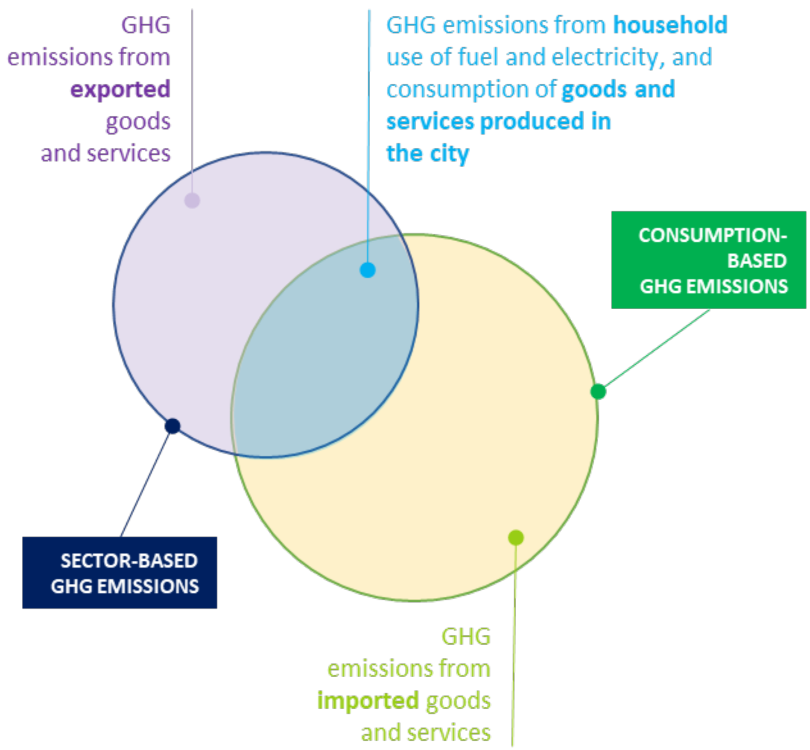


Figure 1: Comparison showing the scale of sector-based emissions versus consumption-based emissions.[5]

Figure 1 compares the scope of sector-based, or geographic, and the consumption-based GHG inventories. Consumption-based emissions can be over twice as much as the geographic-based emissions that this report covers.

[5] C40 Cities Report: Consumption-Based GHG Emissions of C40 Cities. Page 8.

Seattle is partnering with King County on the County's consumption-based emissions inventory analysis update for calendar year 2019, which will be published to King County's website when available.

To advance Seattle's vision of zero waste[6], we support and promote policies and practices that create a circular economy and reduce Seattle waste and carbon pollution as rapidly as possible (e.g., food waste prevention and food rescue, building deconstruction and building materials salvage, promotion of reuse and repair). That's why Seattle is increasingly focusing on waste prevention strategies and metrics in solid waste programs and policies. To prevent waste, which is proven to lead to best results in terms of reducing pollution and resource use, Seattle is looking "upstream" at how products and packaging are made for opportunities to prevent or reduce waste from the start. The consumption-based emissions inventory could potentially provide a baseline for measuring the impacts of waste prevention efforts and information about how to reduce our consumption-related climate impacts.

What is a circular economy?

A circular economy aims to ensure that materials and products keep cycling through new uses and seeks to stop waste from being produced in the first place. The circular economy includes actions such as buying and using less, making and buying products that last longer, designing products and systems for reuse and remanufacture, repair, sharing, donating, or re-selling items so others can use them.

Data Source Considerations

The data collected and analyzed to create this inventory consists of varying levels of accuracy and granularity. Some data sources, like building energy use, provide a much more accurate measure of emissions since they rely on measured data. Other sources, like roadway vehicle miles traveled (VMT), rely on modelled data to estimate the resulting emissions, which requires back- and forecasting to derive emission estimates for non-model years. Ideally, all emissions sources would be measured values, but this is not always possible with some emission categories.

As we evaluate emissions trends with an eye towards future policy development, it is important to keep in mind the certainty – or uncertainty – of individual data elements. Additionally, it is important to continuously evaluate methodology and data sources to increase the certainty and granularity of the report over time.

[6] https://www.seattle.gov/utilities/about/plans/solid-waste/zero-waste

Table 3: 'Core Emissions' Level of Granularity and Certainty

Sector	Category	Data source(s)	Level of certainty	Level of granularity
Core Emissions				
Buildings	**Electricity and Fossil Gas**	Building energy use from SCL and PSE	High – exactly what buildings consume, so we are certain about their corresponding emissions	High – annual data rolled up by sector (commercial, residential) by Census tract
	Steam	Fuel use from CenTrio and the University of Washington	High – exactly what buildings consume, so we are certain about their corresponding emissions	Low – annual data, not temporal or spatial
	Heating Oil	EIA and Census data	Low – estimates based on regional and national data, and not actual consumption data	Low – annual data, not temporal or spatial
Transportation	**Cars and Trucks**	PSRC's SoundCast 2018 model for vehicle miles traveled (VMT); fuel estimates by vehicle class	Low/Med – 2018 modeled data forecasted and back-casted to all inventory years using WSDOT regional urban and rural interstate VMTs	High – data sorted by Census tracts by SOV, HOV2, and HOV3+.
	Rail	Gallons of fuel, ridership miles from Amtrak, Sound Transit	Med – amount of fuel used per gallon is estimated for Amtrak but reported for Sound Transit.	Med – annual data, not temporal
Waste	**Waste**	SPU waste reports on tonnage and waste composition by sector	Med/High – measured information direct from SPU samples and surveys.	High – over 40 different waste stream types, but not spatial or temporal

Table 4: 'Expanded Emissions' Level of Granularity and Certainty

Sector	Emissions Category	Data source(s)	Level of certainty	Level of granularity
Expanded Emissions				
Industry	**Steel, cement, and glass production**	EPA's large emitters database (self-reported)	Med – self-reported emissions, but measurements during testing period are not always indicative of annual operations	Med/High – annual data for each large emitter, but not temporal
Industry	**Electricity and Fossil Gas**	Building energy use from utilities (Seattle City Light and Puget Sound Energy)	High – exactly what buildings consume, so we are certain about their corresponding emissions	High – annual data rolled up by sector (commercial, residential) by Census tract
Transportation	**Air**	Fuel consumption at airports scaled by population	Low – scaling jet fuel consumption by population of Seattle vs. larger region results in a crude estimate	Low – annual fuel consumption in gallons, with no additional detail
Transportation	**Marine**	Combination of NONROAD model, Puget Sound Maritime Inventory	Very Low – data from Washington State Ferries is accurate since it is based on fuel usage. Other sources such as NONROAD data is modeled after EPA MOVES 2014, rather than the more up-to-date EPA MOVES3. The 2021 Puget Sound Maritime Inventory is still being developed.	Med – some granularity with types of marine traffic (pleasure craft, ferries etc.)
Building	**Non-road equipment**	NONROAD modeled data, updated in 2014.	Low – older modeled data, not measured consumption. Relies on scaling by population	Med – some granularity with motor and fuel types.

Seattle's Climate Goals

Seattle remains committed to the emissions reduction targets established through a Council Resolution in 2011, which aims to achieve a 58% emissions reduction by 2030 and net zero carbon by 2050. Seattle's Climate Action Plan in 2013, along with a 2018 Climate Action Strategy, identify focused actions that would reduce emissions on transportation and building sectors. Seattle has further cemented its leadership as a city that centers equity in climate progress through Seattle's Green New Deal and directs a portion of JumpStart Payroll Tax Revenue to support policies and programs that create clean energy jobs and advance an equitable transition from fossil fuels.

Over the past two years, Seattle has worked to advance the directives issued in the Green New Deal Executive Order (EO-2020-01), which calls for all City departments to work together with the Green New Deal Oversight Board (Oversight Board) to advance the goals set forth by the Green New Deal Resolution and Ordinance. In 2021, the City released a Climate Impact Actions report to identify the top ten actions Seattle could take in order to achieve expeditious reductions in emissions. Recommended actions fall under three broad categories: **building a framework to center community needs**; **reducing emissions from the transportation sector**; and **reducing emissions from buildings**. In June 2022, the Oversight Board issued budget recommendations to the City for 2022 and 2023 for an approximately $6.5 million allocation of revenue generated via the Payroll Expense Tax.

Seattle stays committed to accelerating and deepening climate investments and changing how we design and implement policies to meet the scale of the climate crisis. In 2022, Mayor Bruce Harrell put forth the **One Seattle Climate Justice Agenda** framework, which prioritizes targeted investments and community-driven policies that support **building a green economy**, **ensuring a just transition from fossil fuels**, and **building community health and climate resilience**.

Impacts of COVID-19 Pandemic

The COVID-19 pandemic brought unprecedented change and disruption to the typical way of life. Aside from the devastating health and economic impacts on communities, the pandemic shifted people's everyday lives due to the stay-at-home orders and subsequent business closures in March 2020. Like GHG emissions throughout the city, those who were affected the most by COVID-19 were disproportionately lower-income and black, indigenous, and people of color (BIPOC).

COVID-19 impacted every aspect of life, but particularly the transportation sector. Working from home (WFH) became the norm for those privileged to have a job that was conducive to doing so, and commuter traffic effectively came to a halt. As restrictions have eased, personal vehicle travel patterns are ticking back up to their previous levels. Public transit ridership has yet to see the same rebound. Stay Healthy Streets[7], a SDOT initiative created in response to the COVID-19 pandemic, closed residential streets to pass through auto traffic to open them up to people walking, rolling, and biking. Residents began biking more frequently and elected to live in their communities more so than before, which caused a restructuring of individual travel patterns.

The building sector was significantly impacted by the stay-at-home orders and business closures of 2020. Office spaces in downtown remained vacant of workers, shoppers took up e-commerce rather than visiting brick-and-mortar stores, and many restaurants switched to predominantly take-out and outdoor

[7] https://www.seattle.gov/transportation/projects-and-programs/programs/stay-healthy-streets

dining. These dramatic changes caused a shift of decreased energy use from commercial buildings and increased energy use from residential buildings as residents were spending more time at home. Additionally, the waste sector experienced a similar transition – commercial buildings generated less waste and residential buildings generated more waste as Seattleites spent more time at home.

Core Emissions Changes from 2018 - 2020: Key Findings

Buildings Sector (5.2% decrease)

Emissions in the buildings sector decreased modestly between 2018 and 2020 as the pandemic drastically changed where people spent their time. Commercial businesses and offices decreased their need to spend energy on heating, ventilation, and air conditioning (HVAC) as employees were laid off, placed on leave, or began to work from home. Since 2018, emissions from all core building categories decreased except for residential fossil fuels (**Table 5**).

Alternatively, stay-at-home orders increased the amount of time people spent at home, which increased residential energy consumption across all commodities (fossil gas, oil, and electricity) in terms of million metric British thermal units (MMBTU). However, emissions from electricity managed to decrease as the emission factor from Seattle City Light (SCL) decreased by 38.7%, from 32.05 lbs. CO2/MWh to 19.64 lbs. CO2/MWh[8].

The emission calculations for the buildings sector rely on actual measured electricity and fossil gas usage reported by SCL and PSE, resulting in a high level of certainty.

Transportation Sector (24.5% decrease)

Transportation-related emissions drastically changed as passengers decreased vehicle miles traveled (VMT) on roadways, public transit utilization declined, and air travel halted due to COVID-19. Additionally, more efficient vehicles resulted in a decrease in transportation emissions. City mobility programs likely had some impact on lowering VMTs as well and will likely persevere, but traffic count data from Seattle's Department of Transportation (SDOT) indicates that traffic volumes in 2021 and 2022 measured across three key downtown streets are gradually trending back up towards pre-pandemic 2019 levels.

Passenger and truck calculations are based on VMT data modeled by Puget Sound Regional Council (PSRC) for the whole region, prior to scaling to model Seattle VMT. However, there is uncertainty with these values as the underlying model uses a base year of 2018 which is then scaled to inventory years using a ratio of regional VMT from urban highways in the inventory year relative to 2018. This may cause the data to not fully account for interurban travel levels as it is based on highway VMT and not local VMT on Seattle roadways.

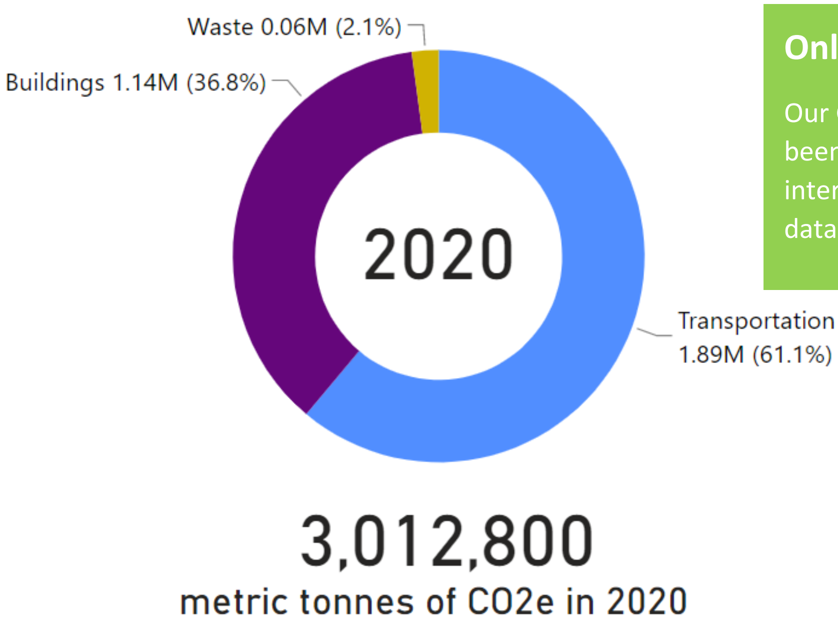
Waste Sector (12.4% decrease)

Waste sector emission calculations are based on Seattle Public Utilities' (SPU's) Solid Waste Composition studies for the commercial, residential, and self-haul waste streams. The major factors contributing to the reduction in waste emissions were a decrease in commercial waste because of COVID-19 and a new residential waste composition study, which showed a decrease in the percentage of recyclable and compostable materials entering the garbage stream as contaminants. This reduction in emissions was coupled with an increase in residential total tonnage, but a decrease in residential emissions. Waste emissions account for just 1.2% of total core emissions, but SPU's consistent efforts to improve the composition of municipal solid waste have led to a 35.5% reduction in emissions since 2008.

[8] 2018 emission factor via The Climate Registry, *Utility-Specific Emission Factors*. 2020 emission factor via internal communication with SCL.

Emissions Overview

Core GHG Emissions



Online Data Dashboard

Our GHG Inventory webpage has been updated for 2020 with interactive dashboards to view the data. Explore the data online here.

Figure 2: Seattle's core GHG emissions by sector in 2020.

Figure 2 above depicts the relative contribution of the transportation, buildings, and waste sectors to city-wide emissions in the year 2020. In 2020, the transportation sector accounted for 61.1% of all core emissions. This is a significant drop in relative contribution from previous years (roughly 66% for inventory years between 2005 and 2018). COVID-19 decreased travel, and subsequently emissions, across all subsectors in 2020. Therefore, the share of emissions from building sources sharply rose to 36.8% of all core emissions from 31.8% in 2018, primarily due to a corresponding decrease in transportation sector emissions.

In the transportation sector, passenger vehicles and commercial trucks contribute to the city's core GHG emissions. Passenger vehicles include single- and high-occupancy vehicles, motorcycles, light trucks, and buses. Commercial trucks include light-, medium-, and heavy-duty commercial trucks. In the building sector, emissions are tracked for residential and commercial buildings. Residential buildings include single- and multi-family residential units (excluding common spaces such as lobbies, hallways etc.). Commercial buildings include small, medium, and large businesses.

Table 5: Seattle's core emissions by category in 2020, the prior inventory year (2018), and baseline year (2008).

Core GHG Emissions Summary Table

Category (mt CO2e)	2008	2018	2020	% change from 2008	% change from 2018
Buildings	**1,274,000**	**1,199,000**	**1,136,000**	**-10.8%**	**-5.3%**
Commercial	**684,000**	**683,000**	**626,000**	**-8.5%**	**-8.3%**
CenTrio Steam	91,000	68,000	63,000	-30.8%	-7.4%
Heating Oil	8,000	-	10,000	25.0%	N/A
PSE	413,000	460,000	433,000	4.8%	-5.9%
Seattle City Light	87,000	68,000	38,000	-56.3%	-44.1%
UW Steam	85,000	87,000	82,000	-3.5%	-5.7%
Residential	**590,000**	**516,000**	**510,000**	**-13.6%**	**-1.2%**
Heating Oil	109,000	57,000	61,000	-44.0%	7.0%
PSE	432,000	422,000	425,000	-1.6%	0.7%
Seattle City Light	49,000	37,000	24,000	-51.0%	-35.1%
Offsets	**(149,000)**	**(132,000)**	**(75,000)**	**-49.7%**	**-43.2%**
Transportation	**2,611,000**	**2,502,000**	**1,887,000**	**-27.7%**	**-24.6%**
Road: Passenger	**2,351,000**	**2,235,000**	**1,680,000**	**-28.5%**	**-24.8%**
Buses	61,000	66,000	51,000	-16.4%	-22.7%
Cars & Light Duty Trucks	2,290,000	2,169,000	1,629,000	-28.9%	-24.9%
Road: Trucks	**260,000**	**267,000**	**207,000**	**-20.4%**	**-22.5%**
Medium & Heavy Duty	260,000	267,000	207,000	-20.4%	-22.5%
Waste	**100,700**	**74,000**	**64,800**	**-35.7%**	**-12.4%**
Commercial	**52,500**	**35,000**	**27,800**	**-47.0%**	**-20.6%**
Residential	**38,300**	**31,600**	**29,700**	**-22.5%**	**-6.0%**
Selfhaul	**9,900**	**7,400**	**7,300**	**-26.3%**	**-1.4%**
Total (mtCO2e)	**3,836,700**	**3,643,000**	**3,012,800**	**-21.5%**	**-17.3%**
Population	**593,588**	**744,955**	**735,157**	**23.8%**	**-1.3%**
Per Capita Emissions (mtCO2e/person)	**6.46**	**4.89**	**4.10**	**-36.6%**	**-16.2%**

A summary of core GHG emissions for 2008, 2018, and 2020 is outlined in **Table 5** above. The rounded emissions values are reported for all core sectors and subsectors. All values are rounded to the nearest thousand metric tonnes (mt) of CO2e, except for the waste sector as these estimates frequently total less than a thousand mt of CO2e. A per-capita emissions value is provided to normalize the data. The greatest percent change in core emissions from 2018 to 2020 was commercial electricity use provided by SCL. The greatest increase in emissions from 2018 to 2020 came from residential heating oil.

