Washington State Greenhouse Gas Emissions Inventory: 1990-2021

By

Greenhouse Gas Inventory Unit

For the
Climate Pollution Reduction Program

Washington State Department of Ecology
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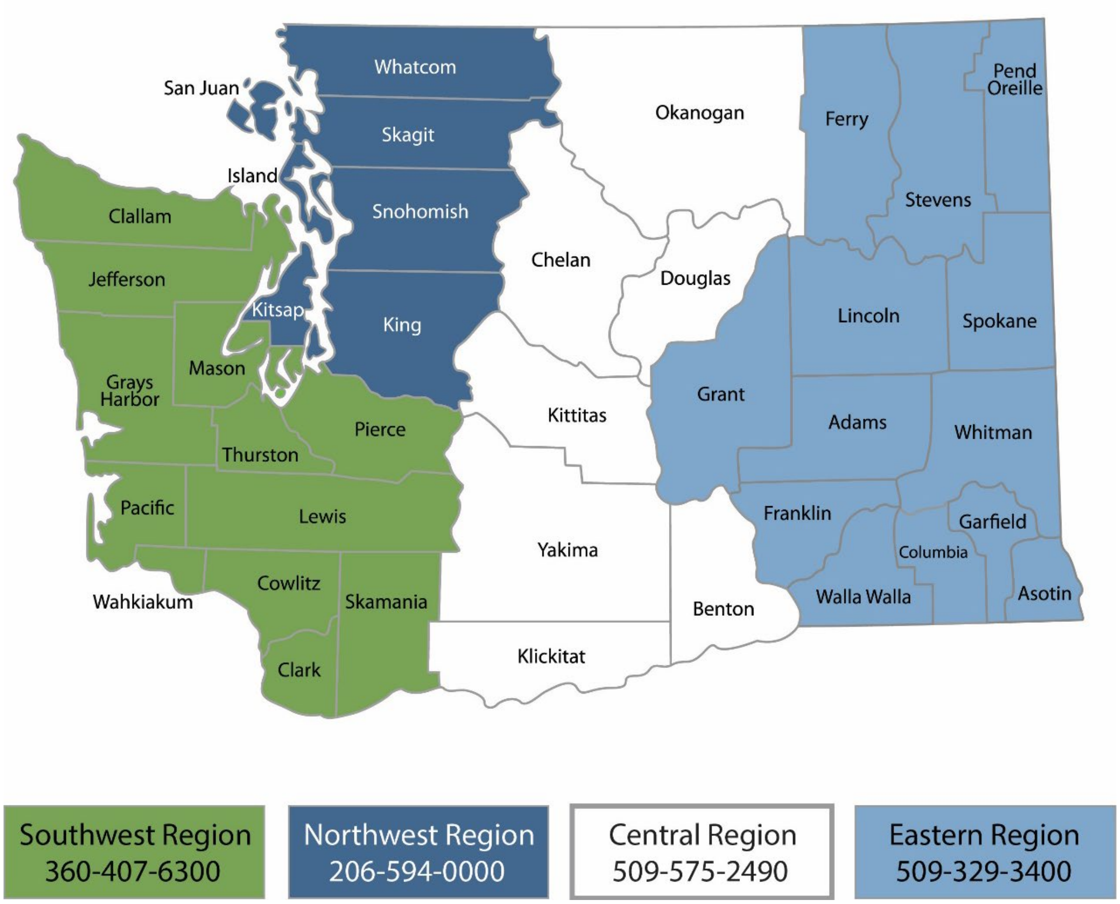

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Southwest	Clallam, Clark, Cowlitz, Grays Harbor, Jefferson, Mason, Lewis, Pacific, Pierce, Skamania, Thurston, Wahkiakum	PO Box 47775 Olympia, WA 98504	360-407-6300
Northwest	Island, King, Kitsap, San Juan, Skagit, Snohomish, Whatcom	PO Box 330316 Shoreline, WA 98133	206-594-0000
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Eastern	Adams, Asotin, Columbia, Ferry, Franklin, Garfield, Grant, Lincoln, Pend Oreille, Spokane, Stevens, Walla Walla, Whitman	4601 N Monroe Spokane, WA 99205	509-329-3400
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Report to Legislature

Climate Pollution Reduction Program
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State of Washington

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Acronyms and Abbreviations

Acronym	Meaning
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent (a unit of measure that represents the cumulative effect of all greenhouse gases in terms of their warming potential relative to carbon dioxide)
EPA	U.S. Environmental Protection Agency
GWP	Global Warming Potential
GtC	Gigaton carbon
HFC	Hydrofluorocarbon
IPCC	Intergovernmental Panel on Climate Change
MMT	Million metric tons
MMT CO_2e	Million metric tons of carbon dioxide equivalent
MWh	Megawatt hour
N_2O	Nitrous oxide
NF_3	Nitrogen trifluoride
PFCs	Perfluorocarbons
RCI	Residential, commercial, industrial (building sector)
SF_6	Sulfur hexafluoride
UTC	Washington Utilities and Transportation Commission
VMT	Vehicle miles traveled

Executive Summary

This report summarizes Washington's greenhouse gas emissions from 1990 through 2021 to track the state's progress against its legal limits on greenhouse gas emissions. This report is required under RCW 70A.45.020(2):

> *By December 31st of each even-numbered year beginning in 2010, the department and the department of commerce shall report to the governor and the appropriate committees of the senate and house of representatives the total emissions of greenhouse gases for the preceding two years, and totals in each major source sector, including emissions associated with leaked gas identified by the utilities and transportation commission under RCW 81.88.160. The report must include greenhouse gas emissions from wildfires, developed in consultation with the department of natural resources.*

By law (RCW 70A.45.020(1)), Washington was required by 2020 to reduce greenhouse gas emissions to what they were in 1990. Washington must also reduce emissions 45% by 2030, 70% by 2040 and 95% by 2050 relative to the 1990 baseline.

1990 baseline emissions are calculated at 93.9 million metric tons carbon dioxide equivalent (MMT CO_2e) based on the latest greenhouse gas inventory methods. Total emissions in 2020 were 88.3 MMT CO_2e and 2021 emissions were 96.1 MMT CO_2e. While Washington surpassed requirements to meet its limit in 2020 with emissions 6% below 1990 levels, statewide emissions rose in 2021 to 2.3% above that limit. Compared to their peak in 2000 of 111.9 MMT CO_2e, Washington's total greenhouse gas emissions declined 14.1% by the end of 2021.

The rise and fall of emissions from 2019 to 2021 was likely driven by the COVID-19 pandemic. The transportation sector made up 86% of the emissions increase. Non-highway transportation (aviation, rail, marine) accounted for 79% of the rebound from 2020 to 2021.

At 38.2 MMT CO_2e, the transportation sector remained Washington's largest source of greenhouse gases in 2021, underscoring the importance of reducing emissions from this sector. While 8.9% below its peak emissions of 41.9 MMT CO_2e, this sector was 7.8% higher in 2021 than the 1990 baseline emissions of 35.4 MMT CO_2e.

The building sector achieved the greatest emissions reductions. At 23.7 MMT CO_2e, 2021 emissions were 30.7% lower than their 1999 peak of 34.2 MMT CO_2e and 5.0% lower than 1990 baseline emissions of 24.9 MMT CO_2e. Emissions from residential, commercial, and industrial on-site combustion of fossil fuels shifted from petroleum as the principal source to natural gas.

Emissions from electricity consumption in 2022 at 17.4 MMT CO_2e were 25.3% lower than peak emissions in 2000 of 23.3 MMT CO_2e and 3.0% higher than 1990 baseline emissions of 16.9 MMT CO_2e. In 2021, electricity consumption emissions were 18.7 MMT CO_2e, 19.6% lower than the peak emissions in 2000 and 10.7% higher than the 1990 baseline. Electricity production within Washington's boundaries from fossil fuels shifted from reliance on coal to natural gas as provisions in RCW 80.80.040 took effect. Electricity imported to Washington from the Northwest Power Pool had a higher carbon intensity than electricity produced in Washington.

Hydropower production dropped by approximately 10% over 20 years, presenting challenges for generating low carbon power in Washington.

Despite the rise in Washington's greenhouse gas emissions from 2020 to 2021, emissions per capita and per dollar of economic output continue to fall. From 1990 to 2021, per capita emissions declined by 35.9% and per Gross Domestic Product (GDP) emissions declined by 64.2%. Washington's total emissions in 2020 and 2021 are very close to 1990 levels, despite historic population and economic growth. To meet emissions limits in future years, however, Washington must ensure that emissions reductions outpace population and economic growth.

The results of this inventory predate the effective dates of many of Washington's major climate policies: the Climate Commitment Act, the Clean Fuel Standard, zero-emission vehicle standards, some fluorinated gas regulations, and clean buildings regulations. The Climate Commitment Act is an economy-wide policy that targets that state's largest emitters of greenhouse gases, while other policies target specific sectors of the economy, such as transportation. Future inventories will show the collective impact of these major climate policies, which are designed to work together to achieve Washington's limits on greenhouse gas emissions.

In addition to accelerating emissions reductions, we expect to increase the responsiveness of future inventories and continue improving the analysis provided in each report. Though the inventory will always be retrospective, the Department of Ecology is pursuing strategies to decrease the lag between the data contained in each report and the date of publication. Unlike past reports, this report shows how sector-specific emissions overlap to provide a more complete picture of emissions within sectors. Ecology will be able to use additional resources to continuously improve this inventory in the years to come.

The Global Carbon Cycle

Carbon is an abundant element required for all life on Earth. While rocks contain most of Earth's carbon, other carbon repositories include the ocean, atmosphere, plants, soil, and fossil fuels. These reservoirs continuously absorb and release carbon. At the broadest level, there are four global carbon pools: the Earth's crust, oceans, biosphere, and atmosphere, each including many complex and active systems (Table 1).[2] Each of these pools contains vastly different quantities of carbon, and each exchanges carbon at different rates.

In greenhouse gas inventories, such as this report, the standard practice is to refer to these exchanges of emission sources and sinks as "carbon fluxes." Positive carbon fluxes, which release more carbon to the atmosphere than they absorb, are known as "carbon sources." Negative carbon fluxes, which absorb more carbon than they release, are known as "carbon sinks."

Table 1. Global carbon pools in gigatons carbon (GtC).[3]

Global carbon pools	Approximate size of carbon pool
Earth's crust/geology	80,000,000 GtC (Fossil fuels are 4,000 GtC of this pool)
Oceans	38,400 GtC
Biosphere/terrestrial ecosystems	2,000 GtC
Atmosphere	750 GtC

The global carbon cycle is the flow of carbon through these pools where it may be stored as a gas, liquid, or solid. Hundreds of gigatons of carbon circulate each year as part of the carbon cycle. The total volume of carbon on Earth does not change, so any change in the cycle that shifts carbon out of one reservoir puts more carbon in another reservoir. Changes that put carbon gases into the atmosphere, mainly either as carbon dioxide (CO_2) or methane (CH_4), result in warmer temperatures on Earth.

Carbon moves through these pools at different rates. The slow carbon cycle takes 100 to 200 million years to move between rocks, soil, ocean, and atmosphere. The fast carbon cycle is tightly tied to the growth and decay of living things. This is measured in much shorter time units that range from a single year to decades. Left unperturbed, the fast and slow carbon cycles

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[2] Falkowski, P.; Scholes, R. J.; Boyle, E.; Canadell, J.; Canfield, D.; Elser, J.; Gruber, N.; Hibbard, K.; Högberg, P.; Linder, S.; MacKenzie, F. T.; Moore, III, B.; Pedersen, T.; Rosenthal, Y.; Seitzinger, S.; Smetacek, V.; Steffen, W. (2000). "The Global Carbon Cycle: A Test of Our Knowledge of Earth as a System". *Science*.
[3] A gigaton (GtC) equals a billion metric tons or 1 billion cubic meters of water (since 1 cubic meter of water weighs 1,000 kilograms). An Olympic-sized swimming pool holds about 2,500 cubic meters of water. 1 gigaton of water would fill about 400,000 Olympic swimming pools.

maintain relatively steady concentrations of carbon in each pool. Over the long term, the natural carbon cycle maintains a balance that helps stabilize temperatures on Earth.

The various greenhouse gases differ both in their ability to warm the planet and in the length of time they stay in the atmosphere. For example, if humans were to cease all CO_2 emissions immediately, it would take about 100 years for half of the carbon humans have emitted to date to sink into the deep ocean or be absorbed by the land. The absorption of carbon slows over time, so it would take thousands of years for the remaining half to be absorbed.

Fossil fuel use has transferred large amounts of carbon from the slow cycle, where it collected over millions of years deep inside geologic structures, into the fast cycle. So far, the biosphere and the ocean have absorbed about 55% of the extra carbon people have put into the atmosphere, while about 45% has stayed in the atmosphere. Eventually, the land and oceans will absorb most of the extra carbon dioxide, but as much as 20% may remain in the atmosphere for many thousands of years.[4]

Because humans put carbon dioxide and methane into the atmosphere more quickly than natural processes can remove it, the amount of CO_2 and CH_4 in the atmosphere is increasing. Methane emitted today lasts about a decade in the atmosphere until it breaks down into carbon dioxide and water; however, methane absorbs and traps much more heat than carbon dioxide. The amount of carbon accumulated in the atmosphere over the past 150 years has not been experienced on Earth in more than three million years.[5] These changes in the carbon cycle impact planetary functions and life on Earth.

Greenhouse gases included in the inventory

Greenhouse gases are substances that contribute to climate change by absorbing energy and slowing the rate at which energy (such as heat or light) escapes into space, essentially insulating and warming the Earth. Of all the greenhouse gases that humans generate, carbon dioxide contributes the most to climate change, but other gases contribute as well.[6]

Global warming potentials (GWPs) allow us to compare the warming impacts of different gases. A GWP describes how much energy a ton of a gas will absorb over a given period (typically 100 years), relative to a ton of carbon dioxide. The larger the GWP, the more that gas warms the Earth relative to carbon dioxide. The GWP provides a conversion for any greenhouse gas to normalized units of “carbon dioxide equivalent,” or CO_2e. The emissions inventory shows greenhouse gases in millions of metric tons carbon dioxide equivalent (MMT CO_2e), unless

[4] NASA Earth Observatory, The Carbon Cycle (https://www.earthobservatory.nasa.gov/features/CarbonCycle)
[5] NOAA, Climate Change: Atmospheric Carbon Dioxide (https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide).
[6] Water vapor is the most abundant greenhouse gas. Anthropogenic carbon emissions from fossil fuels are warming the atmosphere causing an increase in water vapor. Increased water vapor is a consequence rather than a cause of climate change.

otherwise specified. Using carbon dioxide equivalent as a measurement allows us to capture the cumulative impacts of all greenhouse gases in a single number.