Expanded GHG Emissions

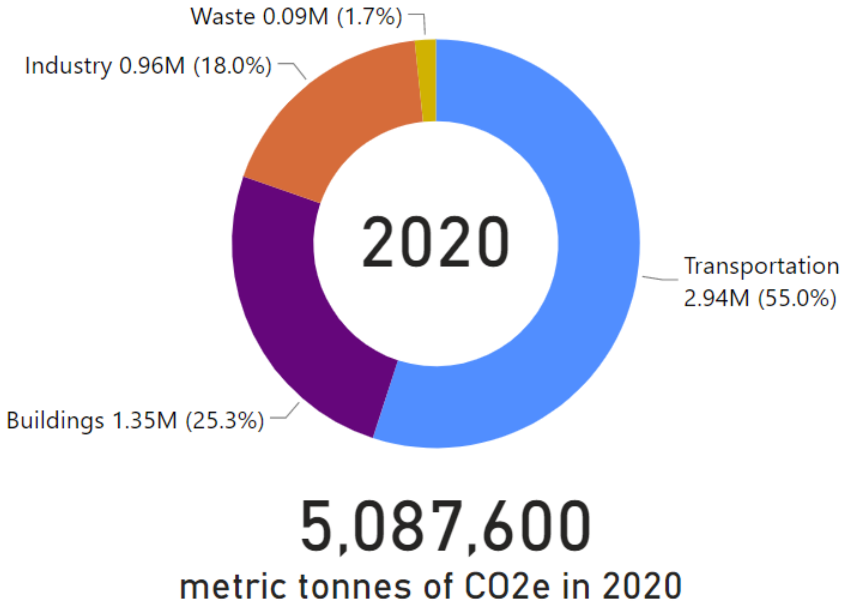


Figure 3: Seattle's expanded GHG emissions by sector in 2020.

A majority of Seattle's expanded GHG emissions stem from the transportation and industry sectors, which includes freight transportation and air travel. In 2020, the transportation sector accounted for 55.0% of the expanded GHG emissions in Seattle, while 25.3% stemmed from the buildings sector, 18.0% from the industry sector, and 1.7% from the waste sector.[9] Air transport and the industrial sector together comprise two of the largest sources of core and expanded emissions in 2020, at around 844 hundred thousand mt CO_2e (15.9% of total) and 962 hundred thousand mt CO_2e (18.0% of total) respectively. Transportation-related emissions experienced the most drastic changes between 2018 and 2020 as passenger rail emissions dropped 58.6% and air transportation emissions dropped 38.4%.

A summary of expanded GHG emissions for 2008, 2018, and 2020 is outlined in **Table 6** below. The rounded emissions values are reported for all core and expanded sectors and subsectors. All values are rounded to the nearest thousand mt of CO2e, expect for the waste sector as these estimates frequently total less than a thousand mt of CO2e. A per-capita emissions value is provided to normalize the data. The greatest percent change in core and expanded emissions from 2018 to 2020 was industrial electricity use provided by SCL. The greatest increase in emissions between 2018 and 2020 came from 'Construction & Demolition' waste.

[9] It is important to note that our this geographic-based emissions inventory only measures lifetime emissions that would be emitted by waste disposed during 2020. Consumption-based emission inventories more accurately account for the impacts of purchasing of goods and services by measuring the embodied emissions associated with production, transportation, use, and disposal of goods, food, and services consumed.

Table 6:Seattle's expanded emissions by category in 2020, the prior inventory year (2018), and baseline year (2008).

Category (mt CO2e)	2008	2018	2020	% change from 2008	% change from 2018
Buildings	**1,432,000**	**1,403,000**	**1,354,000**	**-5.4%**	**-3.5%**
Commercial	**825,000**	**867,000**	**824,000**	**-0.1%**	**-4.9%**
CenTrio Steam	92,000	69,000	63,000	-30.8%	-7.7%
Equipment	140,000	184,000	197,000	40.8%	7.2%
Heating Oil	8,000	-	10,000	22.6%	N/A
PSE	413,000	460,000	433,000	4.8%	-5.7%
Seattle City Light	87,000	68,000	38,000	-56.5%	-44.3%
UW Steam	85,000	87,000	82,000	-3.2%	-5.0%
Residential	**607,000**	**536,000**	**530,000**	**-12.6%**	**-1.2%**
Heating Oil	109,000	57,000	61,000	-44.1%	6.3%
PSE	432,000	422,000	425,000	-1.5%	0.7%
Seattle City Light	49,000	37,000	24,000	-50.6%	-34.9%
Yard Equipment	17,000	20,000	20,000	13.0%	-1.3%
Industry	**1,357,000**	**1,050,000**	**962,000**	**-29.1%**	**-8.4%**
Energy Use	**511,000**	**550,000**	**507,000**	**-0.9%**	**-8.0%**
Equipment	214,000	209,000	211,000	-1.2%	1.2%
Heating Oil	36,000	16,000	18,000	-50.3%	12.5%
PSE	246,000	314,000	271,000	10.2%	-13.5%
Seattle City Light	15,000	12,000	6,000	-58.3%	-47.8%
Fugitive Gases	**24,000**	**22,000**	**21,000**	**-12.1%**	**-6.2%**
Process	**822,000**	**477,000**	**434,000**	**-47.2%**	**-8.9%**
Offsets	**(164,000)**	**(144,000)**	**(81,000)**	**-50.4%**	**-43.5%**
Sequestration	**(187,000)**	**(175,000)**	**(173,000)**	**-7.4%**	**-1.0%**
Transportation	**3,810,000**	**4,085,000**	**2,939,000**	**-22.9%**	**-28.1%**
Air	**972,000**	**1,369,000**	**844,000**	**-13.2%**	**-38.4%**
Marine	**179,000**	**180,000**	**180,000**	**0.4%**	**-0.4%**
Rail	**48,000**	**33,000**	**27,000**	**-43.4%**	**-17.8%**
Road: Passenger	**2,351,000**	**2,235,000**	**1,681,000**	**-28.5%**	**-24.8%**
Road: Trucks	**260,000**	**267,000**	**207,000**	**-20.6%**	**-22.7%**
Waste	**128,900**	**99,500**	**89,200**	**-30.8%**	**-10.4%**
Commercial	**52,600**	**35,200**	**28,000**	**-46.8%**	**-20.5%**
Construction & Demolition	**12,900**	**7,500**	**8,400**	**-35.2%**	**11.2%**
Residential	**38,700**	**31,700**	**29,900**	**-22.6%**	**-5.6%**
Selfhaul	**9,900**	**7,600**	**7,400**	**-25.9%**	**-3.5%**
Wastewater	**14,700**	**17,400**	**15,500**	**5.5%**	**-10.9%**
Total (mtCO2e)	**6,376,900**	**6,318,500**	**5,090,200**	**-20.2%**	**-19.5%**
Population	**593,588**	**744,955**	**735,157**	**23.8%**	**-1.3%**
Per Capita Emissions (mtCO2e/person)	**10.74**	**8.48**	**6.92**	**-35.6%**	**-18.4%**

GDP, Population, and Emissions

Since 2008, Seattle's gross domestic product (GDP) and population have grown dramatically in unison with one another, as is seen in **Figure 4.** As GDP increased 50.4% from 2008 to 2020, the population of Seattle grew by 23.8%. However, a slight decline in population occurred between 2018 and 2020 as COVID-19 impacted economic opportunities in the city. Additionally, some residents working from home may have left as they were no longer geographically anchored to the city by their employer.

Core emissions have continuously decreased from 2008 to 2020, but 2020 showed the largest decrease in emissions relative to the 2008 base year. In 2020, core and expanded emissions decreased substantially due to the impacts of COVID-19 throughout the year.

Expanded GHG emissions decreased inversely with GDP and population growth prior to 2012; however, since the economic boom in 2012, expanded GHG emissions steadily increased along with GDP and economic growth. 2018 expanded GHG emissions are 0.2% greater than 2008 GHG emission levels.

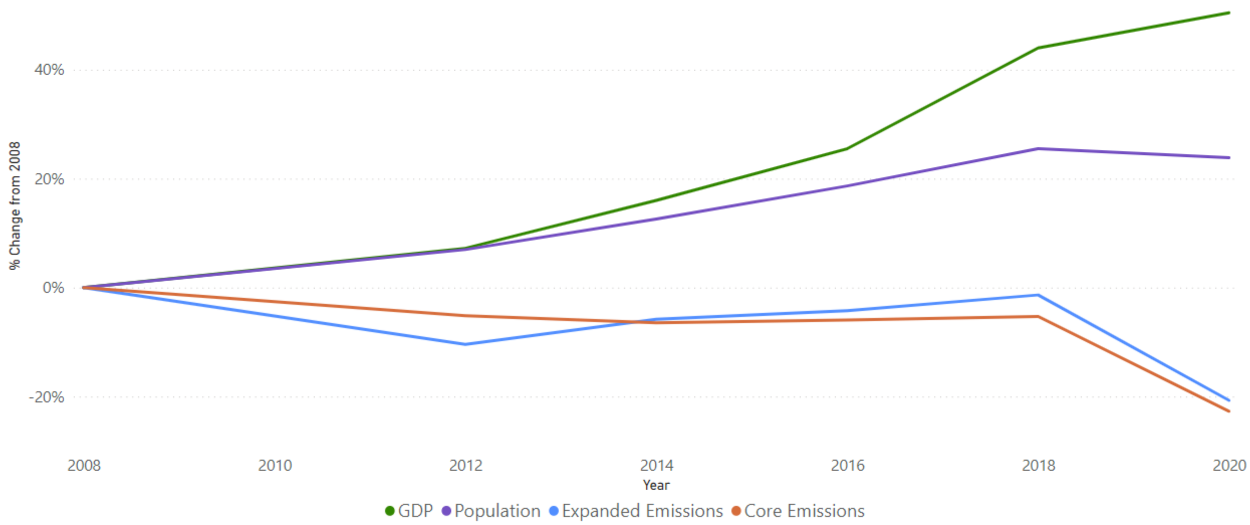


Figure 4: Percent difference from 2008 for GDP, population, and emissions in Seattle from 2008 to 2020.

Detailed Emissions

Transportation Emissions

In the transportation sector, core emissions decreased around 27.7% since 2008 – from 2.61 million $mtCO_2e$ in 2008 to 1.89 million $mtCO_2e$ in 2020 (**Figure 5**). Road transportation has been the largest contributor of emissions since Seattle started tracking emissions in 1990. Total emissions in this sector increased through 2008; however, they have been decreasing since 2008 due to improvements in vehicle fuel economy and changes in VMT. Advances in vehicle technology have increased the average fuel economy for cars and light-duty trucks (including SUVs) in Seattle from about 20.3 miles per gallon of fuel in 2008 to about 24.9 miles per gallon in 2020.[10]

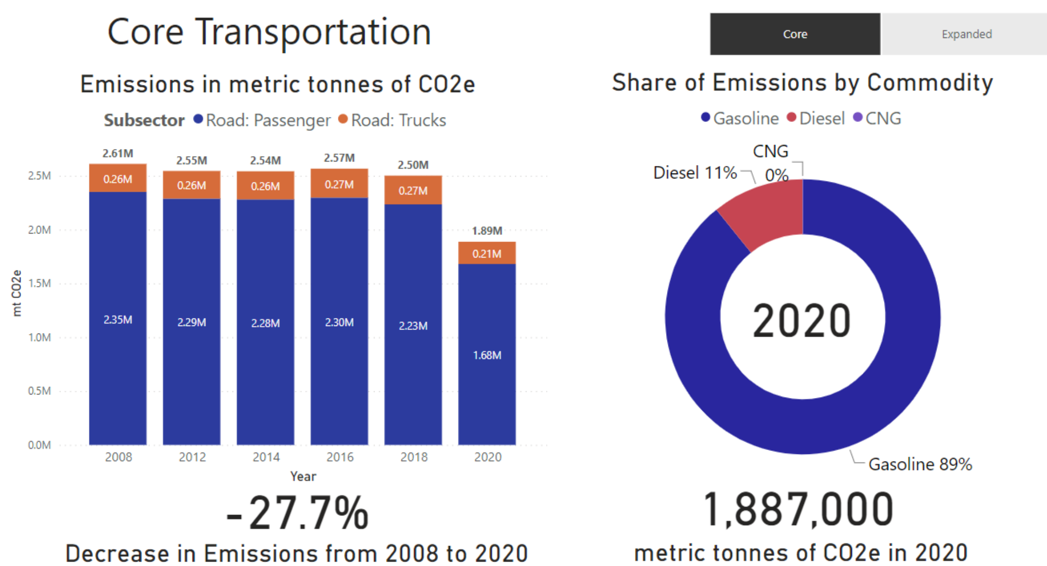


Figure 5: Core transportation emissions by subsector and commodity.

[10] Department of Ecology's 2017 King County *Fuel Economy Performance Measure* calculations.

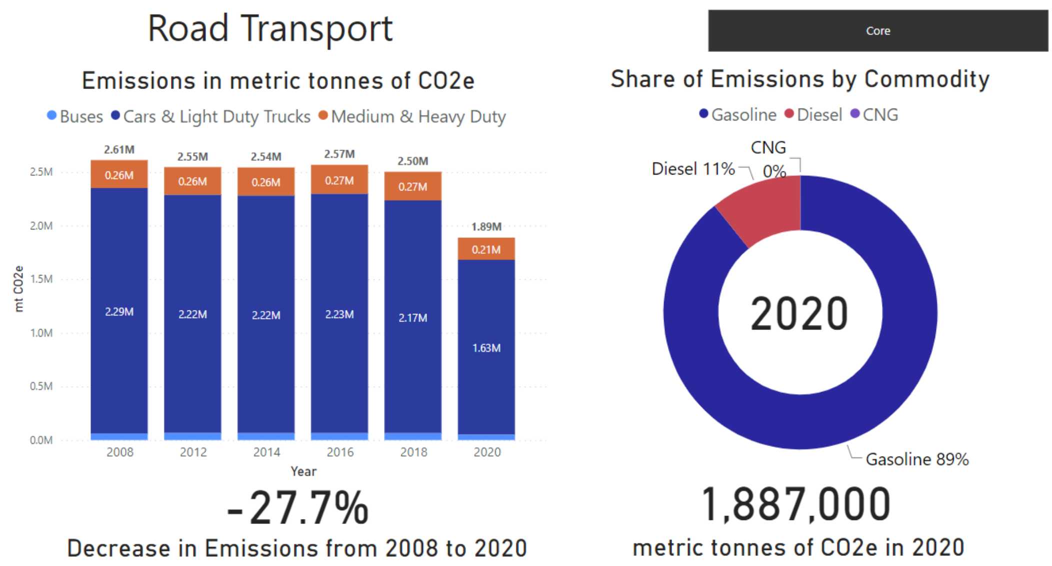


Figure 6: Core Road transportation emissions by category and commodity.

It is important to note that the methodology for calculating road transportation emissions is based on modeled data (See **Appendix D1: Road Transportation**), which carries a higher level of uncertainty compared to emissions from the building sector that are based on measured energy consumption.

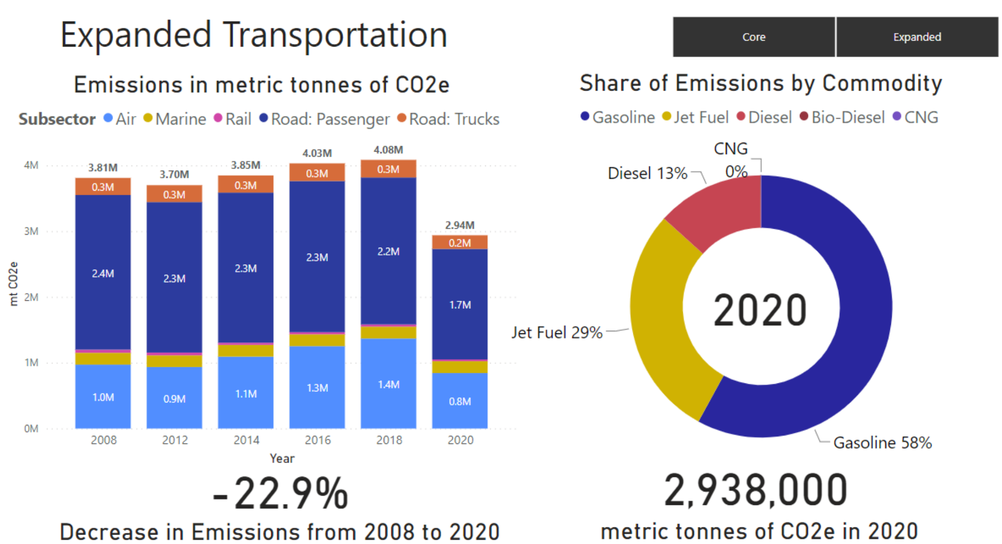


Figure 7: Expanded transportation emissions by category and commodity.

As seen in **Figure 7**, expanded GHG emissions decreased by 22.9% since 2008. Additionally, 2020 experienced a 28.1% reduction in emissions since 2018 due to restricted travel conditions caused by the

COVID-19 pandemic. Most of the decrease in expanded emissions can be attributed to decreased air travel.

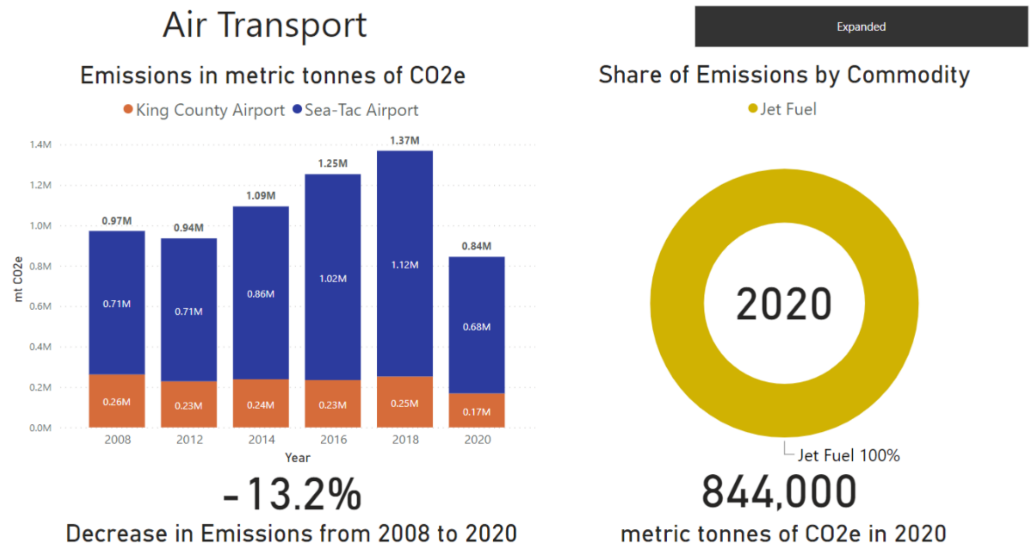


Figure 8: Expanded air transportation emissions by airport and commodity.

Figure 8 displays air transportation emissions decreasing by 13.2% from 972 thousand mtCO_2e in 2008 to 844 thousand mtCO_2e in 2020. When comparing 2018 and 2020, this figure jumps to 38.3%, alluding to the fact that the region has seen a substantial uptick in air travel since 2008 due to increased economic activity and population growth.

Building Emissions

In the building sector, core GHG emissions decreased 5.2% since 2018 – from 1.20 million mtCO_2e to 1.14 million mtCO_2e in 2020, as seen in **Figure 9**.

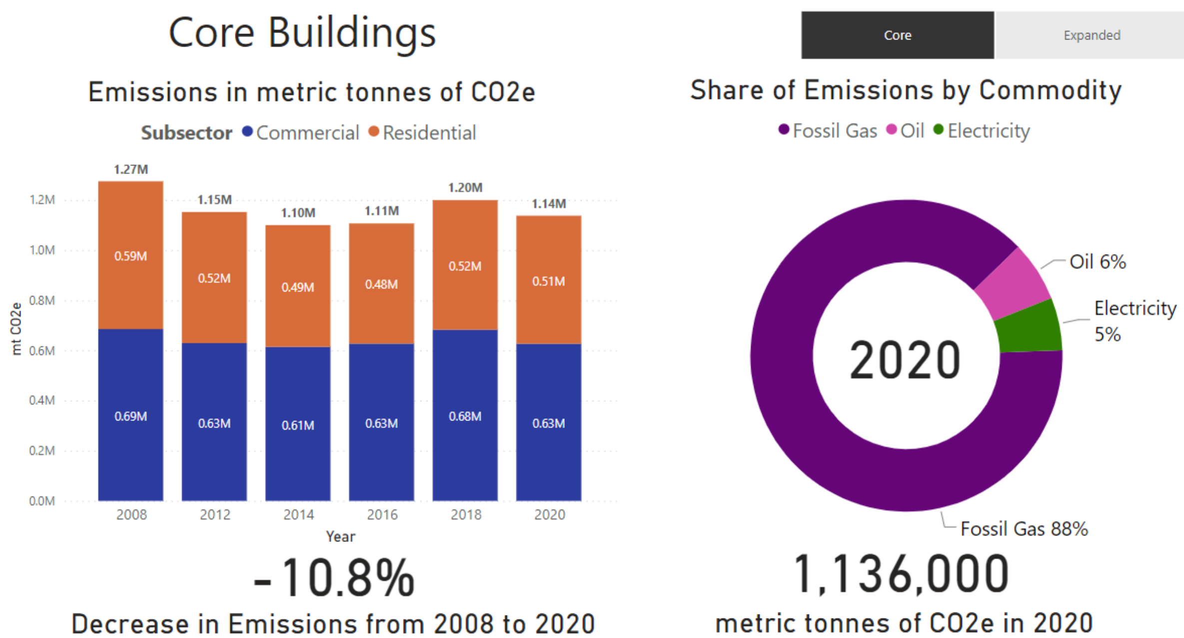


Figure 9: Core buildings emissions by subsector and commodity.

Expanded building sector emissions decreased 4.1% since 2018 – from 1.40 million mtCO_2e in 2018 to 1.35 million mtCO_2e in 2020 per **Figure 10**.

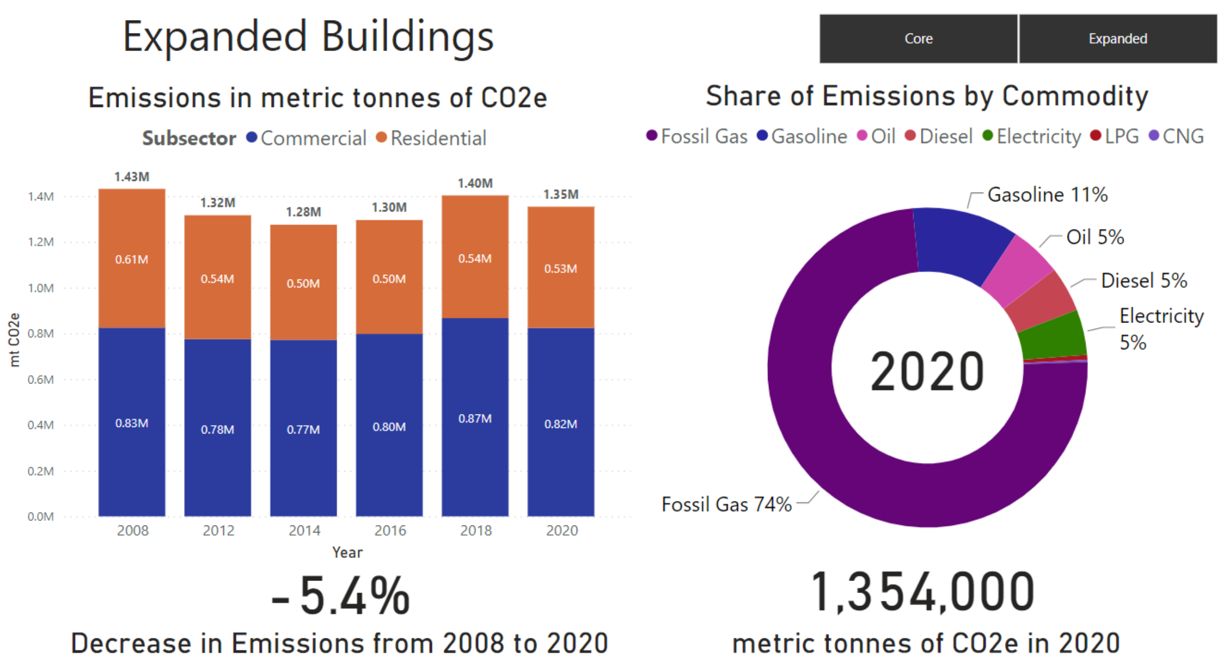


Figure 10: Expanded buildings emissions by subsector and commodity.

About 90% of the electricity that SCL provides to consumers in Seattle comes from low-carbon hydroelectric dams. SCL purchases high-quality local carbon offsets equal to the greenhouse gas emissions resulting from all aspects of SCL's operations, including those created by fossil fuels included in the mix of power the utility buys, employees' travel, and the trucks and other equipment used in its operations. Because of variation in hydroelectricity production from year to year, SCL's external power purchases and the consequent amount of emissions from electricity and carbon offsets purchases varies annually. Therefore, there are significant annual fluctuations in the pre-offset emissions attributable to our electricity use, even if electricity consumption is trending down.

In 2020, electricity, while continuing to be the largest source of energy for Seattle's buildings (54.3%), is responsible for only 5.5% of emissions in this sector, before offsets. **Figure 11** compares the difference between energy usage and emissions between electricity, fossil gas, and oil to highlight the key advantage of electricity as an energy source.

While fossil gas and oil are currently responsible for 92.3% and 1.6% respectfully of building emissions, they only account for 45.7% of the total energy consumed. Commercial GHG emissions decreased by 5.6% from fossil gas between 2018 and 2020. Over the same period, residential GHG emissions increased by about 0.7% from fossil gas and 6.3% from oil.[11] 2020 had about 4% more cooling degree days (CDD) than 2018, which, combined with a higher number of residents being able to work from home, could have contributed to an increase in fossil gas use for heating purposes.

Alternatively, commercial GHG emissions from electricity decreased by 44.3% from commercial sources and 34.9% from residential sources despite total energy from the residential sector increasing from 2018 to 2020. This can be attributed to the emissions factor from SCL decreasing substantially from 2018 to 2020, thanks to cleaner electricity generation. The emission factor from SCL decreased by 38.7%, from 32.05 lbs. CO_2/MWh to 19.64 lbs. CO_2/MWh.[12]

[11] Note that emissions from heating oil are based on estimates from EIA and census data and not on actual consumption data. See Table 3 in the Data Source Considerations section for more details.
[12] 2018 emission factor via The Climate Registry, *Utility-Specific Emission Factors*. 2020 emission factor via internal communication with SCL.

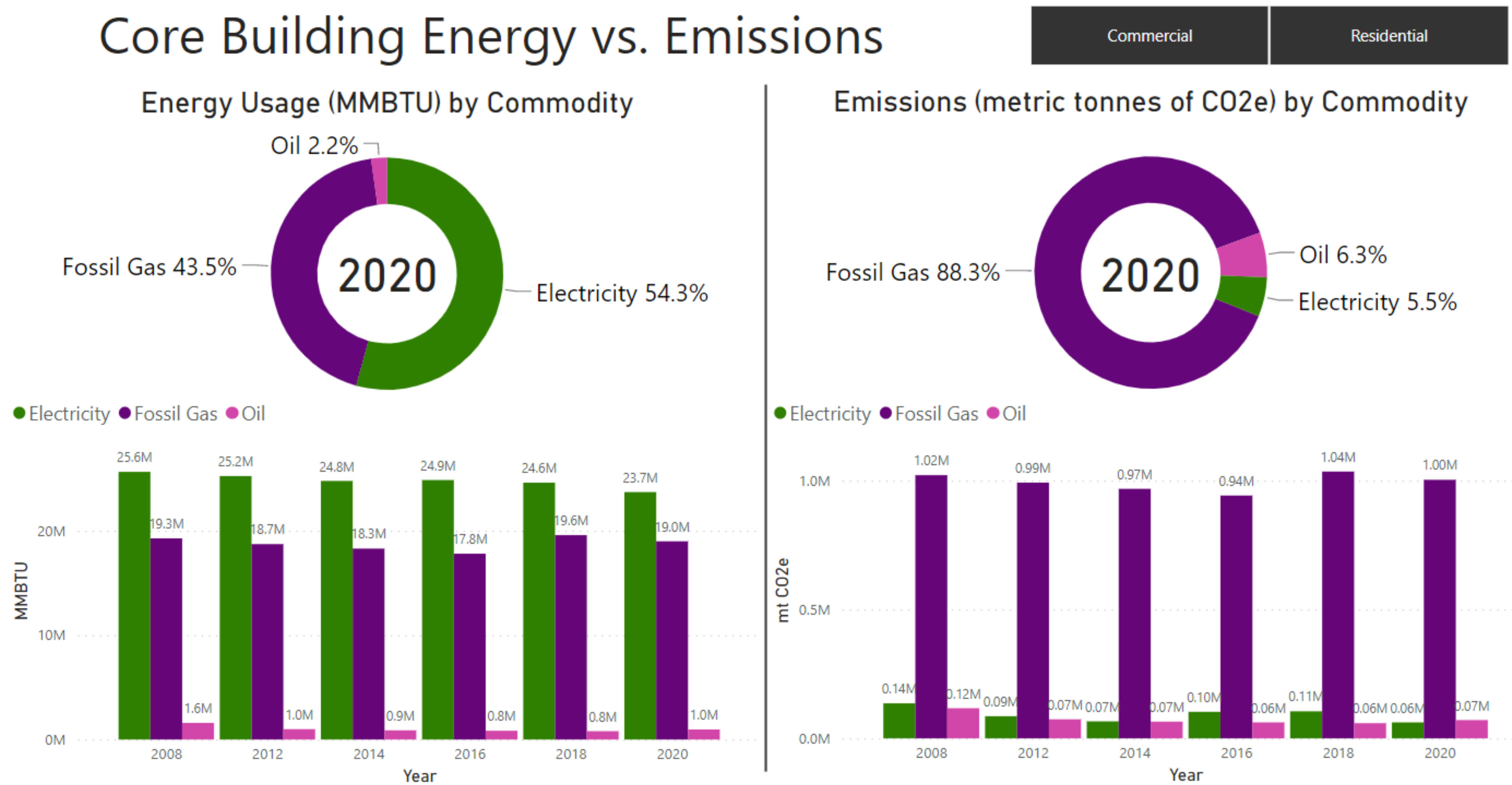


Figure 11: Core Buildings: Energy vs Emissions from Fuel Source

Residential Building Emissions

See **Appendix D5: Residential Building Energy** for more information on methodology for the Residential Building Sector.

See **Appendix D7: Residential & Commercial Building Equipment** for more information on methodology for estimating emissions from equipment for the Residential Building Sector.

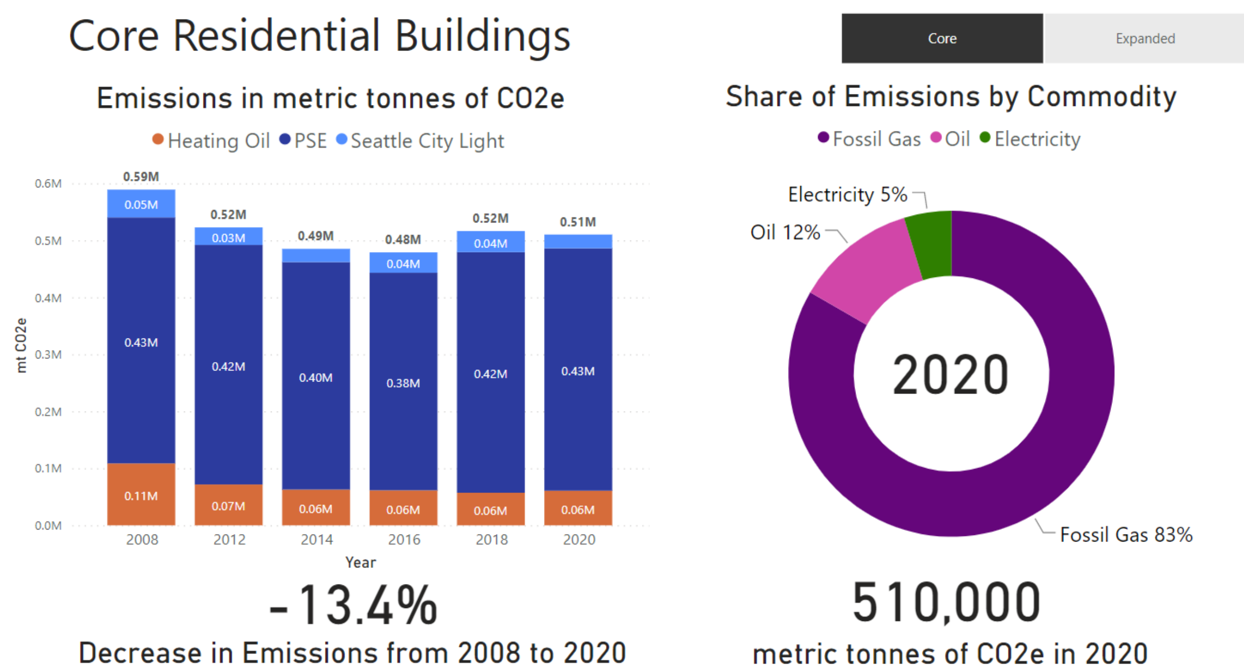


Figure 12: Core residential building emissions by source and commodity.

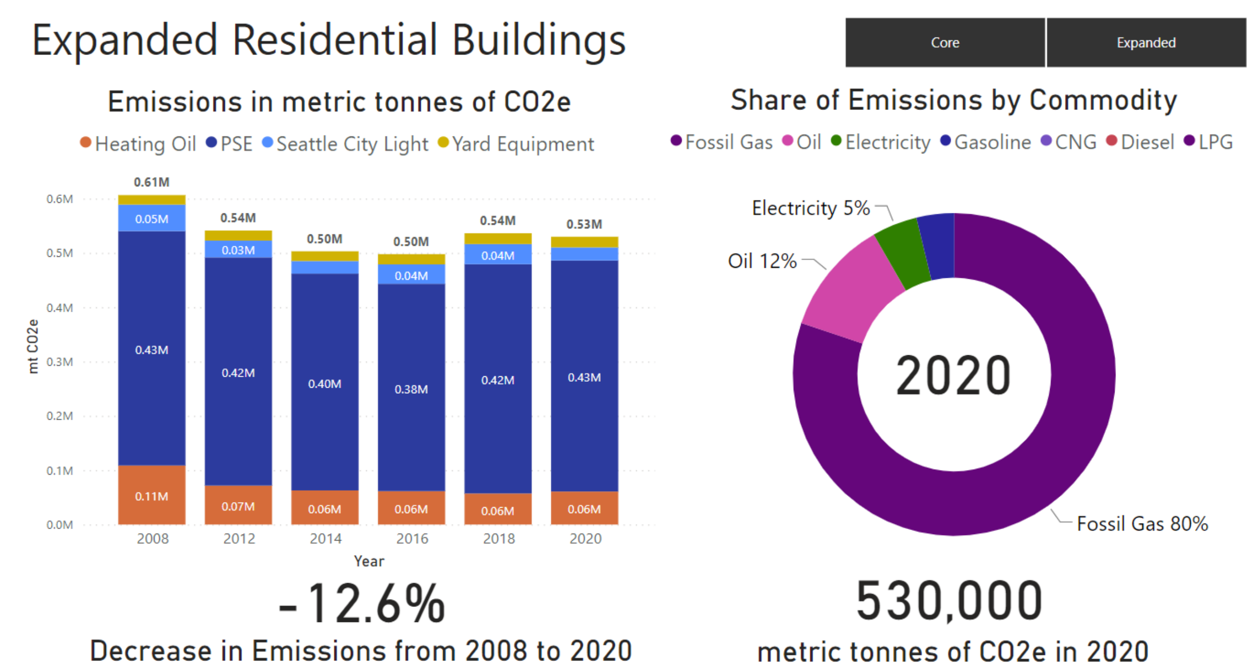


Figure 13: Expanded residential building emissions by source and commodity.

Commercial Building Emissions

See **Appendix D6: Commercial Building Energy** for more information on methodology for the Residential Building Sector.