GWP values are revised over time as new greenhouse gases are recognized and our understanding of greenhouse gas thermal properties advances. Table 2 lists the greenhouse gases that contribute the most to human-caused climate change and shows how their GWPs have changed recently. The previous Washington Greenhouse Gas Inventory used GWPs from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, and this inventory uses those from the IPCC Fifth Assessment Report.

Table 2. Global Warming Potential (GWP) for greenhouse gases.[7]

Greenhouse gas	100-year GWP Fourth Assessment Report	100-year GWP Fifth Assessment Report
Carbon dioxide (CO_2)	1	1
Methane (CH_4)	25	28
Nitrous oxide (N_2O)	298	265
Hydrofluorocarbons (HFCs)	124–14,800	4–12,400
Perfluorocarbons (PFCs)	7,390–12,200	6,630–23,500
Nitrogen trifluoride (NF_3)	17,200	16,100
Sulfur hexafluoride (SF_6)	22,800	23,500

Effects of climate change

Increased greenhouse gas emissions are causing climate-related impacts evident across the globe and well-documented within Washington, too. The principal effect on a large scale and over a long period is known as global warming, and there are numerous other effects that occur more locally and on shorter time scales. While global warming shows steady progress in global data, the effects of climate change often appear as random events locally—for example, flood, drought, extreme weather, ecosystem decline. These impacts affect the lives and livelihoods of people and the ecosystems that sustain life. According to the University of Washington's Climate Impacts Group:

> Climate change will affect peoples' health through increased exposure to extreme heat, wildfire smoke, diseases and other hazards. Changes in patterns of precipitation and snow melt, among other climate impacts, will affect agriculture, the built environment, recreation and other facets of society.

[7] IPCC Fourth Assessment Report and Fifth Assessment Report, 100-year time horizon. This data is reviewed and updated and creates small differences in inventory results each year.

> These impacts will not be distributed equitably among communities; communities of color, Indigenous communities, low-income communities and Northwesterners most dependent on natural resources for their livelihoods stand to experience these impacts first and worst. [8]

These impacts of climate change also create feedback loops that result in additional carbon releases to the atmosphere, worsening the effects over time. For example, some of the increased carbon dioxide in the atmosphere is absorbed by oceans, which increases ocean acidity. This is keenly observed in Washington's shellfish industry, which has been impacted negatively by slower oyster shell formation and growth. Increased ocean acidity also harms other marine life, making it harder for some marine species to absorb carbon and diminishing the ocean's ability to absorb carbon further.[9] The aquaculture industry currently combats ocean acidification by adding sodium carbonate into hatchery waters to help support shell formation. However, this is just a temporary solution that will become less effective as ocean acidity continues to increase.

Altered weather and climate patterns are also having visible impacts by exacerbating conditions for forest fires, which damage valuable working lands and structures, harm human health, and release additional carbon into the atmosphere.[10] Other local climate impacts include decreased snowpack, increased flooding, sea level rise, erosion, drought and other changes to water supply. The list of climate impacts in Washington will continue to grow as the impacts of climate change increase.

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[8] UW Climate Impacts Group, People & Society (https://cig.uw.edu/our-work/people-society/).

[9] WA Department of Ecology, Ocean acidification (https://ecology.wa.gov/air-climate/responding-to-climate-change/ocean-acidification).

[10] UW Climate Impacts Group, Forests & Fire (https://cig.uw.edu/our-work/forests-fire/).

The Inventory in Context

The inventory records Washington's contribution to global climate change and measures our progress toward reducing greenhouse gas emissions. This report follows methodology established in guidelines published by the IPCC. This methodology defines a greenhouse gas emissions inventory as a report on the annual flow of both carbon sources and carbon sinks within a defined geographic border, consistently over time, and separated by anthropogenic (human-caused) and biogenic (natural) sources.[11]

Because the science underpinning greenhouse gas inventories is continually improving, methodologies adjust over time, which can affect inventory results. When methodologies advance, we document those changes in detail and apply them to the whole historical record, to maintain consistency. This means that calculated values may vary slightly among inventory publications due to methodology improvements.

Greenhouse gas emission sources and emissions limits

Greenhouse gases are released from a wide variety of sources, which the IPCC categorizes as follows:

- *Stationary combustion* occurs when equipment is used to produce electricity, steam, heat, or power (such as boilers or generators). There are two ways these occur:
  - *Direct emissions* result from on-site combustion at the point of use.
  - *Indirect emissions* occur off-site when heat or electricity are purchased from a utility provider.
- *Mobile combustion* occurs when fuel is burned for transportation (such as in cars, trucks, ships, trains, and planes).
- *Industrial process emissions* result from manufacturing cement, aluminum, ammonia, and other products where the process itself creates emissions.
- *Fugitive emissions* are released by the production, processing, transmission, storage, or use of fuels and other substances that do not involve combustion (e.g., the release of sulfur hexafluoride from electrical equipment, natural gas pipeline leaks, or emissions of nitrous oxide from fertilizers).

[11] IPCC Guidelines for National Greenhouse Gas Inventories (https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html).

Washington establishes greenhouse gas emission limits in law (Table 3)[12] based on a review of scientific evidence.[13] Net-zero emissions are achieved when greenhouse gases added to the atmosphere by people are balanced by removals over a specified period.[14]

Table 3.Washington greenhouse gas emission limits (RCW 70A.45.020(1)).

Year	Greenhouse gas emissions limit
2020	Reduce to 1990 levels
2030	45% below 1990 levels
2040	70% below 1990 levels
2050	95% below 1990 levels and achieve net-zero emissions

How the inventory was developed

The U.S. Environmental Protection Agency's (EPA's) State Inventory Tool (SIT) provides most of the data used to develop this inventory.[15] The SIT uses data consistently available for all states, even when more accurate and current data may be available for an individual state. EPA updates this tool annually and aligns it with data sources and methodologies used to develop the Inventory of U.S. Greenhouse Gas Emissions and Sinks.[16] The most current data available from the SIT is through 2021.[17]

[12] RCW 70A.45.020: Greenhouse gas emissions reductions (https://apps.leg.wa.gov/rcw/default.aspx?cite=70A.45.020).

[13]Ecology consulted with the University of Washington Climate Impacts Group and published *Washington State Greenhouse Gas Emission Reduction Limits, Report prepared under RCW 70.235.040.* This review will take place again in 2024. Washington State Greenhouse Gas Reduction Limits (https://apps.ecology.wa.gov/publications/documents/1902031.pdf).

[14] IPCC, 2018: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. Glossary.

[15] State and Tribal Greenhouse Gas Data and Resources (https://www.epa.gov/ghgemissions/state-and-tribal-greenhouse-gas-data-and-resources).

[16] Inventory of U.S. Greenhouse Gas Emissions and Sinks (https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks).

[17] Data for the SIT come from the EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks. The EPA collects data for its report to United Nations for the Framework Convention on Climate Change. Those data must be verified and then analyzed following guidance from IPCC to create the National Greenhouse Gas Inventory. The National Inventory is then used to create downscaled data, disaggregated by state, which also requires quality assurance. These data populate the EPA's State Inventory Tool. WA statute requires methodological approaches for some aspects of our inventory that differ from the SIT and the data it uses (for example electric consumption versus electric production). All these steps take time, which is why this report only addresses emissions up to 2021.

The SIT fundamentally relies on two types of data. Information on resource consumption (for example electricity and fossil fuel sales) and economic production (for example iron and steel smelting, or cement production) are gathered by various agencies in the course of their work. Emission factors (for example, mass of carbon dioxide released per megawatt-hour of electricity produced) are determined by scientific analysis for each resource use and production activity. The SIT calculates emissions by multiplying consumption and production data values by emission factors. The processes and science for data collection and determining emission factors are constantly improving. Version 2024.1 of the SIT, released in February 2024, includes changes that update the following:[18]

- Global Warming Potentials for methane, nitrous oxide and other greenhouse gases from IPCC Assessment Report 5
- Emissions factors for natural gas and oil and wastewater
- Carbon flux data for agriculture and land use, land use change, and forestry

The Washington Greenhouse Gas Inventory supplements and replaces default data in the SIT for the analysis of electricity consumption, natural gas leakage, and wildfires.[19]

This inventory reports emissions based on electricity *consumed* in our state rather than emissions based solely on electricity *produced* in our state.[20] Consumption-based electricity emissions for Washington provide a more accurate picture of emissions from electricity, because Washington imports electricity from nearby states in the Northwest Power Pool.[21] This imported electricity is generated from fuel mixes that rely more on fossil fuels, whereas fuel sources used to generate electricity in Washington have relatively low emission rates compared to most other states. Hydropower, natural gas, and wind resources contributed 64%, 15%, and 8% of the Washington's electricity fuel mix in 2021.[22]

RCW 70A.45.020(2) directs that the inventory report shall include "emissions associated with leaked gas identified by the utilities and transportation commission." The Washington Utilities

[18] State Inventory and Projection Tool, US EPA (https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool). A full list of changes to the SIT are available in the "State, Local, and Tribal Inventory Tool Updates Tracker," available on request at "Contact Us about Energy Resources for State, Local, and Tribal Governments" (https://www.epa.gov/statelocalenergy/forms/contact-us-about-energy-resources-state-local-and-tribal-governments).

[19] RCW 70A.45.020: Greenhouse gas emissions reductions (https://apps.leg.wa.gov/rcw/default.aspx?cite=70A.45.020) and WAC 173-444-040: Greenhouse gas content calculation (https://apps.leg.wa.gov/wac/default.aspx?cite=173-444-040).

[20] Standard emissions accounting guidelines, like the SIT, use production-based approaches, which calculate emissions physically occurring within state boundaries. Washington's official inventory results are production-based in all sectors except for electricity.

[21] To make this substitution, Fuel Mix Disclosure program data provided by the Washington State Department of Commerce replace in-state electric power generation emissions from the SIT. The Fuel Mix Disclosure program requires each electric utility in Washington to report the fuel sources used to generate electricity and CO_2 emissions associated with that electricity. Fuel Mix Disclosure (https://www.commerce.wa.gov/growing-the-economy/energy/fuel-mix-disclosure/).

[22] Emissions & Generation Resource Integrated Database (eGRID) (https://www.epa.gov/egrid).

and Transportation Commission (UTC) began reporting leakage data for natural gas from local distribution lines in 2020, which is covered in the "Fossil fuel fugitive emissions" section.

RCW 70A.45.020(2) also requires the inventory report to include "greenhouse gas emissions from wildfires, developed in consultation with the Department of Natural Resources..." These data are addressed in the "Other emissions" section of this report. Ecosystem carbon fluxes in land use, land use change, and forestry are reported separately from other emissions, because the data available for this report have a relatively high level of uncertainty.

Emissions from wood biomass, ethanol, and biodiesel consumption are excluded from the inventory. Based on IPCC guidelines, biogenic carbon emissions are accounted for in the carbon flux of land use, land use change and forestry.[23]

[23] The SIT does not provide bioenergy detail separately. Land use flux is counted in the state where the feedstock was grown and harvested.

Inventory Results Overview

The Washington Statewide Greenhouse Gas Emissions Inventory results for 2020 and 2021 are shown in Table 4 on the following page. In 2020, statewide emissions totaled 88.3 MMT CO_2e—6% lower than the 1990 baseline of 93.9 MMT CO_2e, which is the statutory limit Washington was required to achieve. Total emissions for 2021 rose above the 2020 statutory limit/1990 baseline by 2.3% to 96.1 MMT CO_2e. This represents a total increase of 8.8% compared to 2020, resulting primarily from increased transportation emissions associated with non-highway travel.

The largest source of emissions in 2021 was the transportation sector, at 38.2 MMT CO_2e or 39.7% of total emissions, due to the direct combustion of fossil fuels in internal combustion engines, which is 7.8% higher than 2020 limit within the sector.

The second largest source of emissions in 2021 was on-site fuel combustion at residential, commercial, and industrial buildings, at 23.7 MMT CO_2e or 24.6% of total emissions, which is 5.0% lower than the 2020 limit within the sector.[24] Together, the transportation and building sectors accounted for about 64% of Washington's total greenhouse gas emissions in 2021.

Emissions from electricity consumption—indirect emissions comprised of fuels burned at facilities that provide power to grid-connected end users—were 18.7 MMT CO_2e in 2021. This accounts for 19.5% of total emissions, which was 10.7% higher than the 2020 limit within the sector.[25]

The remaining sectors are smaller emissions sources: agriculture (6.9%), industry (4.5%), waste management (3.4%), and fugitive fossil fuels (1.5%). Together, they comprise 15.6 MMT CO_2e or 16.2% of emissions, slightly less than electricity consumption.

The following tables and diagrams all point to two general observations. First, Washington's greenhouse gas emissions peaked for most sectors in 2000. Second, emissions measured for 2021 are slightly above those for the 1990 baseline and 14.1% below the peak emissions that occurred in 2000.

[24] Fossil fuels are burned in furnaces, stoves, water heat waters, boilers or other machinery. RCI emissions do not include indirect emissions from electricity consumption for machinery.

[25] In Table 4 electricity emissions are not included within the sectors where it is consumed. When electricity emissions are partitioned among end uses, buildings are the largest source of emissions (see Figure 11).

Table 4. Total emissions by sector in million metric tons carbon dioxide equivalent.

	1990	2000	2005	2010	2015	2019	2020	2021
Total MMT CO_2e	**93.9**	**111.9**	**98.4**	**96.6**	**94.4**	**102.4**	**88.3**	**96.1**
Transportation	**35.4**	**41.9**	**39.7**	**35.3**	**36.6**	**40.6**	**31.5**	**38.2**
Gasoline highway	15.2	19.5	18.7	16.0	15.5	17.0	13.6	14.5
Diesel highway	3.5	5.5	5.5	7.4	6.9	6.7	7.1	7.6
Non-highway (aviation, marine, rail)	16.7	16.9	15.5	12.0	14.2	16.9	10.8	16.0
Alternative fuel vehicles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Residential, commercial, and industrial buildings	**24.9**	**28.6**	**23.8**	**23.3**	**23.7**	**25.1**	**23.8**	**23.7**
Coal	0.6	0.3	0.1	0.2	0.2	0.1	0.1	0.1
Petroleum	16.0	17.2	13.4	12.4	12.5	12.0	11.2	10.6
Natural gas	8.4	11.2	10.2	10.7	11.0	13.0	12.5	12.9
Electricity consumption	**16.9**	**23.3**	**19.1**	**20.9**	**19.2**	**21.9**	**17.3**	**18.7**
Coal	16.8	17.4	15.2	15.8	14.0	15.2	8.1	8.8
Natural gas	0.1	5.3	3.6	4.8	4.9	6.2	4.2	4.7
Petroleum	0.0	0.6	0.0	0.1	0.1	0.0	0.0	0.0
Unspecified*	-	-	-	-	-	-	5.0	5.2
Other**	0.0	0.0	0.2	0.1	0.2	0.4	0.1	0.1
Agriculture	**7.3**	**7.4**	**7.1**	**6.9**	**7.2**	**6.9**	**7.0**	**6.6**
Enteric fermentation	3.0	3.0	2.7	2.6	2.9	2.6	2.8	3.0
Manure management	0.9	1.3	1.2	1.3	1.6	1.6	1.7	1.6
Agricultural soils	3.4	3.1	3.2	3.0	2.8	2.7	2.5	1.9
Industrial processes and fugitive emissions	**4.9**	**6.5**	**4.4**	**4.2**	**4.0**	**4.1**	**4.2**	**4.3**
Carbon dioxide emissions	***2.2***	***3.3***	***1.9***	***1.4***	***1.3***	***1.2***	***1.2***	***1.2***
Cement manufacturing	0.0	0.4	0.4	0.3	0.3	0.4	0.4	0.4
Lime manufacture	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0
Limestone and dolomite use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Soda ash	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Aluminum production, CO_2	2.0	1.7	0.8	0.5	0.4	0.3	0.3	0.2
Iron and steel production	0.0	0.8	0.3	0.3	0.3	0.3	0.3	0.3
Ammonia production	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1
Urea consumption	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HFC, PFC, NF_3, and SF_6 emissions	***2.8***	***3.2***	***2.6***	***2.8***	***2.6***	***2.9***	***3.0***	***3.1***
Ozone depleting substances substitutes	0.0	1.0	1.4	1.8	1.8	2.0	2.1	2.2
Semiconductor manufacturing	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Electric power transmission and distribution	0.8	0.4	0.3	0.2	0.1	0.1	0.1	0.1
Aluminum production, PFCs	1.9	1.7	0.8	0.8	0.7	0.7	0.7	0.7
Waste management	**3.4**	**3.0**	**2.9**	**4.6**	**2.5**	**2.5**	**3.1**	**3.2**
Solid waste	2.9	2.4	2.3	3.9	1.8	1.7	2.3	2.5
Wastewater	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.8
Fugitive fossil fuels	**1.1**	**1.2**	**1.4**	**1.4**	**1.3**	**1.4**	**1.4**	**1.4**
Natural gas industry	1.0	1.1	1.3	1.3	1.3	1.4	1.4	1.4
Oil industry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coal mining	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0

* Unspecified emissions data are only available in years following 2019. These are emissions from electricity produced outside of and imported into Washington. ** Combined sources. Data from 2002 to 2019 include "landfill gases," "waste," and "other/biogenic, non-biogenic." Data from 2020 forward include "Other Biogenic."

Figures 1 and 2 below depict annual emissions for each sector between 1990 to 2021. Figure 1 charts the absolute values for each sector to show the relative impacts of each. Overall, the transportation sector's emissions are the largest, and the electricity sector's emissions are the most volatile. Figure 2 charts each sector's contribution to total emissions. Greenhouse gas emissions peaked in 2000 before trending downwards; the years during the COVID-19 pandemic are characterized by high volatility.

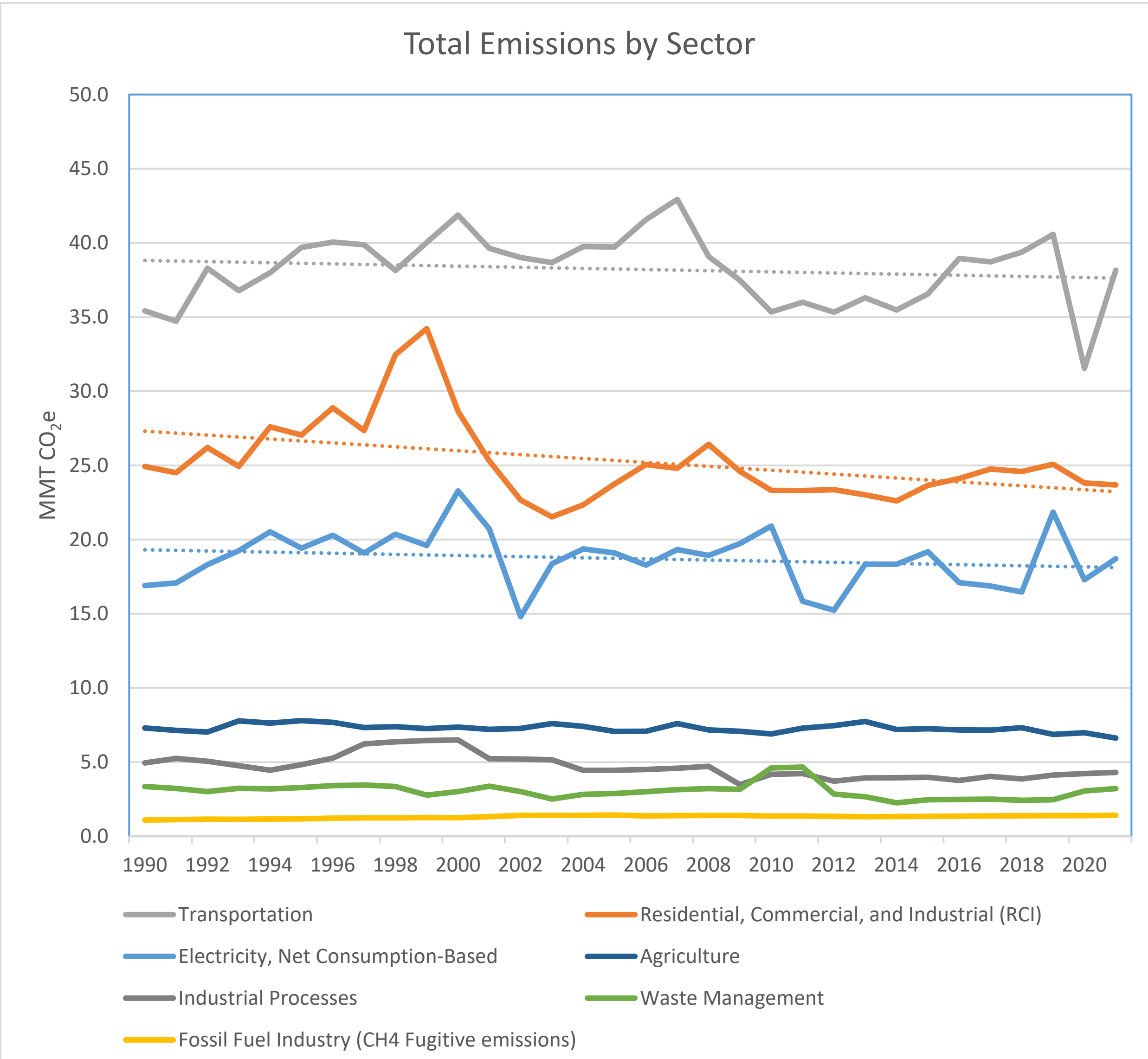

Figure 1. Washington's historical greenhouse gas emissions by sector.

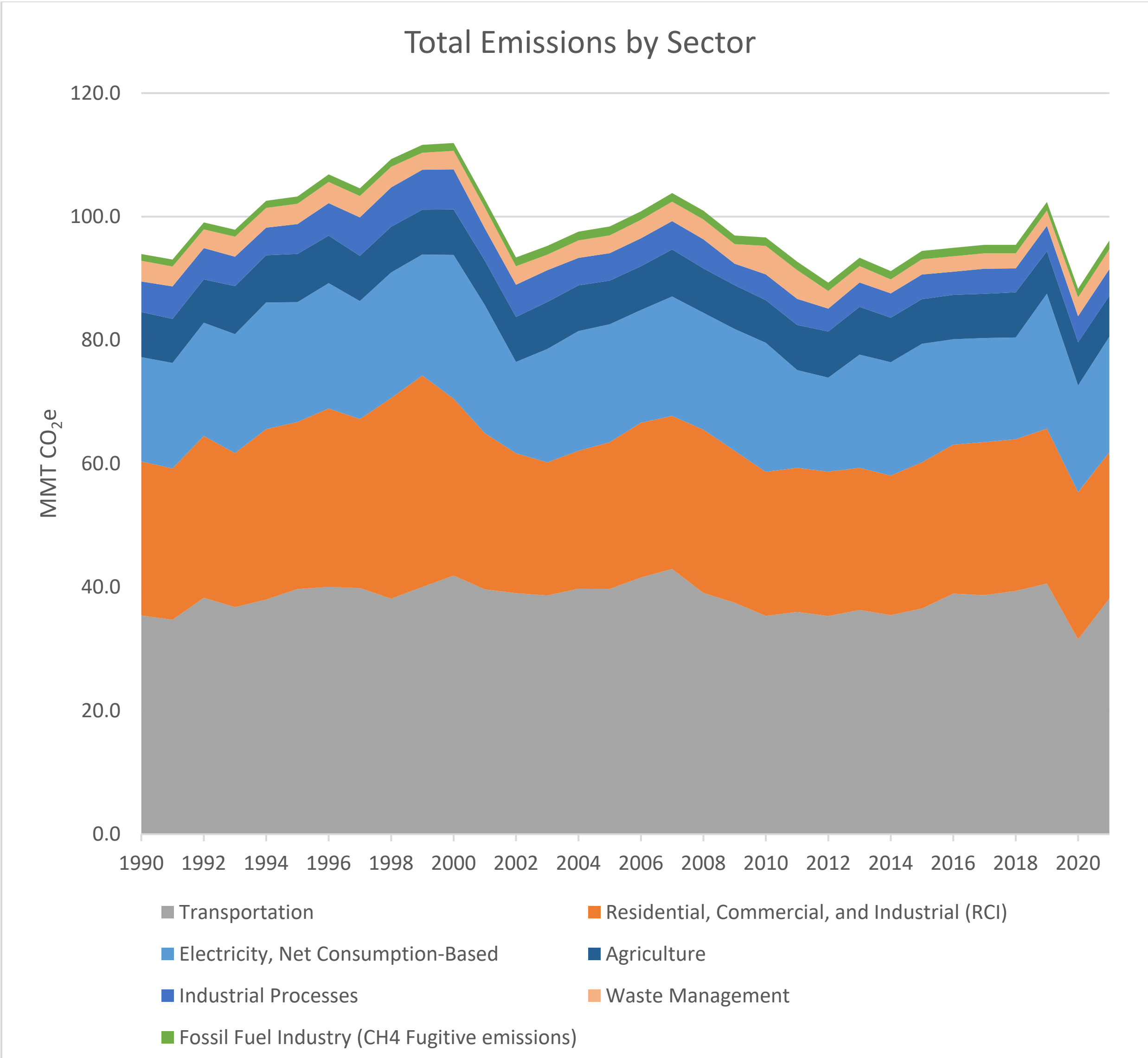

Figure 2. Washington's total historical greenhouse gas emissions.

Greenhouse gas inventory tools undergo iterative and incremental adjustments in methodology as we apply new, more accurate analytical approaches to the complete range of historical data. Between the 2022 and 2024 reports, adjustments to the methodology resulted in slight increases in total emissions estimated for each year included in the report. For example, 1990 emissions were estimated at 93.5 MMT CO_2e in the 2022 report and are now estimated to be 93.9 MMT CO_2e in this report. Figure 3 on the following page compares total emissions from the previous inventory, published in 2022, to this one. There is no statistically significant difference between them.[26]

[26] The average of the differences among all years falls within the standard error for each year's inventory results.

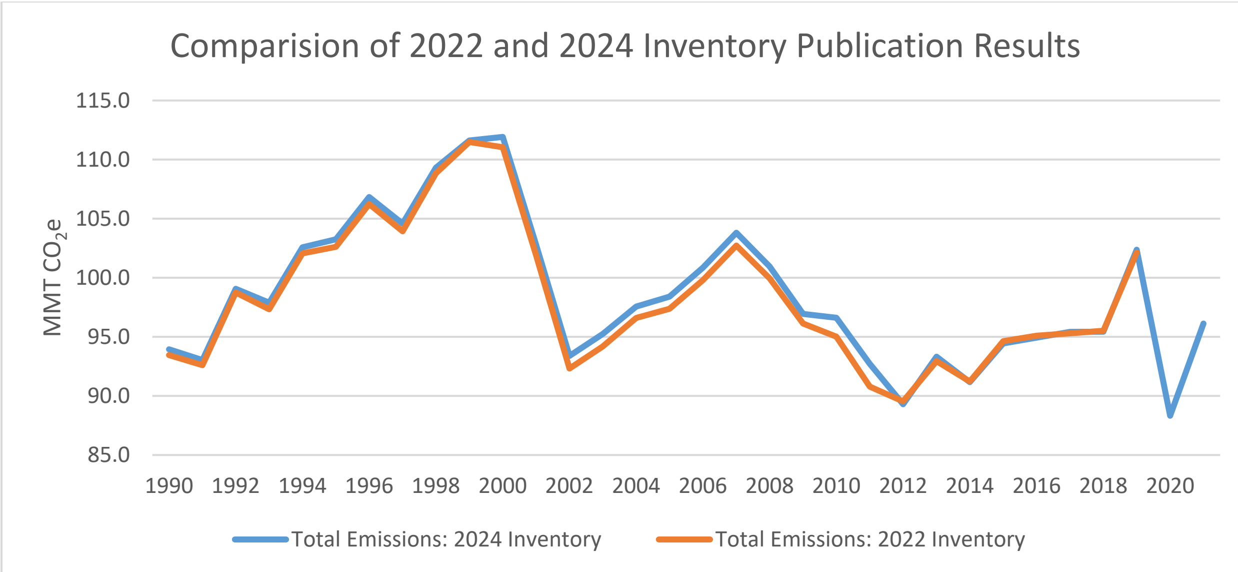

Figure 3. Comparison of current greenhouse gas inventory to previous inventory.