See **Appendix D7: Residential & Commercial Building Equipment** for more information on methodology for estimating emissions from equipment for the Commercial Building Sector.

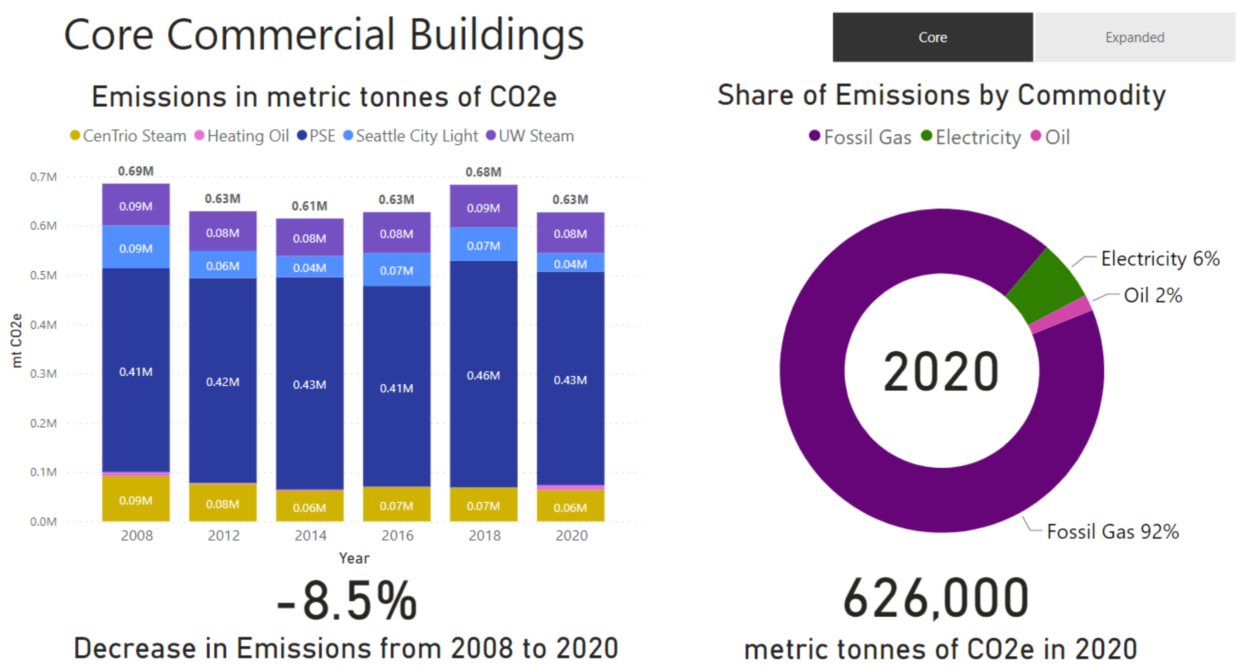


Figure 14: Core commercial building emissions by source and commodity.

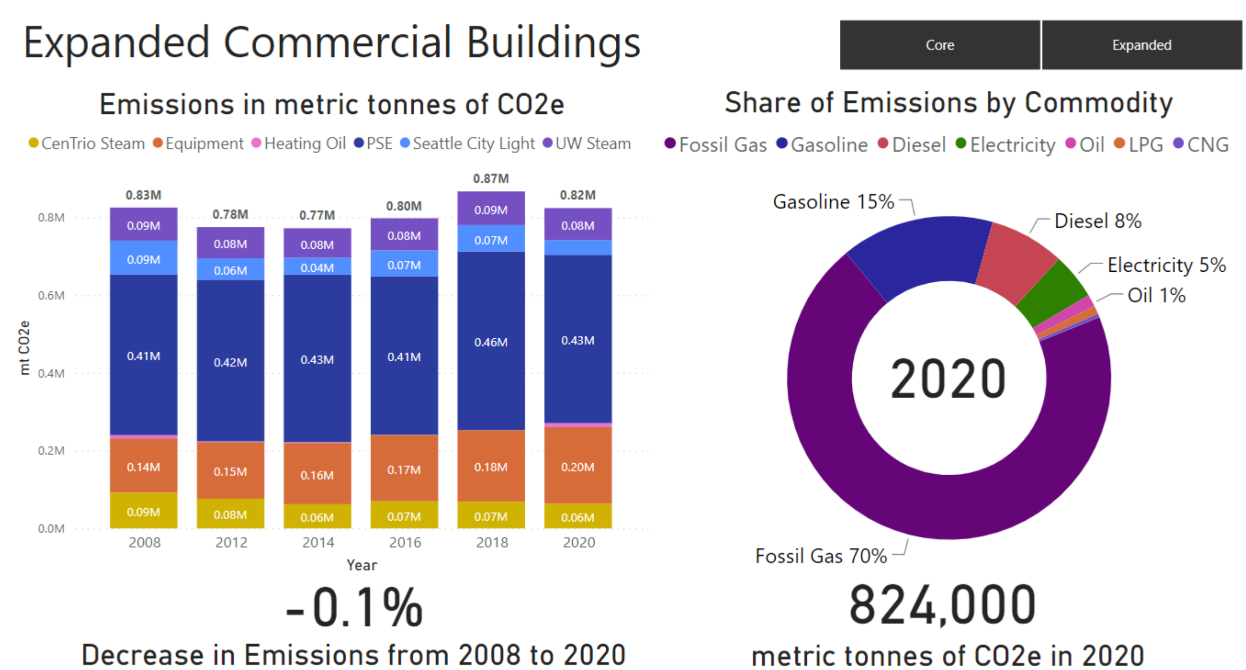


Figure 15: Expanded commercial building emissions by source and commodity.

Industry Emissions

Industry-related emissions decreased 29.1% since 2008 – from 1.36 million mtCO2e in 2008 to 0.96 million mtCO2e in 2020 (**Figure 16**). Industry emissions decreased due to a reduction in industrial process emissions, which was largely due to a reduction in cement emissions.

Since 2008, cement-related emissions decreased by more than half. Emissions from cement production in Seattle stem from the Ash Grove Cement Company's plant in the Duwamish River Valley.

Meanwhile, emissions from fossil gas usage (including gas infrastructure leaks) increased 8.8% since 2008, from 0.27 million mtCO2e in 2008 to 0.29 million mtCO_2e in 2020. Alternatively, a 12.9% drop in fossil gas usage from 2018 was experienced in 2020 as emissions decreased from 0.34 million mtCO_2e in 2018 (**Figure 16**).

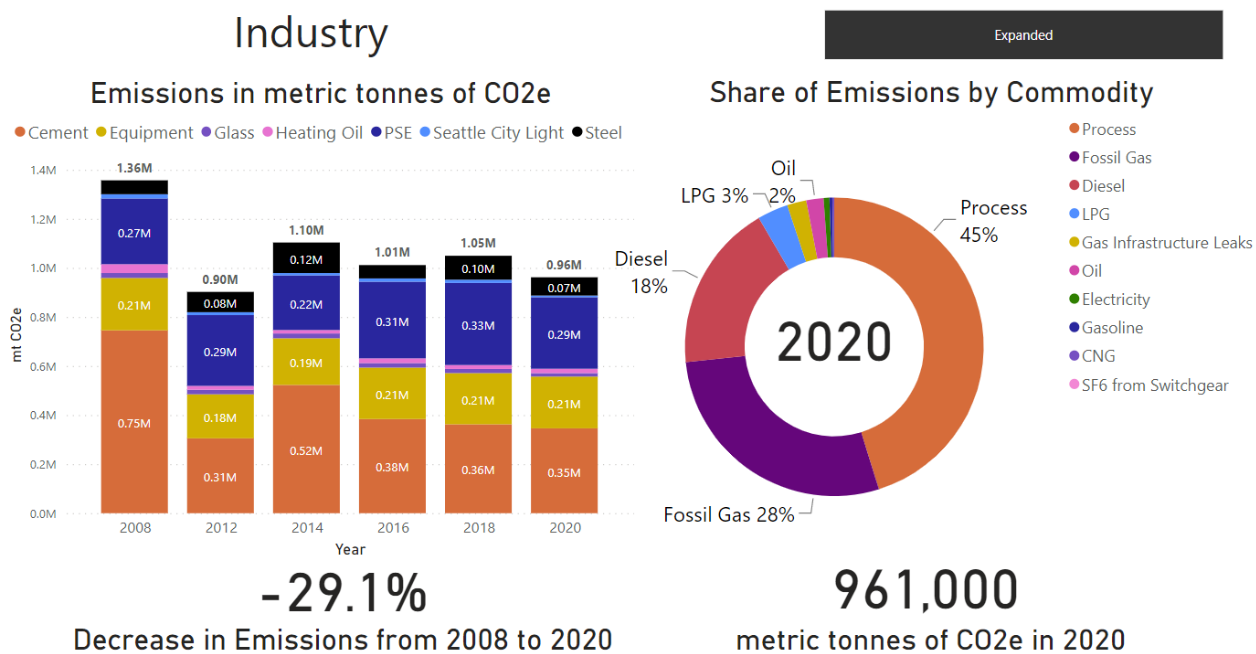


Figure 16: Industrial sector emissions by source and commodity.

See **Appendix D9: Industry** for more information on methodology for the Industry Sector.

Waste Emissions

In the waste sector, core emissions derived from the commercial, residential, and self-haul subsectors have decreased 35.5% from 101 thousand $mtCO_2e$ in 2008 to 65 thousand $mtCO_2e$ in 2020 (**Figure 17**). Expanded emissions, including the core subsectors as well as wastewater and construction & demolition, have decreased 30.8% from 2008 to 2020, or from 128 thousand $mtCO_2e$ to 88.6 thousand $mtCO_2e$ (**Figure 17**). The reduction in waste emissions is due to more waste being diverted to the appropriate stream as well as more waste being prevented in the first place. SPU's 2020 residential waste composition study showed a decrease in the number of organic and recyclable contaminants entering the garbage stream compared to the previous study,[13] which results in a reduction in the amount of carbon-based materials entering our landfills.

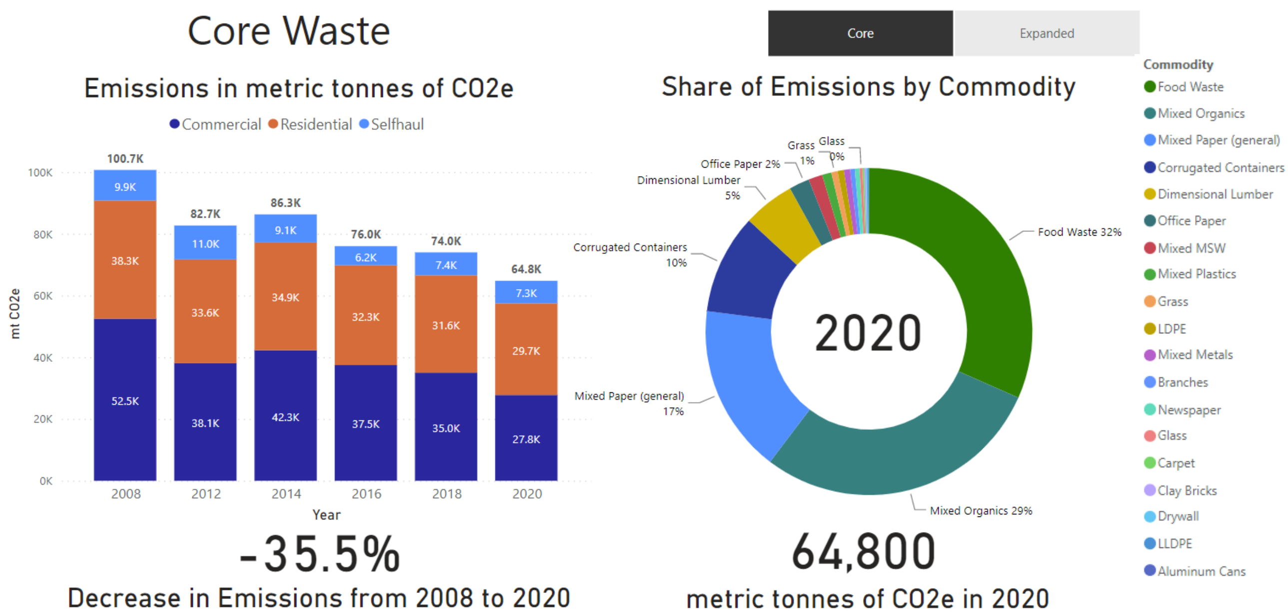


Figure 17: Core waste emissions by subsector and material type.

Since 2007, SPU has developed annual reports[14] to monitor waste prevention, waste diversion, and progress made towards the City's solid waste goals. SPU's emphasis on proper waste diversion and prevention has led to a continued decrease in emissions through reduced tonnage and less-emitting emission factors.

This decline in waste disposal has remained relatively consistent over the years for the various subsectors in the core and expanded emissions (**Figure 18**); however, the 'Commercial' (46.8% decrease) and 'Construction & Demolition' (35.2% decrease) subsectors experienced the highest decline in emissions between 2008 and 2020. Wastewater emissions are the only subsector that has experienced increased emissions since 2008, as they grew 5.5%.

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[13] SPU's *Waste Composition Studies.*

[14] SPU's Annual *Waste Prevention & Recycling Report*s.

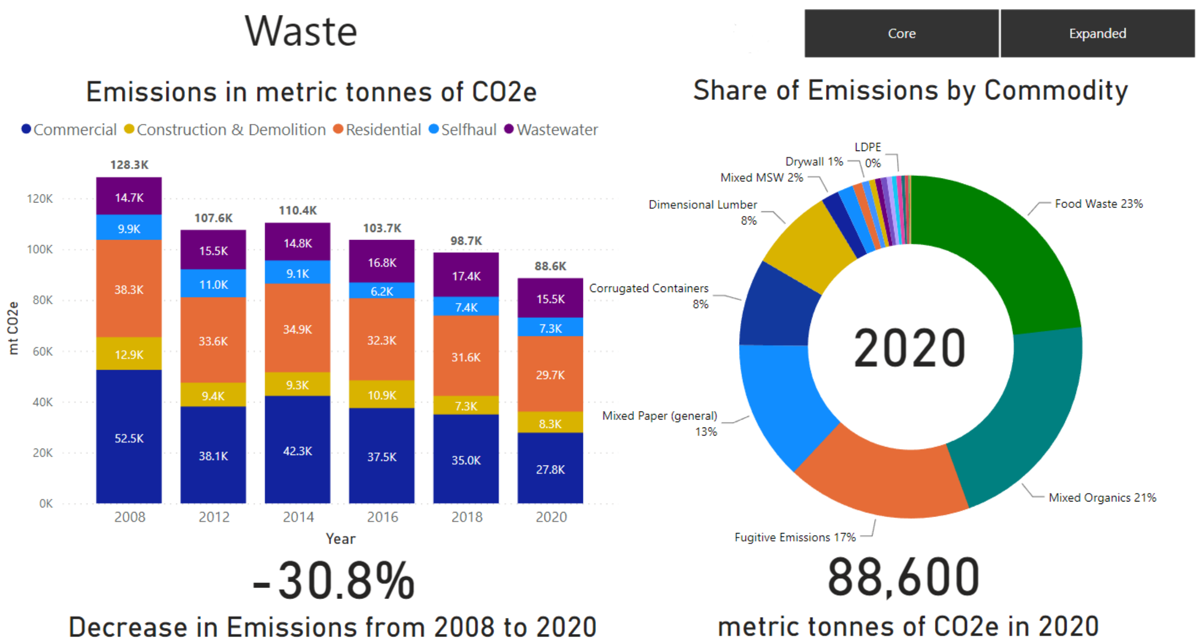

Figure 18: Expanded waste emissions by commodity and stream.

Landfills create emissions through the decomposition of organic materials by aerobic and anaerobic bacteria. Aerobic bacteria initially break down organic matter and release CO_2 as a byproduct. Anaerobic bacteria further break down the organic matter once oxygen has been depleted. The fermentation process produces a biogas that consists of 50% CO_2 and CH_4. This inventory counts only non-biogenic CO_2 emissions (biogenic meaning organic materials), and thus, this inventory may undercount the emissions from the waste sector.[15]

See **Appendix D9: Industry** for more information on methodology for the Waste Sector.

Sequestration and Offset Emissions

There are two sources of negative emissions in the city's GHG inventory: sequestration and offsets. Waste materials composed of organic matter stored in landfills are considered negative emissions in the inventory as they are removed from the atmosphere when they are buried. This sequestration of high-carbon materials leads to a substantial decrease in emissions.

[15] ICLEI Community Protocol, Appendix E- Solid Waste Emission Activities and Sources

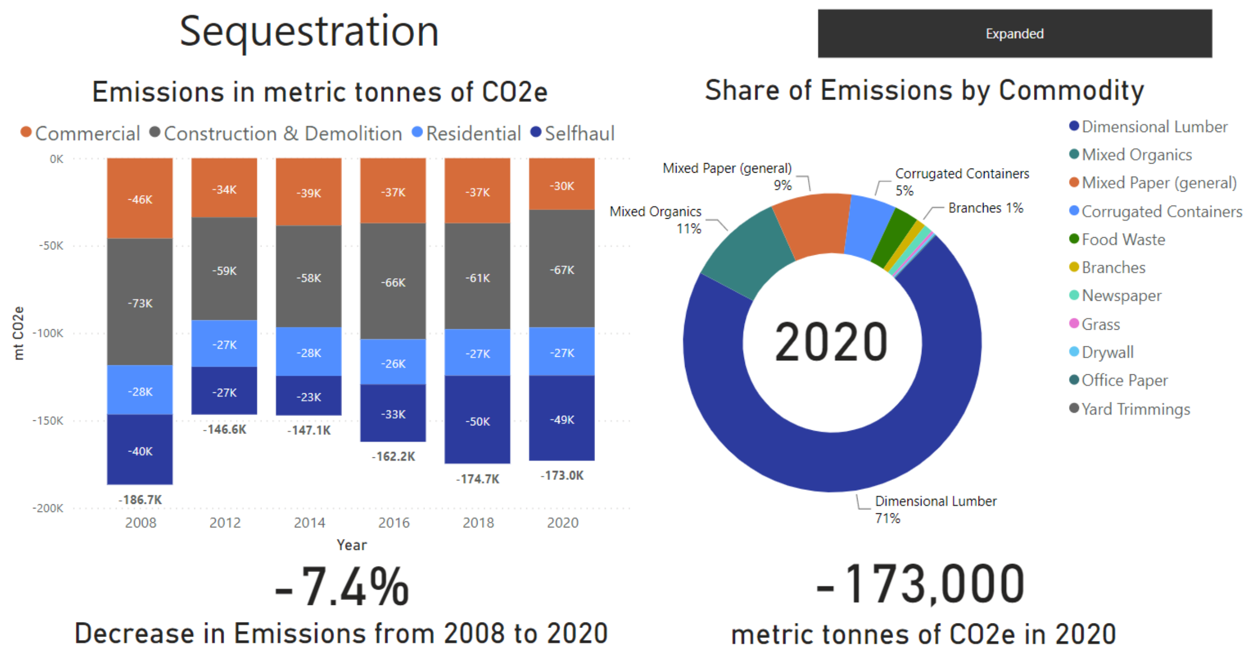

Figure 19: Sequestered emissions by category and commodity.