Carbon intensity

Carbon intensity is a measure of greenhouse gas emissions compared to Washington's growth in population or economy. Figures 4 and 5 depict total emissions, population, gross domestic product (GDP), as well as emissions per capita and emissions per dollar of GDP relative to two baseline years.

Figure 4 represents progress from Washington's emissions baseline year (1990), showing that 2021 emissions are essentially where they were in 1990, even as population and GDP rose. With the origin point at the baseline year, total CO_2e emissions should be nearly or less than 0% to be on track for the 2020 emission limit (as shown). From 1990 to 2021, per capita emissions declined by 35.9% and per GDP emissions declined by 64.2%.

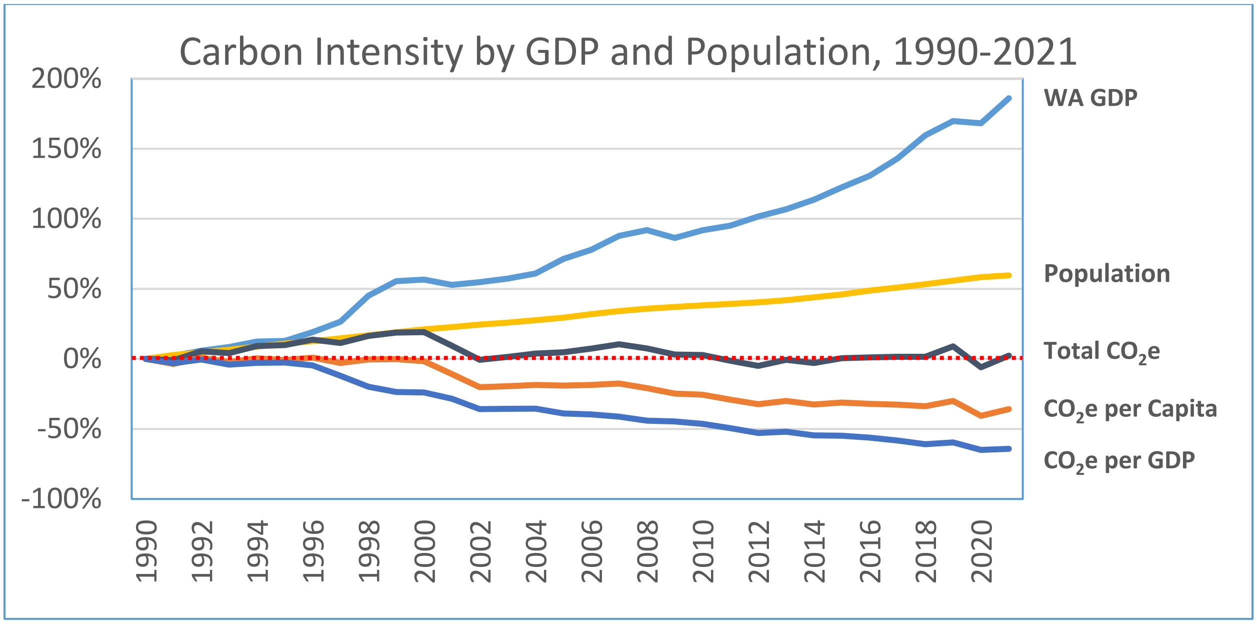

Figure 4. Change in carbon intensity, 1990 to 2021 (GDP chained to 1997 values).

Figure 5 depicts progress since 2000, the year of Washington's highest greenhouse gas emissions. This represents progress since emissions peaked. Percentage change of total carbon dioxide equivalent in Figure 5 should be demonstrably less than zero to be on track for emissions targets (as shown). From 2000 to 2021, per capita emissions declined by 34.8% and per GDP emissions declined by 55.6%.

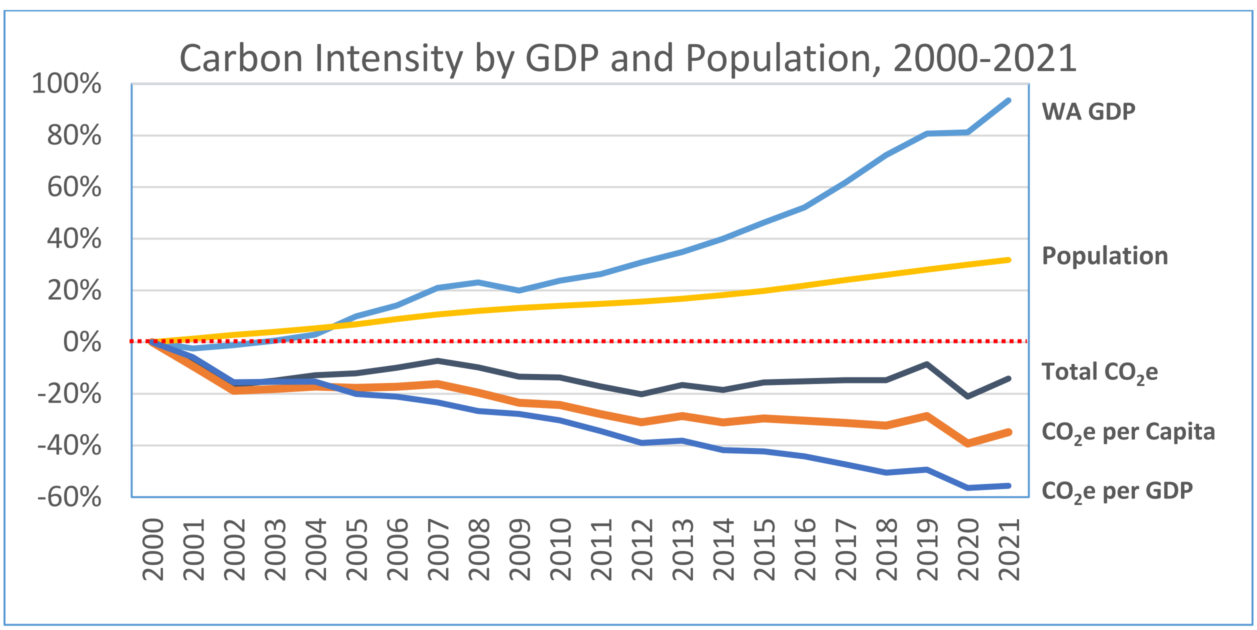

Figure 5. Change in carbon intensity, 2000 to 2021 (GDP chained to 2017 values).

This inventory cannot identify specific reasons for improved carbon intensity indices, yet some economic trends are notable. Washington's growth in information and technology sectors leads to lower energy demand per dollar produced than other sectors like agriculture and manufacturing. Carbon intensity per person and per dollar produced have decreased in both representations, yet advances in energy efficiency occur in the context of higher productivity and population growth, which slows progress to our emission targets.[27] This indicates that technological advances in efficiency must be accompanied by policies that support behavioral energy conservation to transition away from fossil fuels.

[27] In 1865 William Stanley Jevons observed that improved technology for coal burning, contrary to intuition, led to higher overall consumption as the relative cost of the resource dropped. The Jevons Paradox is updated for the modern energy landscape in the Khazzoom–Brookes postulate, which states that increased energy efficiency tends to lead to greater energy consumption.

Sector Analysis

The following sections describe sector-specific trends in greenhouse gas emissions following EPA and IPCC guidelines. To understand how sector emissions are calculated, consider how the emissions from a single factory are attributed to various sectors using the current methodology. Emissions from goods and services that come and go from the factory would be captured in transportation sector calculations. The electricity that the factory requires to operate would be included in the electricity consumption sector calculations. Furnaces or a physical plant may produce thermal or electrical energy on-site, which would be captured in the residential, commercial and industrial buildings sector. And greenhouse gases released during the manufacturing process would be captured in industrial sector calculations.

However, sector emissions overlap in multiple ways. For example, industrial production relies on transportation, electricity, and the use of fossil fuels to run machinery on-site. For the sake of emissions analysis, these different emissions sources are teased apart to prevent double counting (Table 4). This means some sectors, like “industrial process,” may appear as low emitters because only emissions unique to industry—its process and fugitive emissions, but not its energy consumption—are included. Unlike previous reports, the areas of overlap among emissions sources are included in this report’s discussion of each sector to increase understanding of the benefits and limitations of sector-specific analysis.

Electricity consumption

Data for electricity consumption emissions were provided by the Washington Department of Commerce (Table 5). These are fuels burned at centralized facilities to serve grid-connected end users. This sector’s data include emissions for 2022.

- From 2019 to 2020, electricity consumption emissions dropped 21% to 17.3 MMT CO_2e, 2.3% above the 1990 baseline of 16.9 MMT CO_2e for this sector.
- From 2020 to 2021, electricity consumption emissions rose 8.2% to 18.7 MMT CO_2e, 10.7% above the 1990 baseline of 16.9 MMT CO_2e for this sector.
- From 2021 to 2022, electricity consumption emissions dropped 7% to 17.4 MMT CO_2e, 3.0% above the 1990 baseline of 16.9 MMT CO_2e for this sector.
- As of 2021 Washington’s electricity consumption emissions were 19.6% lower than their peak in 2000.
- As of 2022 Washington’s electricity consumption emissions were 25.3% lower than their peak in 2000.

Notably, electricity emissions from coal dropped by 42.1% between 2019 and 2021, when provisions in RCW 80.80.040 took effect.[28] Emissions from natural gas also dropped by 24.2%.

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[28] Provisions enacted in 2011 for RCW 80.80.040 (https://app.leg.wa.gov/rcw/default.aspx?cite=80.80.040) called for greenhouse gas emissions performance standards in baseload electric generation using phased performance benchmarks for coal fired facilities taking effect in 2020 and 2025.

These changes are likely due to the increased use of hydropower, along with record wind and solar electricity production, and public policy. Shifting to 100% non-emitting electricity by 2045 is required by Washington's Clean Energy Transformation Act, which took effect in 2020.

Washington's greenhouse gas inventory uses a consumption approach to calculate emissions for electricity that is based on all electricity used within the state, regardless of where it is generated. Washington relies on electricity generated within its borders and imported from the Northwest Power Pool. Washington's electricity fuel mix largely comprises renewable resources like hydropower and wind, which have no net greenhouse gas emissions. Therefore, they do not appear as emission sources in the following tables and figures.

To meet electricity demand, the state also imports electricity generated in surrounding states, which can come from renewable or fossil fuel-based sources. The Department of Commerce provides information on the greenhouse gas emissions for electricity consumed through its Fuel Mix Disclosure Report (Table 5 and Figure 6), which includes data through 2022.[29] Though hydropower makes up a significant portion of Washington's energy mix, it does not appear because it does not have greenhouse gas emissions.

Table 5. Emissions from electricity consumption (MMT CO_2e).

Emission	1990	2000	2005	2010	2015	2019	2020	2021	2022
Electricity Consumption	**16.9**	**23.3**	**19.1**	**20.9**	**19.2**	**21.9**	**17.3**	**18.7**	**17.4**
Coal	16.8	17.4	15.2	15.8	14.0	15.2	8.1	8.8	8.3
Natural gas	0.1	5.3	3.6	4.8	4.9	6.2	4.2	4.7	3.8
Petroleum	0.0	0.6	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Unspecified	-	-	-	-	-	-	5.0	5.2	5.2
Other*	0.0	0.0	0.2	0.1	0.2	0.4	0.1	0.1	0.1

[29] Fuel Mix Disclosure (https://www.commerce.wa.gov/growing-the-economy/energy/fuel-mix-disclosure/) and RCW 19.29A.060: Fuel characteristics disclosure—Electricity product categories (https://app.leg.wa.gov/rcw/default.aspx?cite=19.29A.060). Long-term trends are difficult to identify due to a recent adjustment in data collection. Prior to 2020, imported electricity was assigned to fuel mix categories based on Washington's fuel mix ratio. After 2020, imported electricity was assigned to a new unspecified category that uses an emission rate reflective of the entire Northwest power pool, which includes utilities in Washington, Oregon, and Idaho and parts of Montana, Nevada, Utah, and California. While this makes comparing data before and after 2020 impossible, the current approach improves tracking for coming years. In the 2024 legislative session, the repeal of RCW 19.405.070 released commerce from the requirement to calculate greenhouse gas emissions for this report.

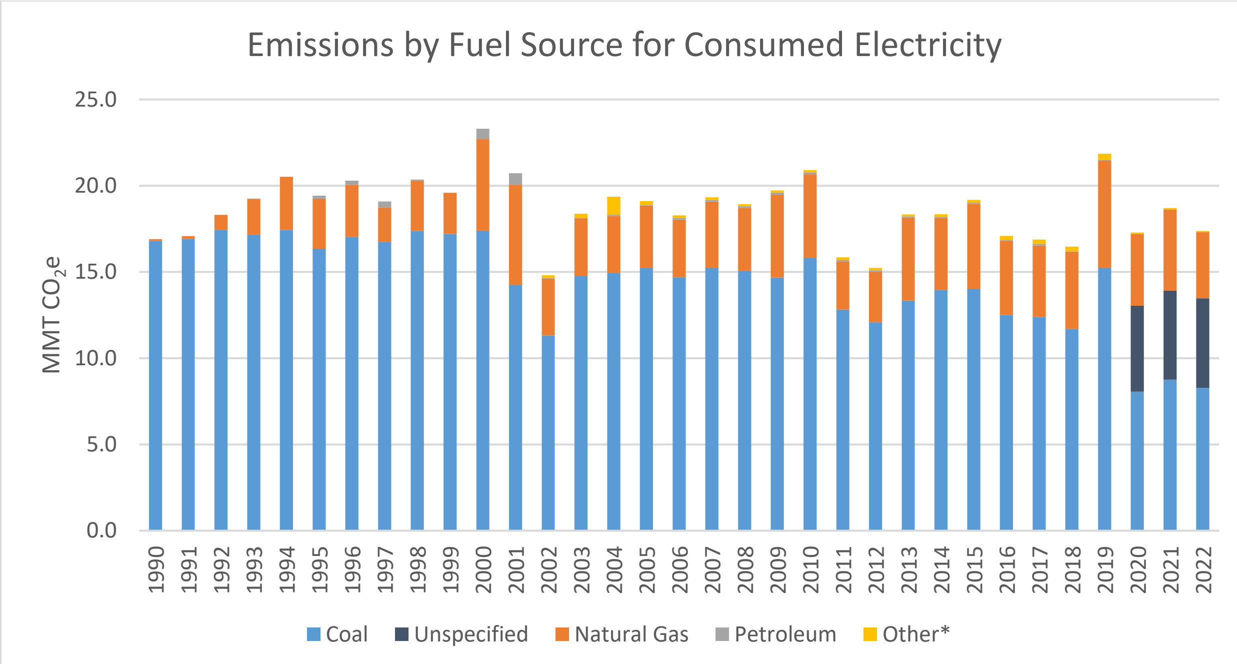

Figure 6. Emissions by fuel source for consumed electricity.

In contrast, the SIT calculates emissions with a production-based approach that only considers the electricity generated physically within the state (Table 6). Figure 7 on the following page compares emissions from electricity production to those from electricity consumption. Washington both imports and exports electricity and is often a net exporter.[30] However, Washington depends on energy imports at times when it cannot meet internal demand. Production-based approaches, therefore, cannot accurately represent Washington's electricity emissions.

Table 6. Emissions by greenhouse gas for electricity produced in Washington.

	1990	1995	2000	2005	2010	2015	2019	2020	2021
Subtotal MMT CO_2e	**7.6**	**8.4**	**14.3**	**14.2**	**13.2**	**10.9**	**13.7**	**11.0**	**9.9**
Emissions from CO_2	7.5	8.4	14.2	14.2	13.2	10.9	13.7	11.0	9.9
Coal	*7.5*	*6.1*	*9.8*	*10.6*	*8.8*	*5.4*	*7.6*	*5.5*	*3.4*
Petroleum	*0.0*	*0.1*	*0.3*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Natural Gas	*0.0*	*2.2*	*4.0*	*3.6*	*4.3*	*5.5*	*6.1*	*5.4*	*6.4*
Emissions from N_2O	0.03	0.03	0.05	0.05	0.05	0.03	0.04	0.03	0.02
Emissions from CH_4	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

[30] Washington Profile: State Profile and Energy Estimates (https://www.eia.gov/state/?sid=WA).

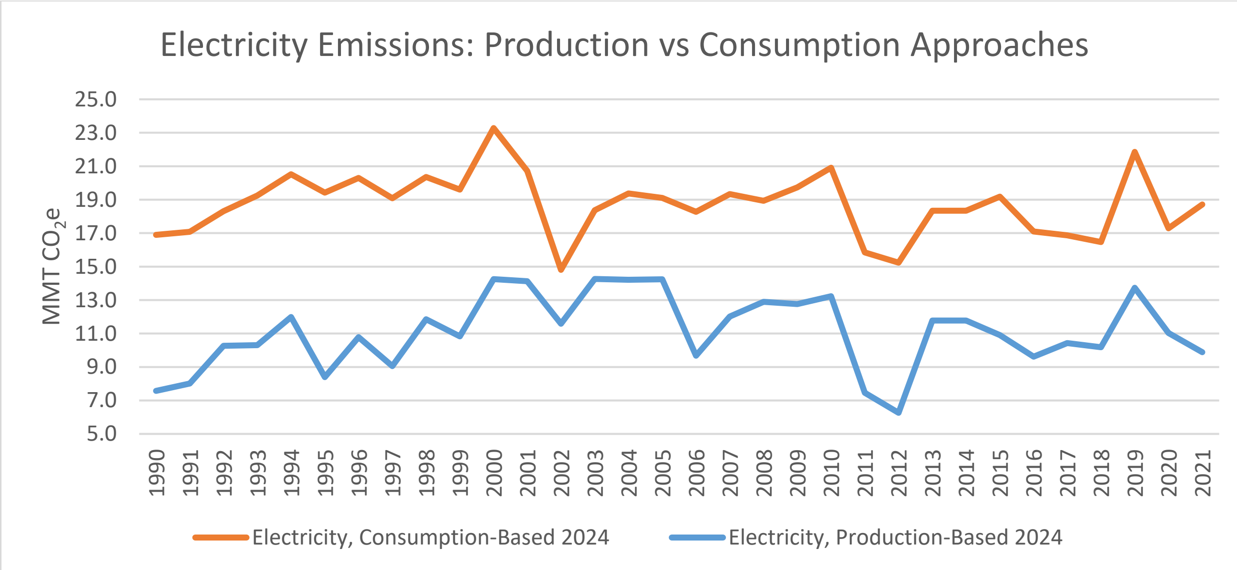

Figure 7. Comparison of production- and consumption-based electricity emissions.

Figure 8 on the following page demonstrates the large influence that hydropower supply plays in determining the greenhouse gas emissions from electricity. Drought dramatically reduces the supply of hydropower in some years because less precipitation is stored in the snowpack that feeds Washington's dams through the summer. Hydropower is classified as a clean energy technology, and when its production increases, it offsets fossil energy use and greenhouse gas emissions decrease. Hydropower production dropped by approximately 10% over 20 years (see 20-year trendline) and has dropped dramatically since 2017. This reduction in hydropower production has resulted in higher demand from fossil energy sources and larger greenhouse gas emissions in low precipitation years. The uncertain future of northwest hydropower is discussed in the Fifth National Climate Assessment,[31] and continuation of this trend will make clean energy provision a challenge.

[31] See Northwest in Fifth National Climate Assessment (https://nca2023.globalchange.gov/).

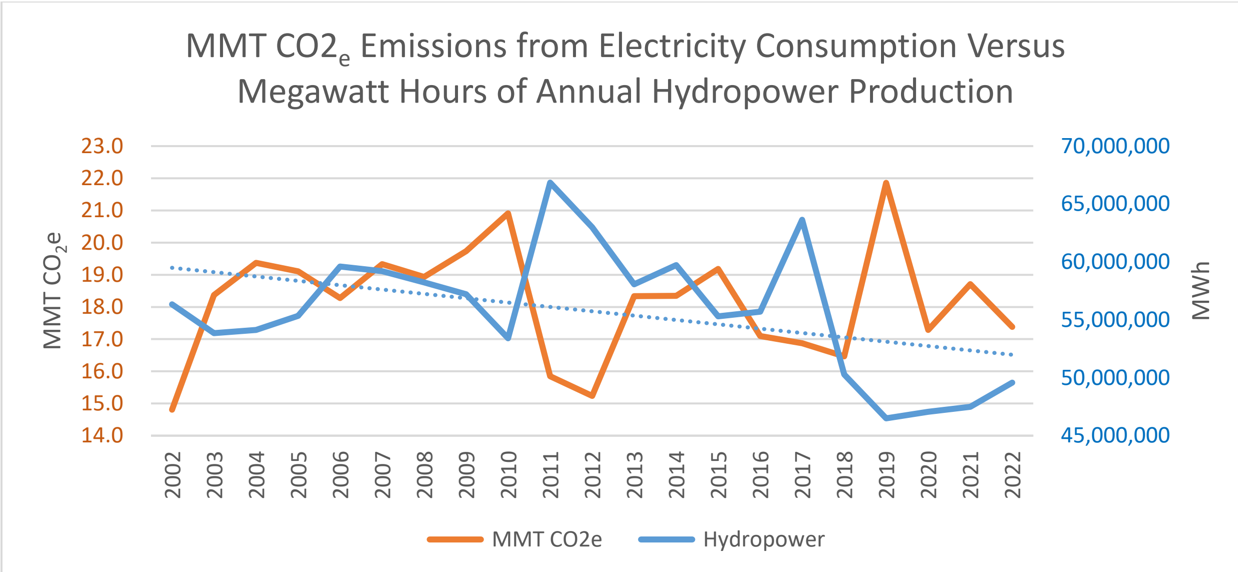

Figure 8. Comparison of consumed electricity and hydropower generation.

Figure 9 on the following page depicts electricity consumption broken down among residential, commercial, and industrial buildings (RCI). This information was calculated by applying data from the US Energy Information Administration (EIA) Electric Sales and Revenue Reports to Department of Commerce Fuel Mix Disclosure data.[32] The electricity consumed for RCI is predominantly for heating and cooling buildings and industrial machinery. Emissions from electricity consumption in the three sectors move in harmony, indicating a strong influence from factors that impact electrical production, rather than consumption within any specific sector. While we see short-term volatility, we see long term emissions increases in residential and commercial buildings, with energy efficiency gains overwhelmed by increased demand. Industrial emissions exhibited a dramatic decline in 2000-2002, an exceptional period described by the Northwest Power and Conservation Council.

> *"Demand response was accomplished through a number of different inducements. These included appeals to the public-spiritedness of consumers by public figures, price signals, and utility "buyback" offers—offers by utilities to pay for reduced consumption. The governors of the Northwest states raised the visibility of the severity of the electricity situation and made public appeals for cutbacks. Some industrial customers exposed to market prices responded in a variety of ways to the sharp increases in wholesale prices, including fuel switching, self-generation, cutbacks and shutdowns, albeit at some significant economic expense. Sixty-three percent of the load reductions came about through various forms of buybacks, over 90 percent of which came from the aluminum industry. In the residential sector, programs like "20-*

[32] Proportions of residential, commercial, and industrial sectors sales are available from data provided by Historical State Data - U.S. Energy Information Administration (https://www.eia.gov/electricity/data/state/). See EIA-861 Annual Electric Power Industry Report (released: 10/5/2023). Applying these proportions to total emissions values in Fuel Mix Disclosure reports gives the values for this study.

20" and its variants offered ratepayers a percentage reduction in their bill for reducing their consumption by the same percentage relative to the same period in the previous year. None of these load reductions came cheap, but they were cheaper than the alternative of paying the market price for the electricity." [33]

The rapid behavioral changes realized through these programs are remarkable and merit further consideration by policy makers.

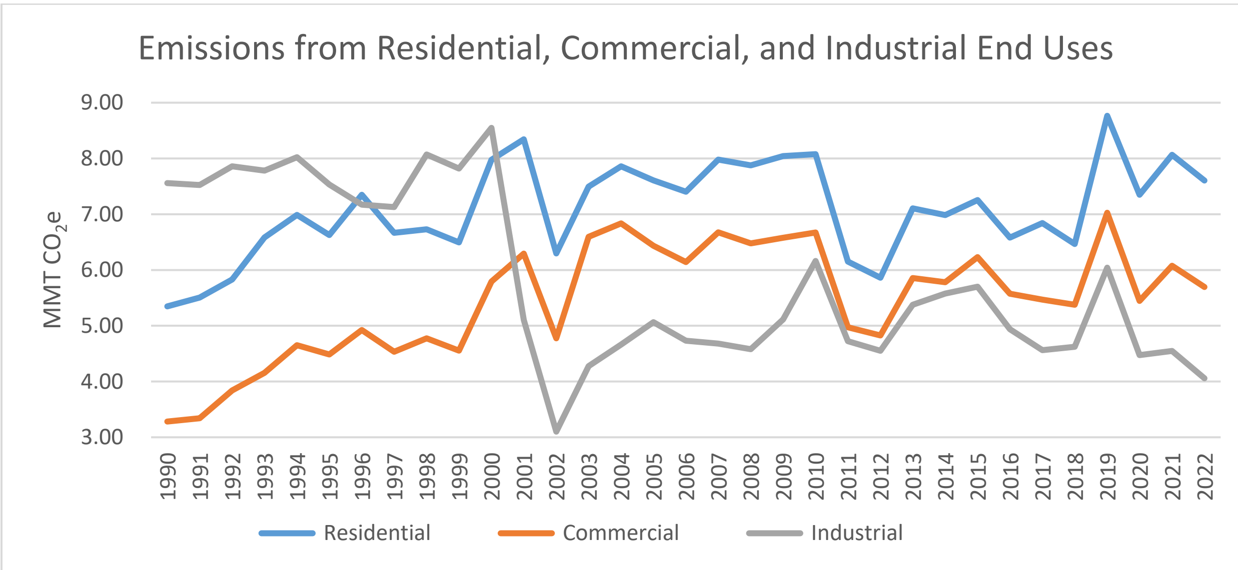

Figure 9. Electricity emissions by building type.

The emissions from the electricity consumption sector can be divided among end use sectors, providing two different perspectives. Figures 10 and 11 represent two views of sector emissions. In Figure 10, emissions from electricity consumption are not apportioned to the sectors that consume the electricity; electricity production is considered as a sector unto itself. In this chart, emissions are accounted essentially at the site of their release.

[33] Northwest Power and Conservation Council, Energy Crisis of 2000/2001 (https://www.nwcouncil.org/reports/columbia-river-history/energycrisis/).

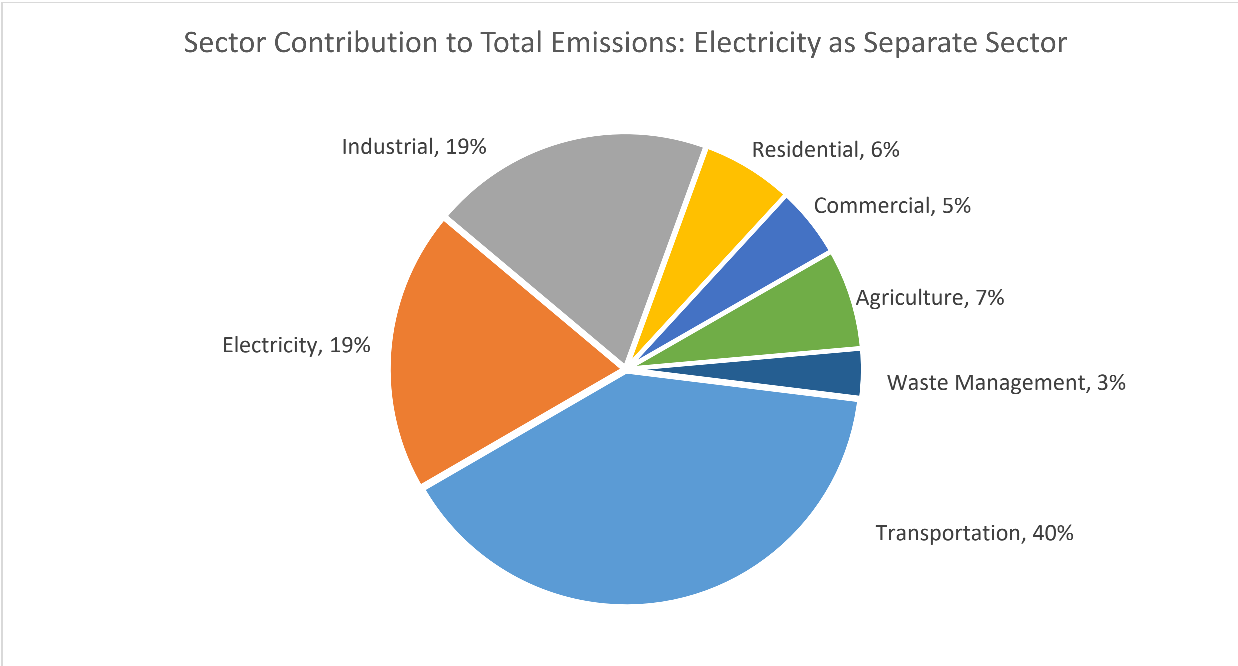

Figure 10. Proportion of emissions by sector with electricity as a stand-alone sector.