Additionally, carbon offsets purchased by an agency to counteract certain sources of emissions contribute to the inventory. SCL and KCWTD are the two agencies that have offset data reported in the inventory.

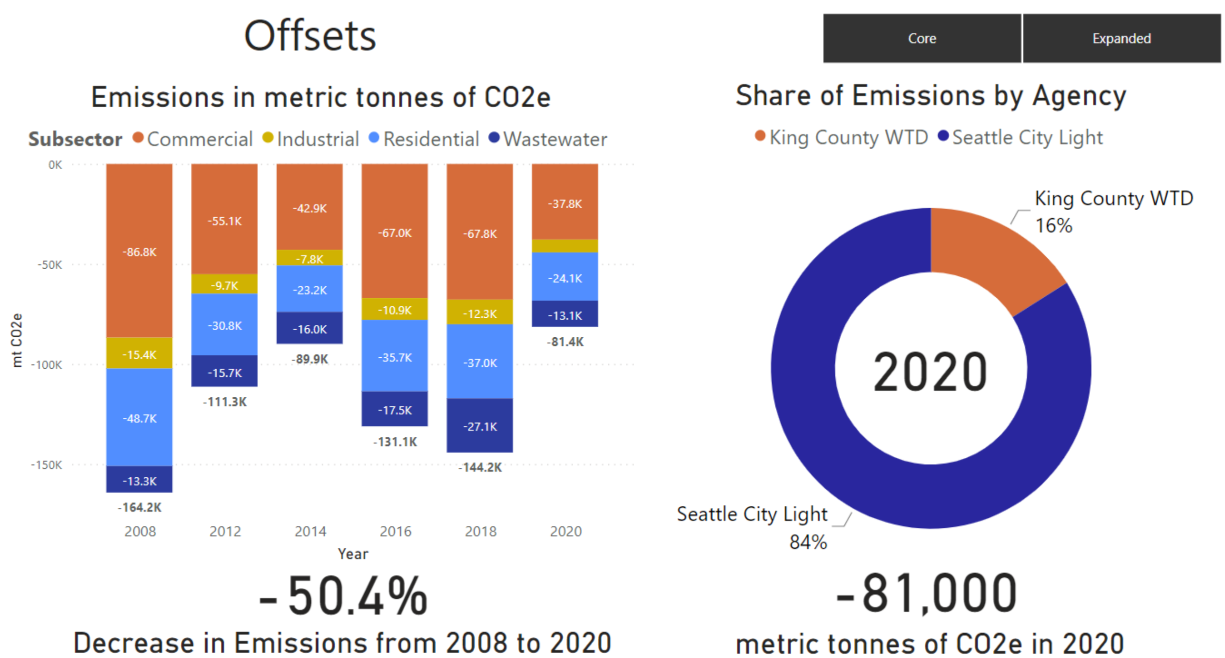

Figure 20: Emissions offset by sector and agency.

Visit this website for more information on Carbon Offsets , and this page for more details on SCL's environmental stewardship strategy.

Per Capita Core GHG Emissions Drivers

Per capita emissions have remained below 2008 levels year-over-year since 2008, demonstrating that improvements in energy use and vehicle fuel efficiencies have led to a decrease in emissions. Core per capita GHG emissions decreased from 4.89 $mtCO_2e$ per resident in 2018 to 4.09 $mtCO_2e$ per resident in 2020. The waterfall graph in **Figure 21** shows several factors contributing to the overall decrease in per capita emissions from 2018 to 2020. The greatest reductions in per capita GHG emissions can be attributed to decreased passenger vehicle travel, more efficient passenger vehicles, and reduced commercial energy usage.

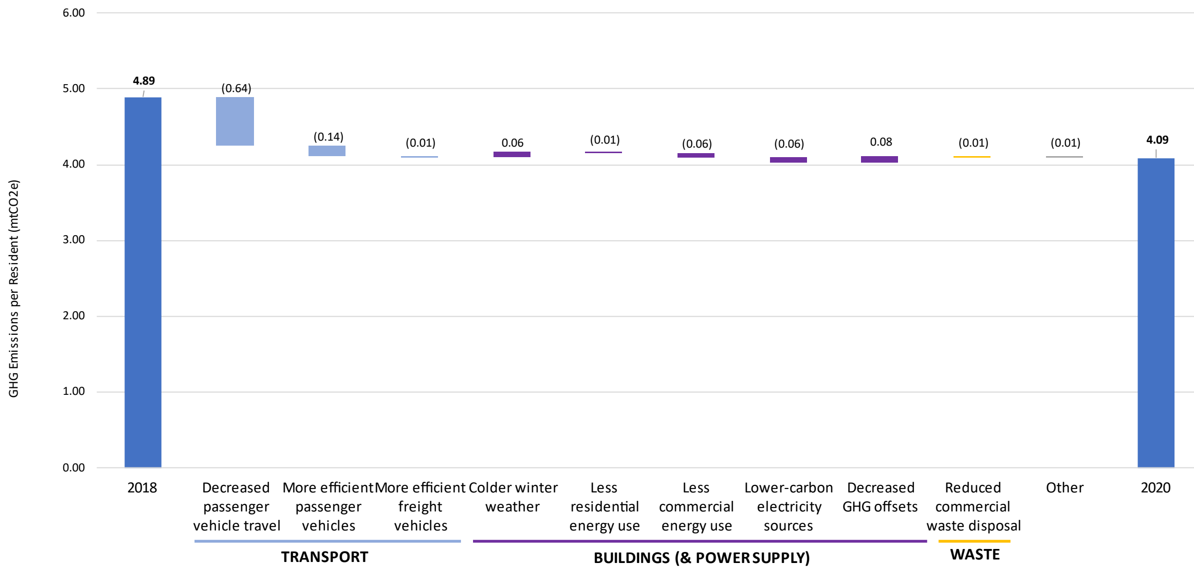

Figure 21: Factors contributing to a reduction in per capita core emissions between 2018 and 2020.

Overall Expanded GHG Emissions Drivers

Excluding Sequestration, the core and expanded GHG emissions for Seattle decreased from 6.49 million mtCO2e to 5.25 million mtCO_2e from 2018 to 2020. Even accounting for population decline, the per capita emissions still dropped from 6.49 million mtCO2e per person to 5.24 million mtCO2e per person.

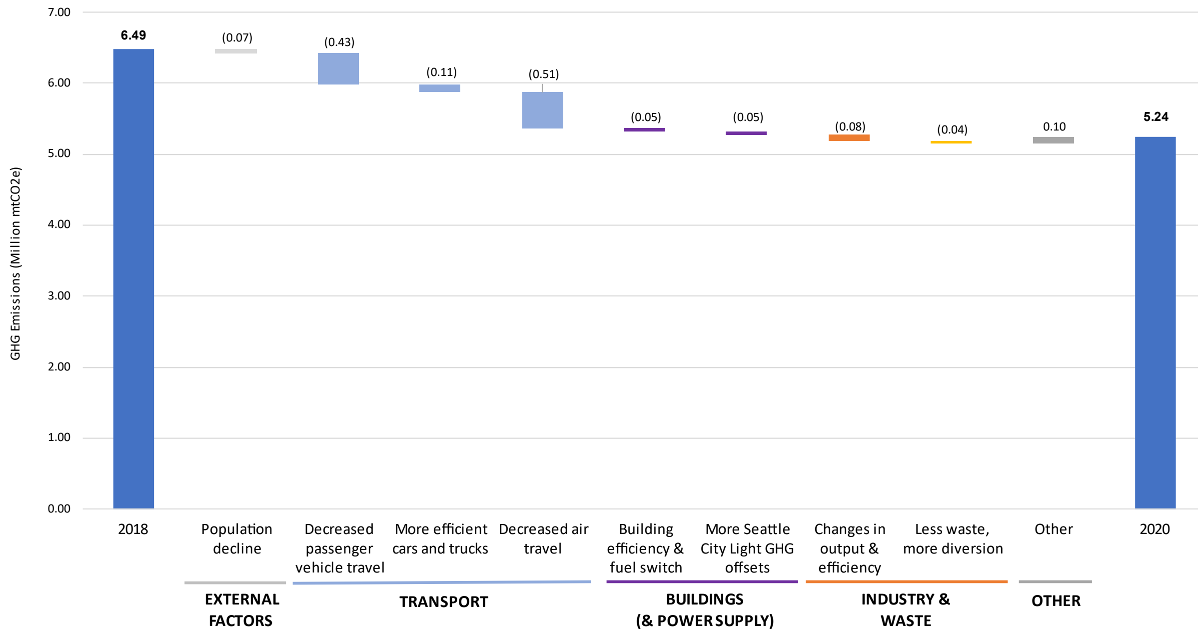

Figure 22: Factors contributing to a reduction in per capita expanded emissions between 2018 and 2020.

Figure 22 shows that the greatest contributors to reduced GHG emissions in Seattle came from decreased air and passenger vehicle travel. Population declined contributed 70,000 mtCO_2e between 2018 and 2020.

Appendix

Appendix A: Detailed Emissions Inventory Tables

Emissions Category	2008	2012	2014	2016	2018	2020
Buildings	**1,431,000**	**1,316,000**	**1,274,000**	**1,296,000**	**1,403,000**	**1,345,000**
Commercial	**824,000**	**775,000**	**771,000**	**798,000**	**867,000**	**815,000**
CenTrio Steam	91,000	76,000	62,000	70,000	68,000	63,000
Fossil Gas	91,000	76,000	62,000	70,000	67,000	63,000
Oil	0	0	0	0	1,000	0
Equipment	140,000	146,000	157,000	170,000	184,000	198,000
CNG	2,000	2,000	2,000	2,000	3,000	3,000
Diesel	39,000	45,000	49,000	53,000	57,000	62,000
Gasoline	95,000	94,000	101,000	109,000	118,000	126,000
LPG	4,000	5,000	5,000	6,000	6,000	7,000
Heating Oil	8,000	2,000	2,000	1,000	0	1,000
Oil	8,000	2,000	2,000	1,000	0	1,000
PSE	413,000	416,000	431,000	407,000	460,000	433,000
Fossil Gas	413,000	416,000	431,000	407,000	460,000	433,000
Seattle City Light	87,000	55,000	43,000	67,000	68,000	38,000
Electricity	87,000	55,000	43,000	67,000	68,000	38,000
UW Steam	85,000	80,000	76,000	83,000	87,000	82,000
Fossil Gas	85,000	80,000	76,000	83,000	86,000	82,000
Oil	0	0	0	0	1,000	0
Residential	**607,000**	**541,000**	**503,000**	**498,000**	**536,000**	**530,000**
Heating Oil	109,000	72,000	63,000	61,000	57,000	61,000
Oil	109,000	72,000	63,000	61,000	57,000	61,000
PSE	432,000	420,000	399,000	382,000	422,000	425,000
Fossil Gas	432,000	420,000	399,000	382,000	422,000	425,000
Seattle City Light	49,000	31,000	23,000	36,000	37,000	24,000
Electricity	49,000	31,000	23,000	36,000	37,000	24,000
Yard Equipment	17,000	18,000	18,000	19,000	20,000	20,000
CNG	0	0	0	0	0	0
Diesel	0	0	0	0	0	0
Gasoline	17,000	18,000	18,000	19,000	20,000	20,000
LPG	0	0	0	0	0	0
Industry	**1,357,000**	**902,000**	**1,104,000**	**1,011,000**	**1,051,000**	**961,000**
Energy Use	**510,000**	**475,000**	**419,000**	**536,000**	**551,000**	**507,000**
Equipment	213,000	179,000	190,000	210,000	209,000	212,000
CNG	2,000	2,000	2,000	2,000	2,000	2,000
Diesel	172,000	149,000	157,000	174,000	173,000	175,000
Gasoline	6,000	3,000	3,000	3,000	3,000	3,000
LPG	33,000	25,000	28,000	31,000	31,000	32,000
Heating Oil	36,000	16,000	14,000	19,000	16,000	18,000

Emissions Category	2008	2012	2014	2016	2018	2020
Oil	36,000	16,000	14,000	19,000	16,000	18,000
PSE	246,000	270,000	207,000	296,000	314,000	271,000
Fossil Gas	246,000	270,000	207,000	296,000	314,000	271,000
Seattle City Light	15,000	10,000	8,000	11,000	12,000	6,000
Electricity	15,000	10,000	8,000	11,000	12,000	6,000
Fugitive Gases	**24,000**	**20,000**	**18,000**	**19,000**	**22,000**	**20,000**
PSE	22,000	18,000	16,000	17,000	21,000	20,000
Gas Infrastructure Leaks	22,000	18,000	16,000	17,000	21,000	20,000
Seattle City Light	2,000	2,000	2,000	2,000	1,000	0
SF6 from Switchgear	2,000	2,000	2,000	2,000	1,000	0
Process	**823,000**	**407,000**	**667,000**	**456,000**	**478,000**	**434,000**
Cement	746,000	305,000	523,000	384,000	363,000	346,000
Process	746,000	305,000	523,000	384,000	363,000	346,000
Glass	20,000	19,000	20,000	18,000	17,000	14,000
Process	20,000	19,000	20,000	18,000	17,000	14,000
Steel	57,000	83,000	124,000	54,000	98,000	74,000
Process	57,000	83,000	124,000	54,000	98,000	74,000
Offsets	**-164,000**	**-112,000**	**-90,000**	**-132,000**	**-144,000**	**-81,000**
Commercial	**-87,000**	**-55,000**	**-43,000**	**-67,000**	**-68,000**	**-38,000**
Seattle City Light	-87,000	-55,000	-43,000	-67,000	-68,000	-38,000
Electricity	-87,000	-55,000	-43,000	-67,000	-68,000	-38,000
Industrial	**-15,000**	**-10,000**	**-8,000**	**-11,000**	**-12,000**	**-6,000**
Seattle City Light	-15,000	-10,000	-8,000	-11,000	-12,000	-6,000
Electricity	-15,000	-10,000	-8,000	-11,000	-12,000	-6,000
Residential	**-49,000**	**-31,000**	**-23,000**	**-36,000**	**-37,000**	**-24,000**
Seattle City Light	-49,000	-31,000	-23,000	-36,000	-37,000	-24,000
Electricity	-49,000	-31,000	-23,000	-36,000	-37,000	-24,000
Wastewater	**-13,000**	**-16,000**	**-16,000**	**-18,000**	**-27,000**	**-13,000**
King County WTD	-13,000	-16,000	-16,000	-18,000	-27,000	-13,000
Electricity	-13,000	-16,000	-16,000	-18,000	-27,000	-13,000
Sequestration	**-186,700**	**-146,600**	**-147,100**	**-162,200**	**-174,700**	**-173,000**
Commercial	**-45,900**	**-33,800**	**-38,500**	**-37,200**	**-37,200**	**-29,500**
Construction Materials	-11,700	-9,500	-9,900	-11,800	-11,800	-9,400
Dimensional Lumber	-11,600	-9,400	-9,800	-11,700	-11,700	-9,300
Drywall	-100	-100	-100	-100	-100	-100
Food Waste	-4,900	-3,500	-3,600	-3,000	-3,000	-2,300
Food Waste	-4,900	-3,500	-3,600	-3,000	-3,000	-2,300
Mixed Materials	-5,900	-5,200	-5,800	-7,400	-7,400	-5,900
Mixed Organics	-5,900	-5,200	-5,800	-7,400	-7,400	-5,900
Paper	-21,900	-15,400	-19,000	-14,100	-14,100	-11,200
Corrugated Containers	-7,200	-600	-3,500	-4,300	-4,300	-3,400

Emissions Category	2008	2012	2014	2016	2018	2020
Mixed Paper (general)	-11,100	-12,100	-12,700	-8,200	-8,200	-6,500
Newspaper	-3,200	-2,400	-2,500	-1,400	-1,400	-1,100
Office Paper	-400	-300	-300	-200	-200	-200
Yard Trimmings	-1,500	-200	-200	-900	-900	-700
Branches	-1,100	0	0	-600	-600	-500
Grass	-400	-200	-200	-300	-300	-200
Construction & Demolition	**-72,500**	**-58,900**	**-58,200**	**-66,400**	**-60,600**	**-67,300**
Construction Materials	-68,300	-55,900	-55,300	-63,100	-57,600	-64,000
Dimensional Lumber	-68,300	-55,900	-55,300	-63,100	-57,600	-64,000
Mixed Materials	-100	-300	-300	-300	-300	-300
Mixed Organics	-100	-300	-300	-300	-300	-300
Paper	-2,200	-2,000	-1,900	-2,200	-2,000	-2,200
Corrugated Containers	-1,200	-900	-900	-1,000	-900	-1,000
Mixed Paper (general)	-1,000	-1,100	-1,000	-1,200	-1,100	-1,200
Yard Trimmings	-1,900	-700	-700	-800	-700	-800
Branches	-1,100	-600	-600	-700	-600	-700
Grass	-100	-100	-100	-100	-100	-100
Yard Trimmings	-700	0	0	0	0	0
Residential	**-28,100**	**-26,600**	**-27,800**	**-25,700**	**-26,500**	**-27,400**
Construction Materials	-2,900	-3,600	-2,700	-2,500	-2,500	-3,700
Dimensional Lumber	-2,800	-3,600	-2,700	-2,500	-2,500	-3,700
Drywall	-100	0	0	0	0	0
Food Waste	-3,700	-2,900	-2,900	-2,700	-2,800	-2,100
Food Waste	-3,700	-2,900	-2,900	-2,700	-2,800	-2,100
Mixed Materials	-9,700	-10,100	-10,100	-9,300	-9,600	-11,300
Mixed Organics	-9,700	-10,100	-10,100	-9,300	-9,600	-11,300
Paper	-10,900	-8,900	-11,500	-10,600	-11,000	-9,700
Corrugated Containers	-1,800	-1,500	-1,100	-1,000	-1,100	-2,700
Mixed Paper (general)	-6,700	-5,900	-7,200	-6,700	-6,900	-6,500
Newspaper	-2,300	-1,400	-3,000	-2,700	-2,800	-500
Office Paper	-100	-100	-200	-200	-200	0
Yard Trimmings	-900	-1,100	-600	-600	-600	-600
Branches	-500	-800	-400	-400	-400	-500
Grass	-400	-300	-200	-200	-200	-100
Selfhaul	**-40,200**	**-27,300**	**-22,600**	**-32,900**	**-50,400**	**-48,800**
Construction Materials	-35,100	-19,800	-16,300	-30,600	-46,900	-45,300
Dimensional Lumber	-34,800	-19,500	-16,000	-30,400	-46,600	-45,000
Drywall	-300	-300	-300	-200	-300	-300
Food Waste	-200	-300	-300	-100	-200	-200
Food Waste	-200	-300	-300	-100	-200	-200
Mixed Materials	-1,300	-1,000	-800	-500	-800	-800
Mixed Organics	-1,300	-1,000	-800	-500	-800	-800