In Figure 11, electricity emissions, which make up 19% of total emissions, are apportioned within the sectors where the electricity is consumed. By comparing the two diagrams we see industrial emissions rise to 24%, residential to 15%, and commercial to 11% of total emissions (totaling 50%). Thus, when electricity consumption emissions are embedded within end use sectors, the RCI building sector becomes the largest source of greenhouse gas emissions overall.

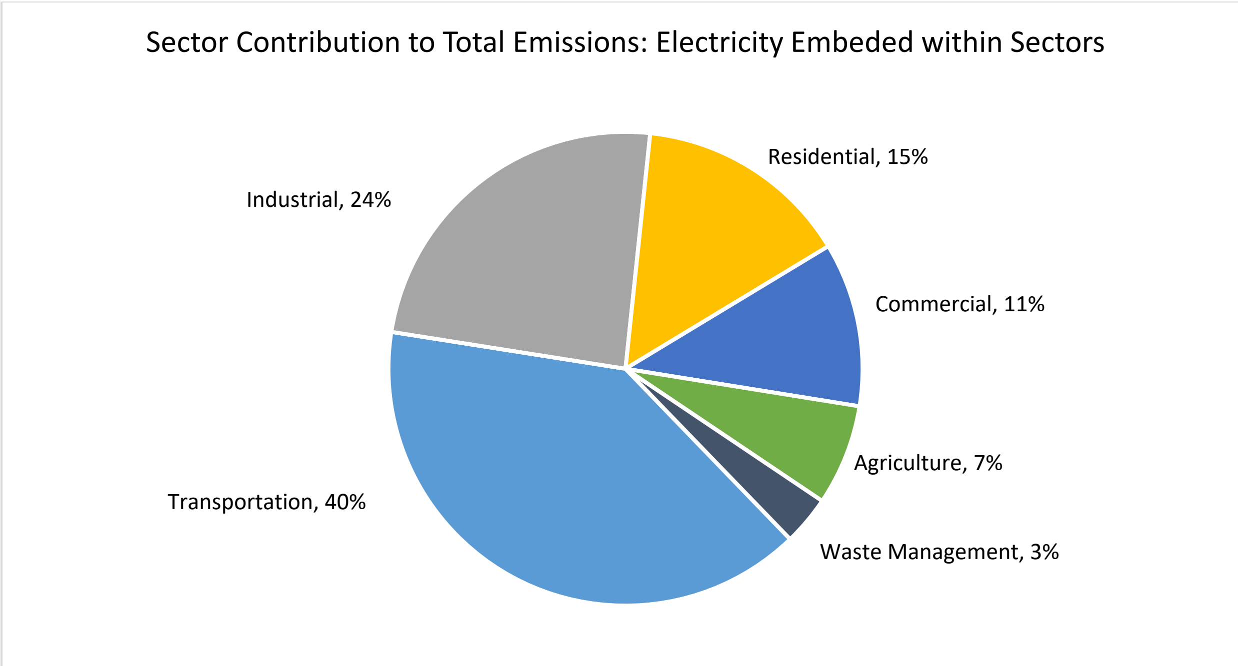

Figure 11. Proportion of emissions by sector including electricity.

Transportation

From 2019 to 2020, transportation emissions dropped 22% to 31.5 MMT CO_2e, 11% below the 1990 baseline of 35.4 MMT CO_2e for this sector. From 2020 to 2021, transportation emissions rose 21% to 38.2 MMT CO_2e, 7.7% above the 1990 baseline. As of 2021, Washington's transportation emissions were 18.9% lower than their peak in 2000.

Transportation emissions mainly come from internal combustion engines that burn petroleum-based fuels. Within this sector, the largest emission sources were the combustion of gasoline by highway vehicles and the combustion of a variety of fuels by non-highway vehicles. Diesel fuel combustion by highway vehicles also contributed substantially (Table 7 and Figure 12). Overall emissions from transportation have remained higher than the 1990 baseline with a notable dip in 2020, with highway diesel emissions growing as highway gasoline emissions dropped. The COVID-19 pandemic likely drove the 22.4% decrease in transportation emissions from 2019 to 2020, and new policies that increase efficiency and electrify the transportation sector should result in emissions reductions in future inventories.

Table 7. Emissions from transportation (MMT CO_2e).

	1990	2000	2005	2010	2015	2019	2020	2021
Transportation	**35.4**	**41.9**	**39.7**	**35.3**	**36.6**	**40.6**	**31.5**	**38.2**
Gasoline Hwy	15.2	19.5	18.7	16.0	15.5	17.0	13.6	14.5
Diesel Hwy	3.5	5.5	5.5	7.4	6.9	6.7	7.1	7.6
Non-Hwy (aviation, marine, rail)	16.7	16.9	15.5	12.0	14.2	16.9	10.8	16.0
Alt fuel vehicles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

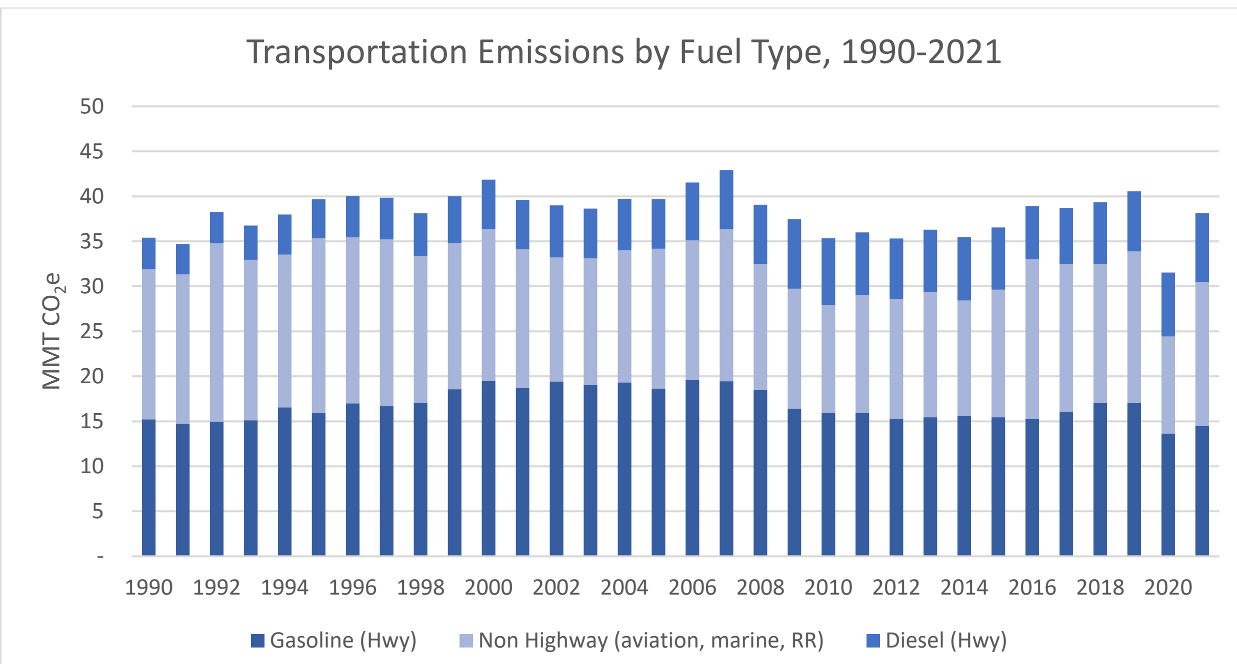

Figure 12. Transportation emissions by fuel types.

Figure 13 presents transportation data on highway vehicle miles traveled compared to highway emissions.[34] As emissions declined over time, vehicle miles traveled rose sharply. Higher fuel efficiency was met with higher transportation demand, which hindered progress to lower emissions. However, the rate of growth in vehicle miles traveled (23%) is remarkably low in the context of Washington's population growth over this period (47%).

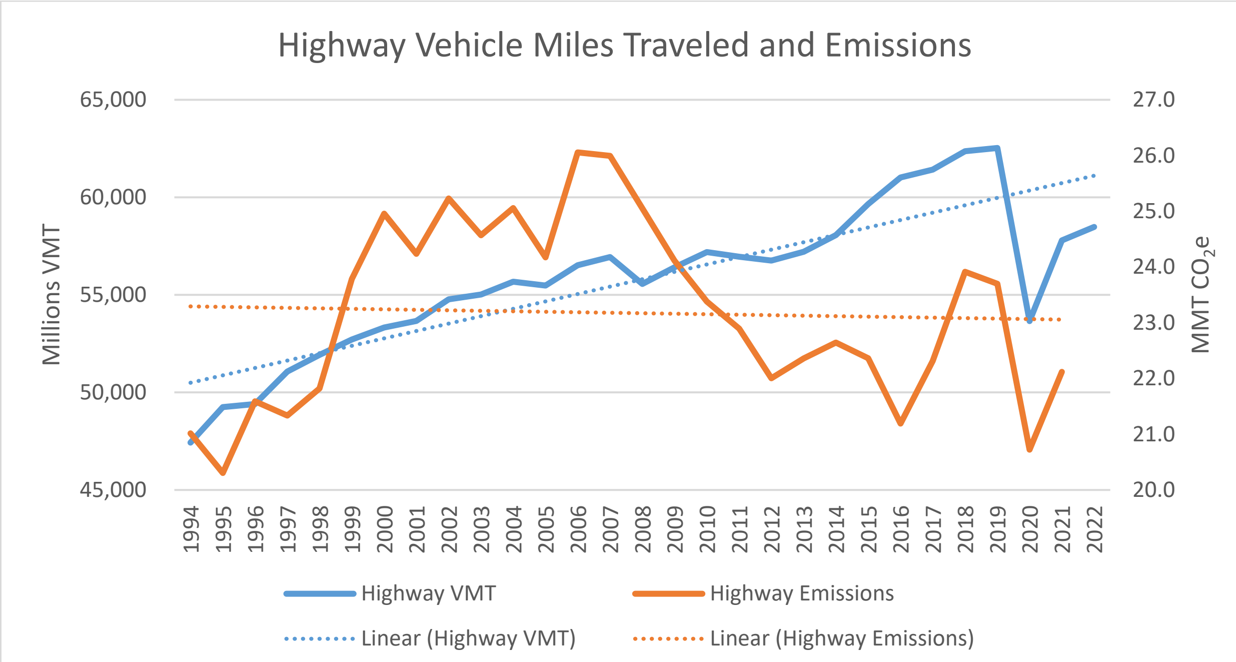

Figure 13. Comparison of highway vehicle miles traveled and emissions.

Figure 14 on the following page allocates the transportation sector emissions from Table 7 to various vehicle types and fuel uses based on the vehicle miles traveled data in the SIT (rather than fossil fuels consumed). The SIT vehicle miles traveled analysis relies on estimates and does not provide the information required for accurate emissions quantities. These figures illustrate generalized and relative quantities for vehicle emissions among types. Among highway vehicles, we can see that passenger cars contribute the most to gasoline-sourced emissions, and heavy-duty vehicles dominate among diesel-sourced emissions. Alternative fuels include methanol, ethanol, compressed natural gas, liquefied natural gas, and liquefied petroleum gas. Ethanol is the most common alternative fuel used in light-duty vehicles, and compressed natural gas is the most common alternative fuel used in heavy-duty vehicles and buses. Non-highway vehicles include watercraft, planes, locomotives, tractors, construction equipment, snowmobiles and other recreational craft. Excluding vessels that use bunker fuels, aircraft and watercraft contribute the most to domestic non-highway emissions.

[34] Data from State Highway Travel, Bureau of Transportation Statistics (https://www.bts.gov/browse-statistical-products-and-data/state-transportation-statistics/state-highway-travel).

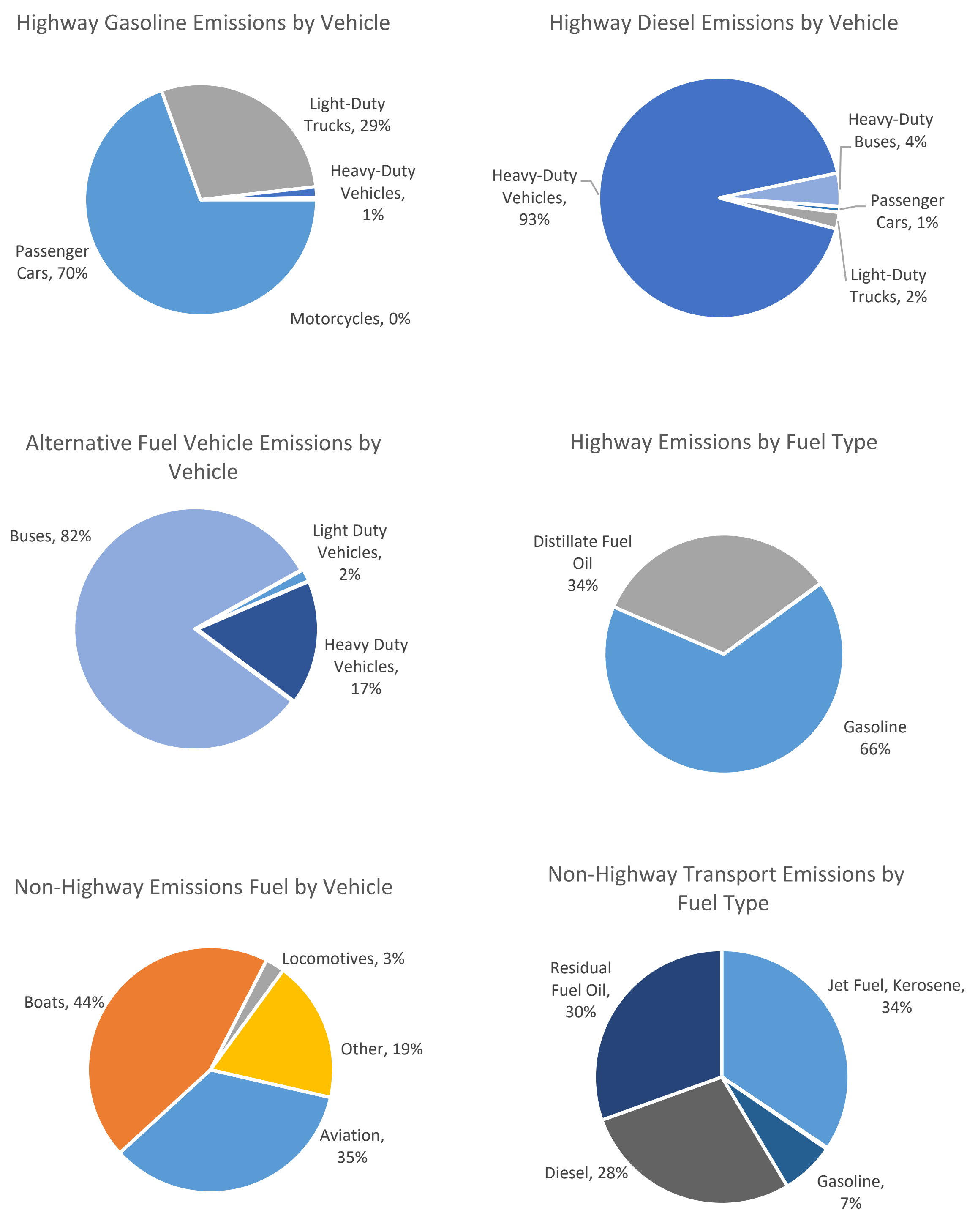

Figure 14. Transportation emissions apportioned by vehicle and fuel type.