Emissions Category	2008	2012	2014	2016	2018	2020
Paper	-3,200	-6,000	-5,000	-1,500	-2,300	-2,300
Corrugated Containers	-1,500	-800	-700	-900	-1,400	-1,400
Mixed Paper (general)	-1,600	-4,500	-3,700	-600	-900	-900
Newspaper	-100	-600	-500	0	0	0
Office Paper	0	-100	-100	0	0	0
Yard Trimmings	-400	-200	-200	-200	-200	-200
Branches	-200	0	0	-100	-100	-100
Grass	-200	-200	-200	-100	-100	-100
Transportation	**3,810,000**	**3,700,000**	**3,848,000**	**4,031,000**	**4,085,000**	**2,938,000**
Air	**972,000**	**936,000**	**1,093,000**	**1,253,000**	**1,369,000**	**844,000**
King County Airport	262,000	228,000	238,000	234,000	252,000	168,000
Jet Fuel	262,000	228,000	238,000	234,000	252,000	168,000
Sea-Tac Airport	710,000	708,000	855,000	1,019,000	1,117,000	676,000
Jet Fuel	710,000	708,000	855,000	1,019,000	1,117,000	676,000
Marine	**179,000**	**176,000**	**179,000**	**180,000**	**181,000**	**180,000**
Hotelling	53,000	43,000	37,000	36,000	36,000	36,000
Diesel	53,000	43,000	37,000	36,000	36,000	36,000
Other Boat Traffic	59,000	62,000	76,000	74,000	74,000	85,000
Diesel	59,000	62,000	76,000	74,000	74,000	85,000
Pleasure Craft	32,000	30,000	25,000	26,000	26,000	26,000
Diesel	6,000	6,000	6,000	6,000	6,000	6,000
Gasoline	26,000	24,000	19,000	20,000	20,000	20,000
State Ferries	35,000	41,000	41,000	44,000	45,000	33,000
Bio-Diesel	0	1,000	2,000	2,000	2,000	3,000
Diesel	35,000	40,000	39,000	42,000	43,000	30,000
Rail	**48,000**	**42,000**	**33,000**	**32,000**	**33,000**	**27,000**
Rail - Freight	41,000	34,000	24,000	23,000	23,000	23,000
Diesel	41,000	34,000	24,000	23,000	23,000	23,000
Rail - Passenger	7,000	8,000	9,000	9,000	10,000	4,000
Diesel	7,000	8,000	9,000	9,000	10,000	4,000
Road: Passenger	**2,351,000**	**2,290,000**	**2,282,000**	**2,297,000**	**2,235,000**	**1,680,000**
Buses	61,000	68,000	66,000	65,000	66,000	51,000
CNG	1,000	1,000	1,000	0	1,000	1,000
Diesel	60,000	67,000	65,000	65,000	65,000	50,000
Cars & Light Duty Trucks	2,290,000	2,222,000	2,216,000	2,232,000	2,169,000	1,629,000
Gasoline	2,290,000	2,222,000	2,216,000	2,232,000	2,169,000	1,629,000
Road: Trucks	**260,000**	**256,000**	**261,000**	**269,000**	**267,000**	**207,000**
Medium & Heavy Duty	260,000	256,000	261,000	269,000	267,000	207,000
Diesel	185,000	184,000	189,000	196,000	196,000	153,000
Gasoline	75,000	72,000	72,000	73,000	71,000	54,000
Waste	**128,300**	**107,600**	**110,400**	**103,700**	**98,700**	**88,600**
Commercial	**52,500**	**38,100**	**42,300**	**37,500**	**35,000**	**27,800**

Emissions Category	2008	2012	2014	2016	2018	2020
Construction Materials	1,000	700	700	900	700	500
Asphalt Concrete	0	0	0	0	0	0
Asphalt Shingles	0	0	0	0	0	0
Carpet	0	0	0	0	0	0
Clay Bricks	0	0	0	0	0	0
Concrete	100	0	0	0	0	0
Dimensional Lumber	900	700	700	900	700	500
Drywall	0	0	0	0	0	0
Fiberglass Insulation	0	0	0	0	0	0
Electronics	100	400	0	0	0	0
CRT Displays	0	0	0	0	0	0
Mixed Electronics	100	400	0	0	0	0
Portable Electronic Devices	0	0	0	0	0	0
Food Waste	22,900	16,400	17,100	14,000	13,300	10,600
Food Waste	22,900	16,400	17,100	14,000	13,300	10,600
Glass	100	100	100	100	100	100
Glass	100	100	100	100	100	100
Metals	300	100	100	200	100	100
Aluminum Cans	0	0	0	0	0	0
Mixed Metals	300	100	100	200	100	100
Steel Cans	0	0	0	0	0	0
Mixed Materials	7,200	6,400	6,900	8,600	7,900	6,300
Mixed MSW	700	700	500	500	300	200
Mixed Organics	6,500	5,700	6,400	8,100	7,600	6,100
Paper	19,100	13,300	16,400	12,300	11,900	9,400
Corrugated Containers	6,400	600	3,100	3,800	3,700	2,900
Mixed Paper (general)	8,900	9,700	10,200	6,600	6,400	5,100
Newspaper	700	600	600	300	300	200
Office Paper	3,100	2,400	2,500	1,600	1,500	1,200
Plastics	900	400	700	900	500	400
HDPE	0	0	0	0	0	0
LDPE	400	100	400	500	300	200
Mixed Plastics	500	300	300	400	200	200
PET	0	0	0	0	0	0
Tires	0	0	0	0	0	0
Tires	0	0	0	0	0	0
Yard Trimmings	900	300	300	500	500	400
Branches	400	0	0	200	200	200
Grass	500	300	300	300	300	200
Construction & Demolition	**12,900**	**9,400**	**9,300**	**10,900**	**7,300**	**8,300**
Construction Materials	7,700	5,900	5,800	6,700	4,300	4,900

Emissions Category	2008	2012	2014	2016	2018	2020
Asphalt Concrete	100	0	0	0	0	0
Asphalt Shingles	1,100	500	500	600	300	400
Clay Bricks	400	400	400	500	200	300
Concrete	100	0	0	0	0	0
Dimensional Lumber	5,100	4,200	4,100	4,700	3,300	3,700
Drywall	900	800	800	900	500	500
Fiberglass Insulation	0	0	0	0	0	0
Electronics	0	0	0	0	0	0
CRT Displays	0	0	0	0	0	0
Mixed Electronics	0	0	0	0	0	0
Portable Electronic Devices	0	0	0	0	0	0
Glass	0	100	100	100	100	100
Glass	0	100	100	100	100	100
Metals	300	100	100	200	100	100
Mixed Metals	300	100	100	200	100	100
Mixed Materials	1,900	1,200	1,200	1,300	800	900
Mixed MSW	1,800	900	900	1,000	500	600
Mixed Organics	100	300	300	300	300	300
Paper	1,800	1,600	1,600	1,900	1,600	1,800
Corrugated Containers	1,000	800	800	900	800	900
Mixed Paper (general)	800	800	800	1,000	800	900
Plastics	300	200	200	300	100	200
Mixed Plastics	300	200	200	300	100	200
Tires	0	0	0	0	0	0
Tires	0	0	0	0	0	0
Yard Trimmings	900	300	300	400	300	300
Branches	400	200	200	200	200	200
Grass	200	100	100	200	100	100
Yard Trimmings	300	0	0	0	0	0
Residential	**38,300**	**33,600**	**34,900**	**32,300**	**31,600**	**29,700**
Construction Materials	300	300	300	200	100	200
Asphalt Concrete	0	0	0	0	0	0
Asphalt Shingles	0	0	0	0	0	0
Carpet	100	0	100	0	0	0
Clay Bricks	0	0	0	0	0	0
Concrete	0	0	0	0	0	0
Dimensional Lumber	200	300	200	200	100	200
Drywall	0	0	0	0	0	0
Fiberglass Insulation	0	0	0	0	0	0
Electronics	100	0	0	0	0	0
CRT Displays	0	0	0	0	0	0

Emissions Category	2008	2012	2014	2016	2018	2020
Mixed Electronics	100	0	0	0	0	0
Portable Electronic Devices	0	0	0	0	0	0
Food Waste	17,400	13,600	13,600	12,600	12,400	9,200
Food Waste	17,400	13,600	13,600	12,600	12,400	9,200
Glass	100	100	100	100	100	100
Glass	100	100	100	100	100	100
Metals	100	200	100	100	100	100
Aluminum Cans	0	0	0	0	0	0
Mixed Metals	100	200	100	100	100	100
Steel Cans	0	0	0	0	0	0
Mixed Materials	10,800	11,200	11,100	10,300	10,000	11,900
Mixed MSW	200	200	100	100	100	200
Mixed Organics	10,600	11,000	11,000	10,200	9,900	11,700
Paper	8,300	7,200	8,900	8,200	8,300	7,500
Corrugated Containers	1,600	1,300	1,000	900	900	2,300
Mixed Paper (general)	5,300	4,700	5,800	5,400	5,400	5,000
Newspaper	500	300	700	600	600	100
Office Paper	900	900	1,400	1,300	1,400	100
Plastics	600	400	500	500	300	500
HDPE	0	0	0	0	0	0
LDPE	300	200	300	300	200	200
LLDPE	0	0	0	0	0	100
Mixed Plastics	300	200	200	200	100	200
PET	0	0	0	0	0	0
PLA	0	0	0	0	0	0
PP	0	0	0	0	0	0
Tires	0	0	0	0	0	0
Tires	0	0	0	0	0	0
Yard Trimmings	600	600	300	300	300	200
Branches	200	300	100	100	100	100
Grass	400	300	200	200	200	100
Selfhaul	**9,900**	**11,000**	**9,100**	**6,200**	**7,400**	**7,300**
Construction Materials	3,400	1,900	1,600	2,800	3,000	2,900
Asphalt Concrete	0	0	0	0	0	0
Asphalt Shingles	100	0	0	0	0	0
Carpet	200	100	100	200	100	100
Clay Bricks	100	0	0	100	100	100
Concrete	200	100	100	100	0	0
Dimensional Lumber	2,600	1,500	1,200	2,300	2,700	2,600
Drywall	200	200	200	100	100	100
Fiberglass Insulation	0	0	0	0	0	0

Emissions Category	2008	2012	2014	2016	2018	2020
Electronics	0	0	0	0	0	0
CRT Displays	0	0	0	0	0	0
Mixed Electronics	0	0	0	0	0	0
Portable Electronic Devices	0	0	0	0	0	0
Food Waste	800	1,400	1,200	500	700	700
Food Waste	800	1,400	1,200	500	700	700
Glass	100	100	100	0	0	0
Glass	100	100	100	0	0	0
Metals	200	100	100	200	200	200
Aluminum Cans	0	0	0	0	0	0
Mixed Metals	200	100	100	200	200	200
Steel Cans	0	0	0	0	0	0
Mixed Materials	2,200	1,700	1,400	1,100	1,300	1,300
Mixed MSW	800	600	500	500	500	500
Mixed Organics	1,400	1,100	900	600	800	800
Paper	2,700	5,200	4,400	1,300	1,900	1,900
Corrugated Containers	1,300	700	600	800	1,200	1,200
Mixed Paper (general)	1,300	3,600	3,000	500	700	700
Newspaper	0	100	100	0	0	0
Office Paper	100	800	700	0	0	0
Plastics	200	300	100	200	200	200
HDPE	0	0	0	0	0	0
LDPE	0	100	0	0	0	0
Mixed Plastics	200	200	100	200	200	200
PET	0	0	0	0	0	0
Tires	0	0	0	0	0	0
Tires	0	0	0	0	0	0
Yard Trimmings	300	300	200	100	100	100
Branches	100	0	0	0	0	0
Grass	200	300	200	100	100	100
Wastewater	**14,700**	**15,500**	**14,800**	**16,800**	**17,400**	**15,500**
Fugitive	14,700	15,500	14,800	16,800	17,400	15,500
Fugitive Emissions	14,700	15,500	14,800	16,800	17,400	15,500
Grand Total	**6,375,600**	**5,767,000**	**6,099,300**	**6,147,500**	**6,319,000**	**5,078,600**

Appendix B: Data Model Change

In 2018, the Seattle GHG inventory transitioned from an Excel-based model to an Excel and Power BI model to improve the efficiency and replicability for future greenhouse gas inventories. Doing this also allows the city to display connected, flexible, and interactive online dashboards on a website. All of the transition base values are now compiled in an Excel workbook called <CityofSeattleEmissionsInputMaster>.

B1: Emissions Calculations

All the numbers needed for the GHG calculations are pulled in from the <CityofSeattleEmissionsInputMaster> Excel workbook, and the calculations are automatically performed using DAX code in calculated columns and measures in Power BI instead of in an Excel workbook as previous years have done.

The GHG calculation methodology for this 2020 inventory remains effectively the same as the 2018 GHG inventory. However, the methodology changed slightly for a few instances to improve accuracy or to retroactively update calculations.

See **Appendix D1**: Road Transportation, D1.1 Light-, Medium-, and Heavy-Duty Vehicles, for revised road transportation methodology based on PSRC's SoundCast 2018 Model.

See **Appendix D1**: Road Transportation, *D1.2 King County Metro and Sound Transit* Busses, for revised CNG emission methodology.

See **Appendix D8**: Waste & Wastewater, *D8.1 Waste Management*, for revised waste composition methodology.

See **Appendix D8**: Waste & Wastewater, *D8.2 Wastewater* Treatment, for retroactive updates to KCWTD's reporting process for wastewater emissions to align with the 2019 IPCC Guidelines.

Appendix C: Source Documentation

The formal inventory is a dataset consisting of electronic files. This set of files is not available to download but can be requested via email through the staff contact listed on OSE's GHG Inventory webpage. The data files are divided into the following categories:

C1: Index file

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

C2: Source files

These files range from categories YR-00 to YR-80. Within each category, files are denoted by the file number that follows the category (i.e. 20-10-XX). The files are organized by category in the following format, with 'YR' indicating the 2-digit year the inventory file corresponds to:

YR-00 Inventory

YR-10 Transportation

YR-20 Buildings

YR-40 Industry

YR-50 Waste

YR-60 Electricity

YR-70 Demographics

YR-80 Reference

As source files are superseded by newer files, the previous versions are archived, and the new information incorporated. In addition, some source files from prior inventory work in Seattle are referenced in <CityofSeattleEmissionsInputMaster.xlsx>. These source files are provided in comments and source notes in the format 14-XX-XX (*2014 Seattle Community Greenhouse Gas Inventory*), 12-XX-XX (*2012 Seattle Community Greenhouse Gas Inventory*), 08-XX-XX (*2008 Seattle Community Greenhouse Gas Inventory*) or 05-XX-XX (*2005 Inventory of Seattle Greenhouse Gas Emissions: Community & Corporate*) and are maintained by the City of Seattle Office of Sustainability & Environment (OSE).

Appendix D: Methodology & Source Notes

D1: Road Transportation

D1.1 Light-, Medium-, and Heavy-Duty Vehicles

ICLEI[16] recommends different protocols for estimating emissions from the transportation sector for self-reported inventories (SRI). TR.1 *Emissions from Passenger Vehicles* recommends methodology and equations for estimating emissions from passenger vehicles. Table TR.1.1, *Descriptions of Input Data Conditions*, details methodology for estimating emissions from passenger vehicles ordered by preference.

Table TR.1.1 **Descriptions of Input Data Conditions**
You may choose different combinations of input data conditions across columns, but not within each column. The input data conditions in each column are presented in order of preference.

Travel Activity (T)	**Emissions or Energy (E)**	**Local Adjustments for vehicle efficiency and fuel type (L)**
For Recommended Method: Model data of all travel originating or terminating within the jurisdictional boundaries of a community, from: **(T1)** an activity-based* regional travel demand model with trip origin and destination data **(T2)** a trip-based travel demand model with trip origin and destination data (four step models) **For Alternate Method Only:** **(T3)** An estimate of VMT within the community from a travel demand model (cordon method), with model calibrated to observed traffic counts within the community; **(T4)** an estimate of VMT within the community from a source other than a travel demand model (see equation TR.1.B.1 below)	**For All Methods:** Output of CO_2, N_2O, and CH_4 for each or the aggregate of all traffic analysis zones within the community from: **(E1)** a fully-integrated modal emissions model (vehicle hours operating for each vehicle specific power bins), such as U.S. EPA MOVES (see Table TR.1.2 for details); **(E2)** a vehicle-mile-traveled (VMT)-based emissions model using VMT and speed outputs from the travel model, such as EMFAC or MOBILE **(E3)** Any post-processing method which relies on aggregated methods of vehicle activity, such as emissions per mile or assumed fuel efficiency (including equations TR.1.B.1 and TR.1.B.2)	**For All Methods:** **(L1)** Adjustments within the model for vehicle mix based on known data on vehicle registrations per community or traffic analysis zone; **(L2)** Post-processing adjustments based on known-data on vehicle registrations per community or traffic analysis zone; **(L3)** Adjustments based on known county-wide or regional average data (includes use of EMFAC county sub-area for California users); **(L4)** Adjustments based on known statewide average data **(L5)** No adjustments, use national averages (model default)

* 'Activity-based' in this context refers to the way in which travel demand is modeled, and is unrelated to the distinction made in this protocol between activities and sources.

Figure 23: ICLEI: Table TR.1.1 Descriptions of Input Data Conditions[16]

D1.1.1 Light-Duty Vehicles

Travel Activity (T) is derived from the T1 methodology, which uses an activity-based regional travel demand model with trip origin and destination data curtesy of PSRC's SoundCast 2018 model[17]. Emissions or Energy (E) is derived from the E3 methodology, which relies on aggregating vehicle activity based on assumed fuel efficiency in the inventory year. Local adjustments for vehicle efficiency and fuel

[16] ICLEI's U.S. Community Protocol, Appendix D Transportation and Other Mobile Emission Activities and Sources
[17] Puget Sound Regional Council, Activity-Based Travel Model: SoundCast 2018

type (L) are derived from L3, which makes adjustments based on an average of measured county-wide data.

Following the T1 methodology for light-duty vehicles, PSRC generated an output from the SoundCast 2018 model to estimate VMTs by origin and destination per Census tract in Seattle for roadway emissions[18]. SoundCast models the travel behavior of individuals and households in the Puget Sound area based on a daily activity pattern derived from sociodemographic and land-use data for the base year of 2018. Trips from origins, and destinations, are compiled and the resulting VMT is calculated based on the Manhattan distance, or distance along the street network, to the destination, or origin. This process is known as an origin-destination pair approach and is recommended per ICLEI[16] for community-scale inventories.

Commute and non-commute VMTs were summarized at the Census tract-level per origin and destination and then averaged to obtain a citywide estimate for an average weekday in the model year. Light-duty vehicles were further delineated by single-occupancy vehicles (SOV), carpools with two passengers (CP2), and carpools with more than two passengers (CP3+). This method counts the entire length of a trip if it's origin or destination resides in a Census tract within the city limits of Seattle. This includes VMT outside the city if it begins or ends within the geographic boundary, but omits trips that both begin and end outside the city, even if they pass through (e.g. on I-5). VMT outside the city limits are included as the City could influence individual travel choices through infrastructure and policy implementation when the origin or destination resides within the city limits

VMTs for an average weekday are then grown by the number of days in a year (365.25 days) as recommended per ICLEI[16]*, TR.1.B.1 VMT Estimate from Passenger Vehicles*, however, this methodology may not accurately capture emissions as travel patterns are significantly different between weekdays and weekends. PSRC uses an annual adjustment factor of 300 to model yearly estimates from daily outputs within their model. The adjustment factor of 365.25 remains in use as it is recommended by ICLEI[16], but it should be reviewed to improve the accuracy within the transportation sector.

D1.1.2 Medium- and Heavy-Duty Vehicles

For medium and heavy-duty vehicles, the T3 methodology was used which incorporated the SoundCast 2018 model to derive VMT that passes through each Census tract regardless of if the origin or destination was in Seattle. VMTs and total daily tons of CO2 were summarized by PSRC at the Census tract-level for medium-duty and heavy-duty vehicles[19]. The T1 methodology used for light-duty vehicle emissions could not be replicated due to difficulties in accurately modeling truck traffic.

Like the methodology for light-duty vehicles, Emissions or Energy (E) is derived from the E3 methodology, which relies on aggregating vehicle activity based on assumed fuel efficiency in the inventory year. Local adjustments for vehicle efficiency and fuel type (L) are derived from L3, which adjusts based on an average of measured county-wide data.

As mentioned earlier in the light-duty methodology, VMTs for an average weekday are then grown by the number of days in a year (365.25 days), as recommended per ICLEI[16]. This methodology should be reviewed to estimate roadway emissions more accurately.

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[18] PSRC SoundCast 2018, Origin/destination model output for cars and light-duty trucks. 20-11-05.

[19] PSRC SoundCast 2018, Intertract VMT model output for medium and heavy-duty trucks. 20-11-06.

D1.1.3 Non-Model Year VMT Adjustments

To estimate VMT for inventory years that are not model years, a percentage of local vehicle activity relative to the base year of 2018 was used to forecast and back-cast values. The same process remains consistent for light-, medium-, and heavy-duty vehicles. The Washington State Department of Transportation (WSDOT) reports yearly urban VMT on state highways in King County[20], which is used to estimate past and future citywide VMTs. WSDOT uses a consistent methodology from year to year for these roads, which carry about half of the VMT in King County. Therefore, this was judged to be a purer signal of yearly changes in VMT than data provided to the federal Highway Performance Management System (HPMS) by WSDOT. The WSDOT data provided to the HPMS for state highway VMTs are supplemented with sampled data from local roads, which has higher uncertainty and a non-standard methodology over time.

D1.1.4 Emissions

To calculate fuel consumption, annual VMTs per class were multiplied by their respective fuel economies derived from PSRC modeling for King County. PSRC provided vehicle fuel efficiency estimates for King County by vehicle class (cars, light trucks, etc.) for 2005 through 2020[10]. For each vehicle category in PSRC's VMT model results (i.e. passenger vehicles, commercial trucks), a composite fuel economy figure was calculated using a weighted average based on the VMT of the vehicle classes in that category based on PSRC's estimated fleet makeup. Finally, annual fuel consumption was multiplied by energy intensities for fuel-specific (gasoline or diesel) carbon contents from the US EPA's national GHG inventory[22]. The methodology for fuel economy calculation is a simplified version of the approach taken in prior years. Previous calculated fuel economy figures have consequently been updated in the inventory.

D1.2 King County Metro and Sound Transit Busses

ICLEI's TR.4, *Emissions from Transit*[16] details methodology for estimating emissions from busses. Emissions from non-electric buses were calculated based on King County Metro (KCM)[21] diesel usage and Sound Transit[21] diesel and compressed natural gas (CNG) usage as reported in the '*2020 Fuel and Energy'* data table from the Federal Transit Administration's (FTA) National Transit Database (NTD). Diesel was converted to CO2e using energy intensities from the US EPA's national GHG inventory[22].

CNG is reported in diesel-gallon equivalents (DGE)[23] in '*2020 Fuel and Energy*' and must be converted to pounds or standard cubic feet[24] (scf) of CNG before applying the emission factor for pounds of CNG to emissions. Since CNG exists in a gaseous state, the volume fluctuates depending on the temperature and pressure. To compensate, CNG measurements rely on the volume of CNG in scf or on the weight of CNG.

In 2020, the methodology was revised as the calculation for 'Road Transportation: Busses: CNG' previously used an emission factor for CNG that was misapplied to DGE of CNG. The updated methodology relies on converting the DGE of CNG to pounds of CNG.

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[20] WSDOT, Annual mileage and travel information. *State Highway Vehicles Miles Traveled*.
[21] KCM – NTD ID: 00001, Mode: MB, TOS: DO; Sound Transit – NTD ID: 00040, Mode: CB, TOS: DO.
[22] EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 2020*, Annex 2, Emissions from fossil fuel combustion
[23] DGE refers to the amount of volume in diesel equivalent to the amount of energy in the volume of CNG. This conversion is for energy content purposes and is not a perfect proxy for emissions.
[24] One standard cubic foot is equal to the volume of one cubic foot at standard pressure (1 ATM) and temperature (20 degrees C).

Finally, bus fuel use was then scaled based on an estimated ratio of miles traveled on routes serving the city of Seattle for both KCM and Sound Transit.

D1.3 Uncertainty

Uncertainty exists in the estimates of VMT as the methodology relies on modeled VMT data from PSRC's 2018 SoundCast model. Values from the 2018 model differ significantly from the 2014 model, however, this is expected as models change substantially over time due to updated data and methodology. The 2018 model superseded the 2014 model and updated VMTs were retroactively applied to earlier years.

A citywide average miles per gallon (mpg) value is derived from the fleet makeup and fuel economy for Seattle's modelled fleet for light, medium, and heavy-duty vehicles based on PSRC's data for each inventory year. This value is then applied to the citywide VMT to estimate fuel consumption from vehicles in Seattle. Since fuel efficiency and VMT vary greatly between different makes and models, some certainty is lost by using a composite value instead of delineating estimated VMT by vehicle type and fleet makeup.

Additionally, vehicular emissions are a function of the vehicle's driving characteristics, which is predominantly impacted by speed and braking. Driving characteristics vary greatly based on the functional class of the roadway, which is not accounted for in the citywide fuel efficiency approach. Currently, VMT on a highway and VMT on a local road are attributed the same fuel efficiency despite being drastically different. Additionally, other components of vehicular travel emit GHG particles, such as brake pad, tire, and road degradation. Therefore, using a fully integrated modal emissions model, such as EPA MOVES3, would provide a more accurate estimate of emissions.

Finally, the methodology for growing weekday VMT to yearly VMT should be reviewed. Traffic engineering methodology typically uses a factor between 300 and 320 to grow weekday average daily traffic (ADT) to yearly daily traffic as traffic conditions differ greatly between weekdays and weekends.

D1.4 Data Needs

To improve the accuracy of the modelled data for light-duty vehicles, E3 and L3 should be upgraded to the methodology for E1 and L1 outlined in Table TR.1.1.

To upgrade the E3 methodology to E1, the EPA MOVES3 model should be used to provide a more accurate estimation of emissions. MOVES3 models vehicle speed, individual mpg per vehicle type, sources of GHG besides fuel consumption, as well as additional metrics impacting emissions from vehicular travel. Since the driving characteristics of a vehicle influences the emissions released, it is important to incorporate this data into the model.

To upgrade the L3 methodology to L1, more granular data for fleet makeup in individual transit analysis zones (TAZs) based on registration data is needed to increase accuracy.

The methodology for factoring PSRC modeled VMT data relies on urban highway VMT from WSDOT for non-model years. However, SDOT provides motor vehicle volumes at 20 locations throughout the city to create a monthly control factor[25]. These factors can adjust VMTs based on measured monthly data

[25] Seattle Department of Transportation, *2021 Traffic Report*, p. 8.

specific to the city. Basing the control factor off SDOT maintained roads, rather than highways, may give a more accurate factor for VMT experienced within the city limits for non-model years.

D2: Air Transportation

ICLEI[16] recommends different protocols for estimating emissions from the air transportation sector for self-reported inventories (SRI). Equation TR.6.B1.1, *CO2e Emissions from Aircraft*, details methodology for estimating emissions from air travel that relies on dispensed jet fuel and aviation gas (AVGAS) volumes. TR.6.D, *Attribution of Air Travel Emissions to your Community*, details methodology to assign a portion of the total emissions to a community.

D2.1 Sea-Tac International Airport

The Port of Seattle provides data through direct correspondence for total jet fuel dispensed at the Sea-Tac Airport (SEA). The percentage of emissions attributed to Seattle was estimated through a comparison of population in the city and the greater Puget Sound region. Using Equation TR.6.D.1, *Attribution of Emissions from Air Travel to your Community*[26], emissions for Seattle from SEA were estimated.

D2.2 King County International Airport

King County International Airport (KCIA) provided data directly to OSE for jet fuel and aviation gas distributed in 2020. All resulting emissions are attributed to Seattle to account for roughly half of emissions associated with air travel to and from KCIA (since presumably fuel associated with inbound flights would be approximately equal to fuel associated with outbound flights, assuming similar origins and destinations). The KCIA emissions do not include fuel for aircraft operated by Boeing, which are fueled at a separate facility and for which fuel use data is not available for all inventory years.

D2.3 Uncertainty

Uncertainty in air travel emissions from SEA attributed to Seattle is relatively high. Even though fuel usage at the airport is documented, the method for attributing emissions to Seattle assumes that passenger travel for household and business travel is identical (per resident and employee, respectively) across the region, despite demographic differences (e.g., in income, or in type of employment). Due to COVID-19, the enplaning passenger survey (EPS) at SEA, which provided data on the origin and destination of passengers, was paused in Q1 of 2020. This created uncertainty in the percentage of passengers attributed to Seattle in 2020, which saw atypical flight travel patterns due to COVID-19.

By contrast, uncertainty in emissions at KCIA is relatively low as it is based directly on fuel usage data.

D2.4 Data Needs

More recent data for the number of passengers traveling to and from Seattle is needed to improve the accuracy of the city's attributed emissions percentage. This can be improved if SEA resumes their EPS efforts on a quarterly or yearly basis.

D3: Rail Transportation

D3.1 Rail – Passenger

Passenger rail emissions result from the Amtrak Cascades train that stops in Seattle as it travels between Portland, Oregon and Vancouver, British Columbia. The average number of gallons of diesel fuel per

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[26] ICLEI US Protocol Append D - Transportation and Other Mobile Emissions Activities and Sources.

passenger-miles was estimated based on national consumption data from the Bureau of Transportation Statistics (BTS) Table 4-27[27]. The table reports an aggregate of energy intensity (Btu/revenues passenger-mile) for diesel and electric energy consumed by rail at the national level, which is then converted to diesel gallon equivalents (DGE) per revenue passenger-mile to estimate fuel intensity.

National average fuel use per mile was scaled by the number of riders on the Cascade route as reported by WSDOT in the *Amtrak Cascades: 2020 Performance Data Report*. Consistent with the origin-destination pair methodology employed for vehicle trips, only half of the emissions associated with trips that begin or end in Seattle are attributed to the city's emissions totals.

Using the NTD's *2020 Fuel and Energy* data table, emissions from Sound Transit's Sounder commuter rail service[28] were estimated based on diesel usage reported for Sound Transit.

The city is a major destination for commuters on the Sounder, but the route also serves areas outside of the city limits. To compensate for outside trips, half of the emissions associated with the Sounder were assigned to Seattle. This is consistent with the origin-destination pair methodology employed to estimate other types of transport emissions in this inventory.

D3.2 Rail – Freight

Freight rail emissions were taken directly from the Puget Sound Maritime Air Forum *2016 Puget Sound Maritime Air Emissions Inventory (PSMAEI)*. Estimates of locomotive related emissions associated with the Port of Seattle[29] and the Northwest Seaport Alliance (NWSA) North Harbor[30] were extracted. These include emissions arising from locomotive activity moving into or out of the ports, emissions while idling at the ports, and emissions from the trains as they travel in the greater Puget Sound region while traveling to or from the ports. Emissions for prior years were recalculated to use this same definition and were scaled to each inventory reporting year (e.g. 2014) from the closest year in which a Puget Sound Maritime Emissions Inventory was conducted (e.g., 2016) using the tonnage of cargo handled at the Seattle ports as reported in the PSMAEI.

D3.3 Uncertainties

Uncertainty in freight emissions is high due to the reliance on the PSMAEI, which is released every five years. The most recent report available is from 2016, but an updated report for 2021 is in development. Since freight rail emissions are scaled by tonnage of cargo at Seattle ports, which is reported on in the PSMAEI, the values post-2016 do not differ as the value used to scale remains the same due to lack of updated data.

D3.4 Data Needs

To improve the accuracy of freight rail transportation emissions, the *2021 PSMAEI* needs to be inputted once it is released to the public.

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[27] BTS. Table 4-27: 'Energy Intensity of Amtrak Services (loss-adjusted conversion factors)'
[28] NTD ID: 00040, Mode: CR, TOS: PT
[29] *2016 PSMAEI* Table 9.56, '2016 Port of Seattle Maritime-related Emissions within the Airshed, tpy'
[30] *2016 PSMAEI* Table 9.46, '2016 NWSA North Harbor Maritime-related Emissions within the Airshed, tpy and %'

D4: Marine Transportation

D4.1 Pleasure Craft

Marine pleasure craft emissions for 2014 were obtained from the Washington Department of Ecology's *2014 Comprehensive Inventory*. This inventory calculated emissions using the EPA MOVES 2014a NONROAD model for King County. Equipment types included in the inventory's pleasure craft emissions are 'Inboard/Sterndrive', 'Outboards', and 'Personal Water Craft' for diesel and gasoline engines.

The inventory inputs identical values for King County estimates during non-modelled inventory years after 2014. This was done as emissions from pleasure craft likely have a non-linear relationship with GDP, population, employment, and other sociodemographic indicators. Therefore, forecasting emissions from the model year to non-model years would likely increase uncertainty in the reported estimate.

King County modeled emissions were then scaled by the ratio of Seattle's population to King County's population to estimate the share of emissions likely attributed to Seattle. This leads to a minimal variation between reported values for inventory years between 2014 and 2020. The EPA released the MOVES 3 NONROAD model in 2020 but estimates from this model have yet to be incorporated into the city's inventory.

D4.2 State Ferries

Emissions from state ferries attributable to Seattle were calculated using fuel cost, gallons, and route data from Washington State Ferries' Fiscal Year 2021 Route Statements (**20-12-02b**).

D4.3 Other Ship and Boat Traffic

Emissions for all ships and boats other than the Washington State Ferries and recreational boats were based on the Puget Sound Maritime Air Forum's *2016 Puget Sound Maritime Air Emissions Inventory* (PSMAEI). These other types of vessels include large container ships, bulk cargo ships, and tankers as well as cruise ships, which collectively are called "Ocean Going Vessels", or OGVs. The emissions associated with these OGVs that are included in Seattle's inventory are for energy use when the ships are secured at berth at each port, termed "hoteling", as well as energy used during maneuvering of the vessels while entering and leaving port. All estimates for OGV hoteling and maneuvering emissions are taken from the PSMAEI and were calculated as the sum of those from NWSA's North Harbor and Port of Seattle[29].

Other types of boats considered include tugboats, towboats, fishing vessels, and any other government or commercial vessel besides the ferries and recreational boats considered above, collectively called "harbor craft." Estimates for these emissions were adapted from those reported for King County[31], all of which were assumed to be attributable to Seattle, since the two ports included in the PSMAEI – Port of Seattle and the NWSA's North Harbor – are both in Seattle. The estimate from Table 4.5[31] was reduced by an estimate in PSMAEI for recreational vessels[29], and this inventory's estimate for ferries[32] was further deducted. This leaves an estimate for harbor vessels in the city without ferries and recreational boats.

[31] *2016 PSMAEI* Table 4.5, '2016 Total Study Area Commercial Harbor and Government Vessel Emissions by County and Regional Clean Air Agency, tpy'

[32] Seattle's *GHG Inventory Report*, Transportation: Marine: State Ferries

D4.4 Uncertainty

Uncertainty in emissions data for Washington State Ferries is relatively low, as they are based on fuel usage reports. By contrast, other sources, such as pleasure craft emissions, exhibit high uncertainty as they rely on modeled data that is difficult to forecast accurately.