Residential, commercial, and industrial fossil fuel combustion

From 2019 to 2020, residential, commercial and industrial (RCI) emissions, also referred to as "building emissions," dropped 5.0% to 23.8 MMT CO_2e, 4.5% below the 1990 baseline of 24.9 MMT CO_2e for this sector. From 2020 to 2021, building emissions declined 0.6% to 23.7 MMT CO_2e, 5.0% below the 1990 baseline of 24.9 MMT CO_2e. As of 2021, Washington's building emissions are 17.3% lower than their 2000 levels.

Emissions from this sector peaked earlier, in 1999, at 34.2 MMT CO_2e, and 2021 emissions are 30.7% lower than those. These emission reductions of 10.5 MMT CO_2e from the peak represent Washington's most significant emissions reductions within one sector.

The buildings sector data in SIT calculations only include emissions from on-site combustion of fossil fuels. Electricity consumption data are not included in these values to prevent double counting. Table 8 includes data from the SIT for on-site combustion of fuels. Annual Electric Power Mix data from the EIA allow us to apportion electricity consumption data among residential, commercial, and industrial building end uses (Table 9).[35]

Table 8. Building emissions from on-site fossil fuel combustion by fuel type (MMT CO_2e).

	1990	2000	2005	2010	2015	2019	2020	2021
RCI Fossil Fuels On-site	**24.9**	**28.6**	**23.8**	**23.3**	**23.7**	**25.1**	**23.8**	**23.7**
Coal	0.6	0.3	0.1	0.2	0.2	0.1	0.1	0.1
Petroleum	16.0	17.2	13.4	12.4	12.5	12.0	11.2	10.6
Natural gas	8.4	11.2	10.2	10.7	11.0	13.0	12.5	12.9

Table 9. Indirect building emissions from electricity consumption by end use (MMT CO_2e).

	1990	2000	2005	2010	2015	2019	2020	2021
RCI Electricity Consumption	**16.2**	**22.3**	**19.1**	**20.9**	**19.2**	**21.8**	**17.3**	**18.7**
Residential	5.3	8.0	7.6	8.1	7.3	8.8	7.3	8.1
Commercial	3.3	5.8	6.4	6.7	6.2	7.0	5.4	6.1
Industrial	7.6	8.5	5.1	6.2	5.7	6.0	4.5	4.5

Values for Table 8 and Table 9 are summed in Table 10. When electricity consumption is included in the buildings sector, its emissions exceed those of the transportation sector. Figure 11 shows that buildings made up 50% of Washington's 2021 emissions when electricity consumption emissions were included.

[35] Megawatt hours sold to end users, including residential, commercial, and industrial, are available from data provided by Historical State Data - U.S. Energy Information Administration (https://www.eia.gov/electricity/data/state/). See EIA-861 Annual Electric Power Industry Report (released: 10/5/2023). Weighting electrical consumption emissions from Table 4 using the proportions of each end use relative to all electricity sold gives the values for this analysis.

Table 10. Building emissions from on-site fossil fuel combustion and electricity consumption (excluding industrial process emissions).

MMT CO2e	1990	2000	2005	2010	2015	2019	2020	2021
RCI Total Emissions	**41.1**	**51.0**	**42.9**	**44.2**	**42.8**	**46.9**	**41.1**	**42.4**
RCI fossil fuels on-site	24.9	28.6	23.8	23.3	23.7	25.1	23.8	23.7
RCI electricity consumption	16.2	22.3	19.1	20.9	19.2	21.8	17.3	18.7

Figure 15 presents the fuel mix proportions for building electricity consumption in 2021. Note that unspecified fuels from imported electricity make up a substantial portion at 28%. Although coal is not a large contributor to emissions from on-site combustion in buildings, it contributes 47% of emissions through electricity consumption. Comparing these numbers to the total emissions from electricity consumption in Table 4 shows that nearly all electricity is consumed by the buildings sector. This points to the continued need for electricity conservation, especially in residential buildings (see Table 9), in addition to transitioning to non-emitting resources.

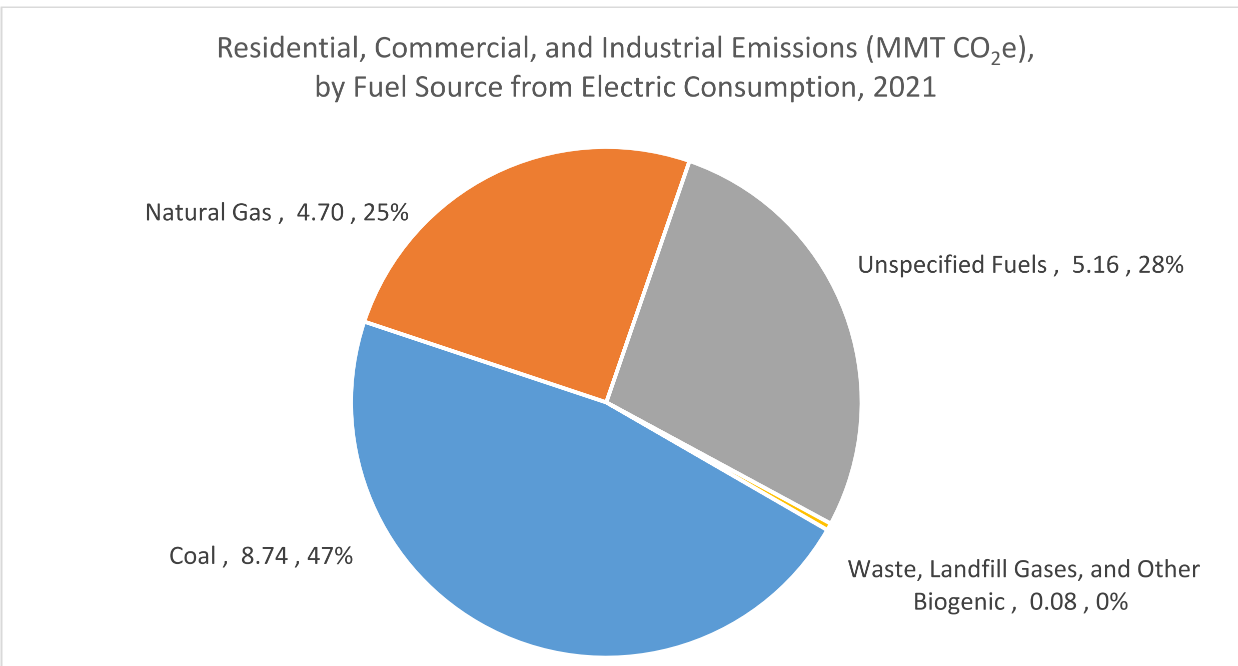

Figure 15. Proportion of RCI electricity emissions by fuel type.

Agriculture

From 2019 to 2020, agriculture emissions rose 1.6% to 7.0 MMT CO_2e, 4.3% below the 1990 baseline of 7.3 MMT CO_2e for this sector. From 2020 to 2021, agriculture emissions decreased by 5.2% to 6.6 MMT, 9.3% below the 1990 baseline. As of 2021, Washington's agriculture emissions are 10.0% lower than emissions in 2000.

Agricultural emissions from crop and animal production comprise the combined effects of carbon dioxide, methane, and nitrous oxide. Production of meat and dairy products account for the largest portion of greenhouse gas emissions in this sector. The largest single source of emissions comes from enteric fermentation from livestock digestion processes, also known as cow burps (Table 11).

This sector's emissions do not include those associated with fertilizer production, which are beyond the ability of this inventory to assess. The Haber-Bosch process is the main process used for fertilizer production and relies heavily on methane as a feedstock in an energy intensive process that combines atmospheric nitrogen, methane, and water to produce ammonia (NH_3). The fertilizer industry alone accounts for about 2-3% of global energy consumption, with ammonia production making up 80% of that energy.[36] Since the importation of fertilizers into Washington is not included in this inventory's estimate of agriculture emissions, it may significantly underestimate emissions attributable to this sector from a consumption perspective.

Table 11. Emissions from agriculture (MMT CO_2e).

	1990	2000	2005	2010	2015	2019	2020	2021
Agriculture	**7.3**	**7.4**	**7.1**	**6.9**	**7.2**	**6.9**	**7.0**	**6.6**
Enteric fermentation	3.0	3.0	2.7	2.6	2.9	2.6	2.8	3.0
Manure management	0.9	1.3	1.2	1.3	1.6	1.6	1.7	1.6
Agricultural soils	3.4	3.1	3.2	3.0	2.8	2.7	2.5	1.9

[36] Ammonia, Industrial Efficiency Technology & Measures (https://www.iipinetwork.org/wp-content/Ietd/content/ammonia.html).

Industrial process and fugitive emissions

From 2019 to 2020 industrial process and fugitive emissions rose 2.6% to 4.2 MMT CO_2e, 14.4% below the 1990 baseline of 4.9 MMT CO_2e for this sector. From 2020 to 2021, industrial process and fugitive emissions rose 1.9% to 4.3 MMT CO_2e, 12.8% below the 1990 baseline. As of 2021, Washington's industrial emissions are 33.6% lower than emissions in 2000.

Industrial emissions occur from chemical reactions and leaks of industrial chemicals associated with manufacturing, excluding the processing and distribution of fossil fuels, which are included in other sectors. Table 12 presents the industrial emissions calculated by the SIT. These do not include emissions from on-site fossil fuel combustion or electricity consumption for buildings and machinery.

Data from the industrial sector indicate that the release of ozone-depleting substance substitutes (mostly refrigerants used in air conditioning) is the largest single contributor to this sector's emissions, making up more than half of the total. Refrigerant emissions are steadily rising. These potent greenhouse gases can be thousands of times more powerful than carbon dioxide (Table 2), and Washington has regulations aimed at reducing leaks and phasing out the use of harmful refrigerants in stationary refrigeration and air conditioning equipment. While these emissions are currently tracked at the manufacturer level as an industrial product, they are consumed in residential, commercial, industrial, and transportation sectors. Perfluorocarbon (PFC) released during aluminum production is the second largest source of industrial process emissions.

Table 12. Emissions from industrial processes and escaped gases (MMT CO_2e).

	1990	2000	2005	2010	2015	2019	2020	2021
Industrial processes and fugitive	**4.9**	**6.5**	**4.4**	**4.2**	**4.0**	**4.1**	**4.2**	**4.3**
Carbon dioxide emissions	***2.2***	***3.3***	***1.9***	***1.4***	***1.3***	***1.2***	***1.2***	***1.2***
Cement manufacture	0.0	0.4	0.4	0.3	0.3	0.4	0.4	0.4
Lime manufacture	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0
Limestone and dolomite use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Soda ash	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Aluminum production, CO_2	2.0	1.7	0.8	0.5	0.4	0.3	0.3	0.2
Iron and steel production	0.0	0.8	0.3	0.3	0.3	0.3	0.3	0.3
Ammonia production	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1
Urea consumption	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HFC, PFC, NF_3, & SF_6 emissions	***2.8***	***3.2***	***2.6***	***2.8***	***2.6***	***2.9***	***3.0***	***3.1***
Ozone depleting substance substitutes	0.0	1.0	1.4	1.8	1.8	2.0	2.1	2.2
Semiconductor manufacturing	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Electric power transmission and distribution	0.8	0.4	0.3	0.2	0.1	0.1	0.1	0.1
Aluminum production, PFCs	1.9	1.7	0.8	0.8	0.7	0.7	0.7	0.7

A more holistic assessment of industrial emissions can be done by including emissions from sectors accounted for elsewhere in the inventory: on-site fossil fuel combustion and indirect emissions from electricity consumption (Table 13). In this analysis, on-site fossil fuel combustion is the largest emission source (Figure 16). A closer examination of the fossil fuels used by industry shows petroleum combustion as the largest source of emissions overall for industrial activities (Figure 17).

Table 13. Total emissions from industrial sector (MMT CO_2e).