The Puget Sound Maritime Air Forum releases a PSMAEI every five-years with the previous report being released in 2016. Due to COVID-19, the 2021 report was delayed. Many of the values in the Marine Transportation sector were grown from the *2016 PSMAEI* report using a ratio of total tonnage relative to 2016 delivered through the NWSA. Total tonnage for the inventory was inputted for years prior to 2016 from values reported in the PSMAEI. Since the 2021 report has not been published yet, emission estimates for hoteling emissions use the same ratio of tonnage and report the same value.

D4.5 Data Needs

Incorporating the results for Seattle from the EPA MOVES3 NONROAD model will increase certainty in the data by adding an additional yearly estimate for the MOVES3's model year – 2020.

Once the Port of Seattle releases the *2021 PSMAEI* report, more accurate estimates for marine activity can be incorporated into the inventory.

D5: Residential Building Energy

Fuel-specific emissions factors (gCO_2/L) from the US EPA's national GHG inventory[33] were utilized in calculating emissions from residential buildings.

D5.1 Electricity

SCL provided residential building electricity consumption (GWH) within Seattle for all inventory years through personal communication with OSE. SCL also provided emission factors (Mg of CO_2/MWh) from electricity generation for each inventory year through direct communication. The SCL emission rate was multiplied by residential electricity consumption to obtain total emissions.

D5.2 Direct Fuel Use (Fossil Gas)

PSE provided data through direct correspondence for the total count of residential customers and total natural gas dispensed (therms) for each inventory year.

D5.3 Direct Fuel Use (Heating Oil)

Seattle residential oil use was estimated from Washington State distillate fuel oil and kerosene sales by end-use, which is reported by the U.S. Energy Information Administration (EIA)[34] and scaled to Seattle by the ratio of Seattle homes with oil heat to Washington State homes with oil heat as reported by the U.S. Census Bureau[35]. Seattle's heating oil usage was also scaled by the ratio of heating degree days (HDD) in Seattle to the population-weighted statewide average number of HDD[36]. This scaling is necessary because heating demand in Seattle is somewhat less than the statewide average, which includes areas with colder winter temperatures.

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[33] EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 2020*, Annex 2, Emissions from fossil fuel combustion

[34] EIA *Distillate Fuel Oil and Kerosene Seles by End Use*, pet_cons_821use_dcu_SWA_a.xls

[35] U.S. Census Data: DP04: SELECTED HOUSING CHARACTERISTICS 2020 ACS 5-year

[36] Seattle: KSEA Station; HDD 65 deg F; Washington, population-weighted HDD: NOAA Weighted HDDs in Washington

D5.4 Uncertainty

Uncertainty in electricity and fossil gas emissions is quite low since it is based directly on utility data. Uncertainty in residential oil use emissions is relatively high since it is scaled from statewide data. In all categories, uncertainty is high in the categorization of energy use between different classes of users, such as commercial, residential, and industrial. This split is based on utility rate class, which involves some mixing of sources between categories.

D5.5 Data Needs

Data for residential buildings that burn heating oil needs a more accurate estimate for Seattle based on regional data, rather than ratioing a statewide estimate.

D6: Commercial Building Energy

Fuel-specific emissions factors (gCO_2/L) from the US EPA's national GHG inventory[331] were utilized in calculating emissions from commercial buildings.

D6.1 Electricity

SCL provided commercial building electricity consumption (GWH) within Seattle for all inventory years through personal communication with OSE. SCL also provided emission factors (Mg of CO_2/MWh) from electricity generation for each inventory year through direct communication. The SCL emission rate was multiplied by commercial electricity consumption to obtain total emissions.

D6.2 Direct Fuel Use

D6.2.1 Fossil Gas

PSE provided data through direct correspondence for the total count of Seattle commercial businesses and total natural gas dispensed (therms) for each inventory year. Fossil gas use at steam plants and for commercial equipment use as CNG are assumed to be included in PSE's reported commercial sector fossil gas totals but are subtracted from the total reported by PSE and given separately for the purposes of this inventory.

D6.2.2 Petroleum

Seattle commercial building oil use was estimated using Washington State Distillate Fuel Oil and Kerosene sales by end-use, which is reported by the U.S. EIA[37], prorated by the ratio of Seattle to Washington State commercial employment[38]**.**

D6.3 Steam

Emissions from fossil gas for steam production was sourced directly from CenTrio (formerly Emwave) through OSE's District Energy Greenhouse Gas Emissions Reporting Form. UW's fossil gas use for steam production was also shared with OSE through direct communication.

D6.4 Uncertainties

Uncertainties in commercial building emissions estimates are similar to residential buildings: low uncertainty for fossil gas and electricity; high uncertainty for oil use.

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[37] EIA *Distillate Fuel Oil and Kerosene Seles by End Use*, pet_cons_821use_dcu_SWA_a.xls

[38] PSRC *2020 Covered Employment Estimates by Jurisdiction*

D6.5 Data Needs

Data for commercial buildings that burn petroleum needs a more accurate estimate based on regional data, rather than ratioing a statewide estimate of fuel sold.

D7: Residential & Commercial Building Equipment

D7.1 Residential Yard Equipment (Petroleum)

King County yard equipment emissions in 2014 were estimated by the Washington Department of Ecology using EPA's NONROAD 2014a model. This data was then grown using a ratio of King County population in the inventory year to King County population in the 2014 model year.

Emissions by petroleum type were tabulated **(14-40-02)**, prorated for Seattle by the ratio of Seattle to King County population **(16-70-11).** The NONROAD model has not been updated with 2020 data from the EPA NONROAD MOVES3 model, so data used for 2020 before scaling with population is identical to what was used in 2014.

D7.2 Commercial Equipment (Fossil Gas and Petroleum)

Emissions from commercial equipment powered by CNG and petroleum fuel in King County were estimated by the Washington Department of Ecology using EPA's NONROAD 2014a model. This data was then grown using a ratio of King County population in the inventory year to King County population in the 2014 model year. Emissions were tabulated by fuel type and sector **(14-40-02)**, then scaled to Seattle by the ratio of Seattle to King County commercial employment **(18-70-11).** The NONROAD model has not been updated with 2020 data from the EPA MOVES3 NONROAD model, so data used for 2020 before scaling with population is identical to what was used in 2014.

D7.3 Uncertainty

Uncertainty is high for residential and commercial equipment since it is based on a national model that has not been updated for the inventory since 2014.

D7.4 Data Needs

The EPA MOVES3 NONROAD model needs implemented in the inventory to increase accuracy of reported values.

D8: Waste & Wastewater

D8.1 Waste Management

Material-based estimates of solid waste hauled and landfilled in each inventory year were calculated based on waste composition studies developed by Seattle Public Utilities (SPU)[39] for construction and demolition, self-haul, residential, and commercial waste generated within Seattle. The most recent waste composition study for the respective waste stream was then applied to the reported annual tonnage to obtain an estimate of tonnage per material for each sector, which was then compiled in **20-50-07**. Emission factors for landfilling and carbon sequestration by category of solid waste were taken from EPA's WARM model (**18-50-09**) and compiled in **20-50-07**.

Emissions were calculated in Power Bi based on the emission factors and carbon sequestration of the material as well as the emissions associated with hauling the material to the landfill facilities.

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[39] SPU Solid Waste Composition Studies. *Residential Waste Composition; Commercial and Self-Haul Waste Streams Composition; Construction, Demolition, and Land Clearing Waste Composition.*

Transportation emissions associated with hauling waste were based on EPA's default assumption of emissions associated with 20 miles of travel plus additional emissions associated with 234 miles of travel by class-1 freight rail to landfill facilities in Arlington, OR (average distance of 254 miles from Seattle).

Previously, the methodology relied on a single waste composition study per subsector to estimate the share of emissions for all inventory years. In 2020, all waste composition studies from SPU were implemented and closest in time was applied for the respective year. Therefore, waste emissions will differ from previous inventories.

D8.2 Wastewater Treatment

Wastewater treatment emissions for 2020 were provided via email by the King County Wastewater Treatment Division (KCWTD) for the West Point, South, Brightwater, Carnation, and Vashon treatment plants. In 2020, KCWTD's changed their reporting process for wastewater emissions to account for fugitive emissions more accurately per the 2019 IPCC Guidelines. KCWTD provided a summed emission total for all treatment sites for previous years. When data for inventory years was not present, a linear interpolation derived emission values for missing years.

The new methodology included CH_4 and N_2O emissions from the wastewater treatment process and removed the emissions from the incomplete combustion of CH_4 from flares as detailed in **Table 7.**

Table 7: KCWTD Revised Methodology per 2019 IPCC Guidelines

Source	**Description**	**2019 IPCC Guidelines**
Biogas scrubber water	Methane released (CH_4 slip) when scrubber water is discharged in the primary effluent distribution channel	-
Incomplete combustion in flares	Release of methane (CH_4) due to combustion efficiency < 100%	Removed
N_2O (aeration)	Nitrous oxide (N_2O) produced during the wastewater treatment process	Revised
Digestion Cover Gap CH_4	Release of methane (CH_4) due to gap in digester covers	-
CH_4 from receiving water body	Release of methane (CH_4) in receiving water bodies	Added
N_2O from receiving water body	Release of nitrous oxide (N_2O) in receiving water bodies	Added

D8.3 Uncertainty

Uncertainty in waste management emissions include estimates of methane release based on waste composition and methane release collection efficiencies over time (including for the future, which would affect methane emissions from waste generated in 2020). There is some uncertainty in both values, although the impact on total Seattle emissions is likely to be relatively small due to the miniscule overall contribution of this source. Wastewater treatment uncertainty includes methane capture rate, which is likely uncertain, although applied to a small portion of emissions.

D8.4 Data Needs

Due to SPU's periodic reporting of updated waste composition studies and annual total tonnage, there are no outstanding data needs from this sector.

D9: Industry

As a part of the EPA's Greenhouse Gas Reporting Program (GHGRP), the EPA requires mandatory reporting for commercial and industrial facilities that emit over 25,000 metric tonnes of CO2e annually[40]. This reporting from the EPA is the source for some of the categories outlined in the Industry Sector.

Of the six EPA Large Emitters Industrial Facilities, four (Ardagh Glass, Ash Grove Cement, NuCor Steel, and CertainTeed Gypsum) are located in the Duwamish Valley. The other two not within the Duwamish valley are the University of Washington in the University District and CenTrio Steam in downtown.

Due to a history of industrial-related pollution, the Duwamish Valley has been designated a EPA superfund site and the surrounding areas remain disproportionately exposed to higher health risks. Seattle's Duwamish Valley Program (DVP) was created to address inequities in the Duwamish Valley through principals designed for environmental justice and equitable outcomes[41].

9.1 Cement

A majority of industrial emissions stem from the creation of cement, which is made by heating a mixture of limestone, clay, and several other materials to create a mixture vital for construction and urban development. Process emissions from cement are released in one of two ways: from the energy needed to heat the mixture and from the chemical reaction of limestone ($CaCO_3$) to lime (CaO) when the mixture is heated[42]. Recently, the U.S. cement industry has faced restricted growth due to closed or idle plants, underutilized capacity, and relatively inexpensive imports[43].

9.2 Steel & Glass

Emissions for both Steel and Glass are self-reported in EPA's Large Emitters Database for 2010 through 2020. Steel emissions are from Seattle's predominant manufacturer, Nucor (an electric arc furnace that produces crude steel). Glass operations emissions are from manufacturing at Seattle's Ardagh Glass (formerly Saint-Gobain Containers).

9.3 Fugitive SF_6 Emissions

SCL provided provisional fugitive SF_6 emissions for 2020 via internal communication, which was converted to CO_2e emissions based on the 100-year global warming potential (GWP) of SF_6 (22,800) from the IPCC Fourth Assessment Report[44].

9.4 Fugitive Methane Emissions

Fugitive methane emissions were taken from PSE's *2020 Greenhouse Gas Inventory*. This data source represents a change in methodology made in the 2018 inventory that moves from an accurate yet resource-intensive process to a simpler and more reliable estimate from PSE.

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[40] EPA FLIGHT, Facility Level GHG Emissions Data

[41] Seattle's Duwamish Valley Program, *Duwamish Valley Action Plan*, June 2018.

[42] IPCC, Industrial Process Sector, *CO2 Emissions from Cement Production*

[43] U.S. Geological Survey, *Mineral Commodity Summaries: Cement*, January 2022.

[44] IPCC, *Fourth Assessment Report (AR4)*, 2007 as reported by the EPA in *Emission Factors for Greenhouse Gas Inventories,* March 2020.

9.5 Uncertainty

Uncertainty is relatively high for all categories of process and fugitive emissions, particularly for steel production. There is significant variability in reported process emissions between years, much of which can be attributed to the emission testing methodology. Nucor manufactures several different grades of steel with unique chemistries – each of which affects emission levels – in varying quantities throughout the year. Since process emission testing occurs over a three-day period every year, the chemistry of the scrap being tested is not consistent and is likely not representative of the annual aggregate chemistry of Nucor's steel output. Additionally, Nucor's total output changes depending on the market condition.

Appendix E: Tracking Metrics

Metric by Category	2008	2012	2014	2016	2018	2020
Employment						
Employment	436,943	441,043	469,907	508,264	548,468	587,781
Population						
Population	593,588	635,063	668,342	704,352	744,955	735,157
Buildings: Residential & Commercial						
Building Emissions per resident (MT CO2e/resident)	2.15	1.81	1.65	1.57	1.61	1.55
Buildings Emissions (MT CO2e)	1,274,257	1,152,079	1,099,691	1,106,428	1,199,295	1,137,129
Commercial Electricity (MMBtu)	16,426,275	16,195,285	16,089,965	16,214,747	15,917,456	14,480,942
Commercial Emissions (MT CO2e)	685,118	629,230	614,492	627,436	682,902	626,928
Commercial emissions per employee (MT CO2e/employee)	1.57	1.43	1.31	1.23	1.25	1.07
Commercial emissions per resident (MT CO2e/resident)	1.15	0.99	0.92	0.89	0.92	0.85
Commercial energy per employee (MMBtu/employee)	63.33	61.25	57.19	52.75	50.21	43.50
Commercial Energy Use (MMBtu)	27,672,290	27,014,228	26,873,319	26,809,590	27,539,480	25,567,946
Commercial Fossil gas (MMBtu)	11,125,978	10,795,743	10,752,903	10,584,413	11,597,827	10,947,121
Commercial GHG intensity of energy (kg CO2e/MMBtu)	24.76	23.29	22.87	23.40	24.80	24.52
Commercial Heating oil (MMBtu)	120,038	23,200	30,451	10,430	24,197	139,884
Cooling degree days (CDD)	195	181	372	291	411	429
Energy use per capita per heat demand (GJ per capita per 1000 HDD)	6.27	5.96	6.47	6.20	5.76	5.46
Heating degree days (HDD)	5,062	4,738	3,948	3,827	4,065	4,505
Residential Electricity (MMBtu)	9,221,131	9,048,915	8,687,005	8,645,691	8,690,914	9,227,138
Residential Emissions (MT CO2e)	589,139	522,849	485,199	478,992	516,393	510,201
Residential emissions per resident (MT CO2e/resident)	0.99	0.82	0.73	0.68	0.69	0.69
Residential energy per resident (MMBtu/resident)	31.74	28.26	25.55	23.71	23.43	24.61
Residential Energy use (MMBtu)	18,841,311	17,948,088	17,077,941	16,699,192	17,451,153	18,095,441
Residential Fossil gas (MMBtu)	8,148,439	7,927,928	7,539,972	7,220,722	7,985,580	8,045,041
Residential GHG intensity of energy (kg CO2e/MMBtu)	31.27	29.13	28.41	28.68	29.59	28.20

Metric by Category	2008	2012	2014	2016	2018	2020
Residential Heating oil (MMBtu)	1,471,740	971,245	850,964	832,780	774,659	823,262
Total Buildings GHG intensity of energy (kg CO2e/MMBtu)	56.03	52.42	51.28	52.09	54.39	52.72
Total energy per degree day (MMBtu/DD)	8,848	9,141	10,174	10,566	10,052	8,850
Total energy use (residential + commercial) (MMBtu)	46,513,601	44,962,315	43,951,260	43,508,782	44,990,633	43,663,387
Transportation						
Emissions per mile (kgCO2e/VMT)	0.47	0.46	0.44	0.43	0.41	0.38
Freight emissions per person (MT CO2e/resident)	0.44	0.40	0.39	0.38	0.36	0.28
Freight truck emissions per mile (kgCO2e/VMT)	1.04	1.03	1.01	0.99	0.96	0.94
Freight Truck VMT (miles)	250,330,005	249,399,011	257,665,775	271,080,821	277,099,229	219,916,930
Freight Truck VMT/person (miles/resident)	421.72	392.72	385.53	384.87	371.97	299.14
Passenger emissions per mile (kgCO2e/VMT)	0.45	0.44	0.42	0.40	0.38	0.36
Passenger emissions per person (MT CO2e/resident)	3.96	3.60	3.41	3.26	3.00	2.29
Passenger VMT (miles)	5,275,597,804	5,256,545,861	5,480,227,488	5,764,617,331	5,893,530,847	4,683,978,742
Passenger VMT/person (miles/resident)	8,888	8,277	8,200	8,184	7,911	6,371
Road Emissions (MT CO2e)	2,610,841	2,545,224	2,542,230	2,566,456	2,501,814	1,887,668
Road Emissions per person (MT CO2e/resident)	4.40	4.01	3.80	3.64	3.36	2.57
VMT (miles)	5,525,927,809	5,505,944,872	5,737,893,263	6,035,698,152	6,170,630,076	4,903,895,672
VMT per resident (miles/resident)	9,309	8,670	8,585	8,569	8,283	6,671
Waste Management						
Emissions per ton disposed (MT CO2e/ton)	0.80	0.75	0.77	0.74	0.69	0.54
Nonresidential waste (tons)	267,676	204,562	197,304	204,385	239,030	207,211
Nonresidential waste per resident (tons/employee)	0.61	0.46	0.42	0.40	0.44	0.35
Residential waste (tons)	127,219	111,420	112,211	103,911	107,485	119,903
Residential waste per resident (tons/resident)	0.21	0.18	0.17	0.15	0.14	0.16
Waste Emissions (MT CO2e)	101,225	83,317	86,941	76,612	74,511	65,276
Waste Emissions per resident (MT CO2e/resident)	0.17	0.13	0.13	0.11	0.10	0.09