	1990	2000	2010	2015	2019	2020	2021
Total industrial emissions	**29.8**	**32.2**	**25.6**	**25.2**	**25.1**	**22.5**	**22.0**
On-site fossil fuel combustion	18.4	20.1	14.7	15.1	14.5	13.5	13.1
Indirect electricity CO_2e	6.5	5.6	6.8	6.1	6.5	4.8	4.5
Industrial process and fugitive	4.9	6.5	4.2	4.0	4.1	4.2	4.3

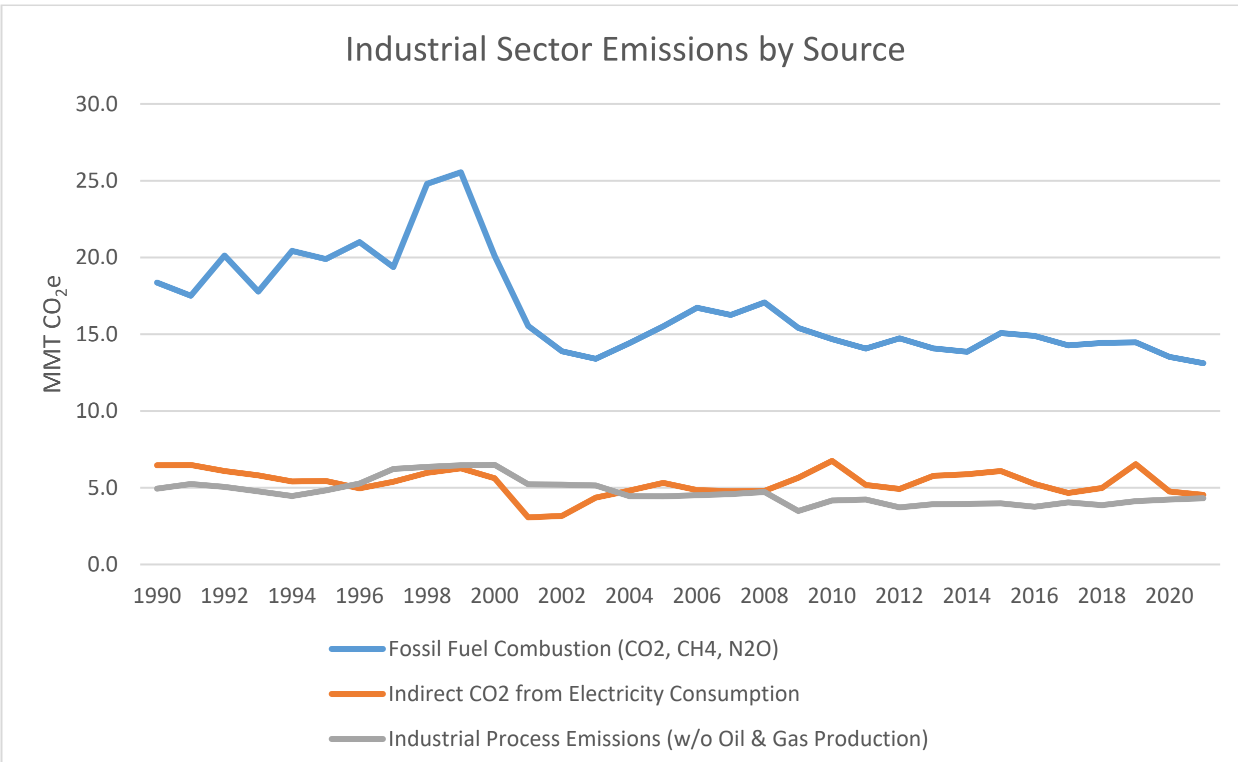

Figure 16. Industrial emissions by source.

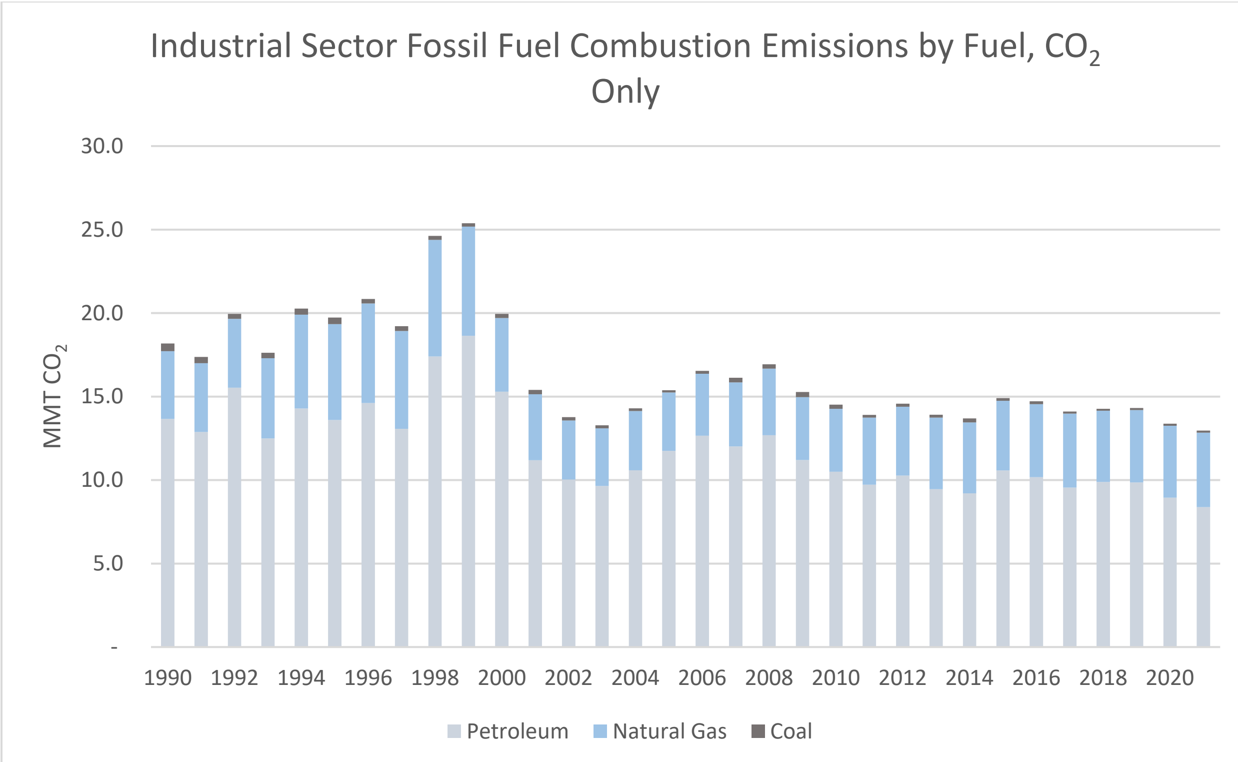

Figure 17. Industrial emissions from on-site fossil fuel combustion by fuel type.

Waste management

From 2019 to 2020, waste management emissions rose 23.5% to 3.1 MMT CO_2e, 6.0% below the 1990 baseline of 3.4 MMT CO_2e for this sector. From 2020 to 2021, waste management emissions rose 9.1% to 3.2 MMT CO_2e, which is 4.0% below the 1990 baseline. As of 2021, Washington's waste management emissions are 6.9% higher than emissions in 2000.

Emissions from landfills and wastewater treatment include uncaptured methane from the decomposition of organic materials. Where waste is burned, CO_2 and N_2O emissions replace methane emissions. Table 14 presents the emissions from waste management calculated by the SIT. Of the 3.2 MMT CO_2e in 2021 from waste management, 2.4 MMT come from solid waste and 0.8 MMT come from wastewater.

Almost all the emissions from solid waste (2.3.MMT CO_2e) come from uncaptured methane resulting from organic material decomposition. Most of wastewater emissions are methane (0.5 MMT CO_2e) with N_2O contributing somewhat less (0.2 MMT CO_2e). Methane makes up 2.8 MMT CO_2e, the vast majority, of waste management emissions. These are predominantly from stationary point sources (e.g. landfills).

In 2024, Ecology adopted a new rule (Chapter 173-408 WAC, Landfill Methane Emissions)[37] establishing new requirements for municipal solid waste landfills including technology, performance, monitoring, and reporting requirements.

Table 14. Emissions from waste management (MMT CO_2e).

	1990	2000	2005	2010	2015	2019	2020	2021
Waste management	**3.4**	**3.0**	**2.9**	**4.6**	**2.5**	**2.5**	**3.1**	**3.2**
Solid waste	2.9	2.4	2.3	3.9	1.8	1.7	2.3	2.5
Wastewater	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.8

[37] https://ecology.wa.gov/regulations-permits/laws-rules-rulemaking/closed-rulemaking/wac-173-408

Fugitive fossil fuel emissions

From 2019 to 2020 fugitive fossil fuel emissions rose 0.2% to 1.4 MMT CO_2e, 28.0% above the 1990 baseline of 1.1 MMT CO_2e for this sector. From 2020 to 2021, fugitive fossil fuel emissions rose 1.2% to 1.4 MMT CO_2e, 29.5% above the 1990 baseline emissions. As of 2021, Washington's fossil fuel fugitive emissions were 13.3% higher than this sector's emissions in 2000.

Fugitive fossil fuel emissions predominantly consist of methane escaping during the mining, processing, refining, and transport of fossil fuels. Washington does not currently mine fossil fuels, yet it ranks fifth for fuel refining in the nation and serves as a transit point for natural gas export. Table 15 presents the fossil fuel fugitive emissions calculated by the SIT, which stem mainly from the transmission and distribution of natural gas.

Table 15. Fugitive fossil fuel emissions (MMT CO_2e).

	1990	2000	2005	2010	2015	2019	2020	2021
Fugitive fossil fuels	**1.1**	**1.2**	**1.4**	**1.4**	**1.3**	**1.4**	**1.4**	**1.4**
Natural gas industry	1.0	1.1	1.3	1.3	1.3	1.4	1.4	1.4
Oil industry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coal mining	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0

The UTC, following RCW 81.88.160, must provide aggregate data about the volume and causes of gas leaks (Table 16), as submitted by gas pipeline companies.[38] UTC data only includes leaks from the distribution of natural gas to end users such as homes and businesses, unlike the SIT results, which also include emissions from transmission and production. Therefore, the results are not directly comparable. Overall, the differences between the two modes of calculation are notable and require further investigation that will be presented in future statewide reports. Further, UTC data are not available earlier than 2020, so using those data for baseline computation is impossible. Emissions totals from the SIT are used in this inventory to maintain consistency in year-over-year analysis.

Table 16. Fugitive gas amounts and emissions from natural gas distribution by cause.

Causes	Gas loss (Mcf)	MMT CO_2e	MMT CO_2e
2020 totals	**62,053.35**	**29,827.62**	**0.03**
Operational practices	7,054.65	3,387.22	0.00
Excavation and other damages	51,998.07	24,997.97	0.02
Estimated loss, unrepaired leaks	3,000.63	1,442.43	0.00
2021 totals	**88,232.06**	**42,833.28**	**0.04**
Operational practices	4,743.41	2,696.10	0.00
Excavation and other damages	59,477.75	28,593.94	0.03
Estimated loss, unrepaired leaks	24,010.90	11,543.24	0.01

[38] https://app.leg.wa.gov/RCW/default.aspx?cite=81.88.160

Other emissions

There are emissions that are not included in the total emissions of Washington by IPCC convention.

Bunker fuels

Bunker fuels are those that are transferred into ships and planes that travel internationally and are not included in Washington's total emissions by international convention. Instead, they are accounted for through the International Civil Aviation Organization and the International Maritime Organization (see Figure 18 below).

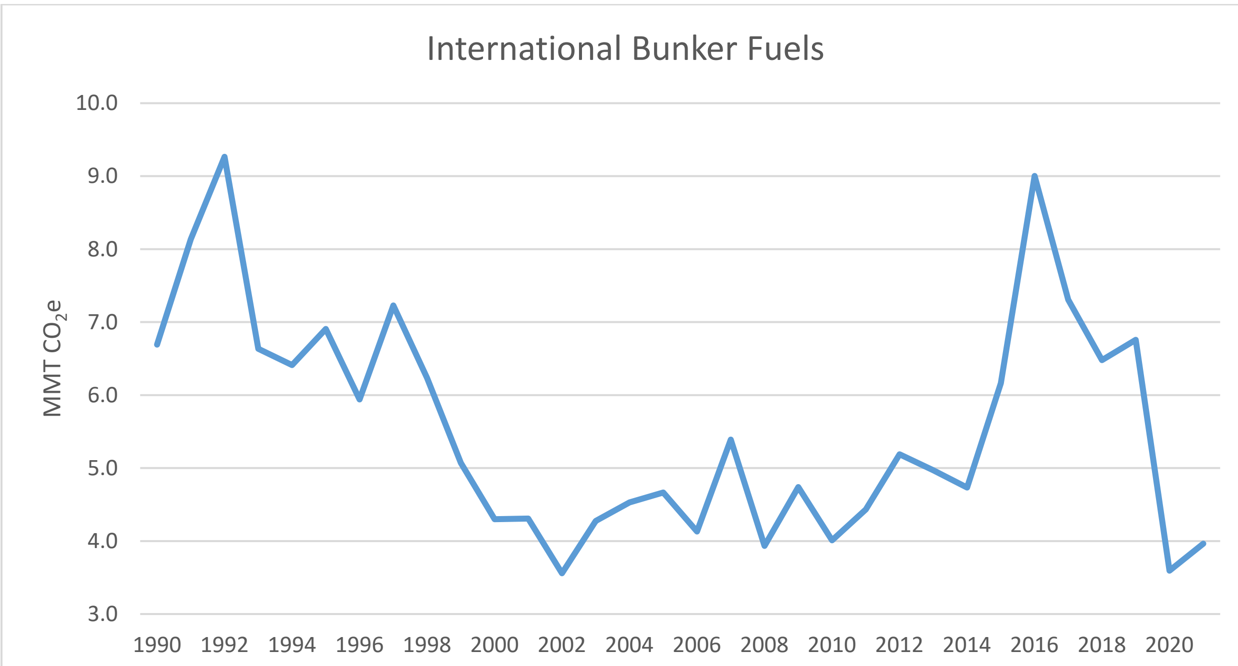

Figure 18. Emissions from international bunker fuels.

Land use, land use change, and forestry

Trees, shrubs, and grasses from the varied natural systems of Washington add and remove greenhouse gases from the atmosphere continuously. Natural lands usually act as a sink for carbon; however, they can rapidly become a source during years with large wildfires (Table 17). According to data from the Department of Natural Resources, the number of acres burned from wildfires has trended upward since 1990 (Figure 19). More frequent wildfires in 2015 and 2020 resulted in net additional greenhouse gas emissions from natural systems in these years. Degradation leads to decreasing absorption of carbon by these systems.

Following precedent established in preceding inventories, these emissions are not included in calculation of Washington's total emissions. This is because the inventory is focused primarily on emissions that result directly from Washington's economy. While emissions from natural and working lands are also important, they are tracked separately as including them would make it more difficult to assess the state's progress in decarbonizing its economy and the impact of policy interventions.

Table 17. Emissions from land use, land use change, and forestry (MMT CO_2e).

	1990	2000	2005	2010	2015	2019	2020	2021
Total	**(22.4)**	**(19.4)**	**(19.7)**	**(20.4)**	**6.1**	**(19.7)**	**4.1**	**(4.3)**
Forest carbon flux	(22.3)	(18.3)	(21.0)	(22.8)	(24.5)	(22.7)	(22.3)	(21.8)
Forest land remaining Forest land	*(22.8)*	*(18.9)*	*(21.5)*	*(23.4)*	*(25.3)*	*(23.5)*	*(23.1)*	*(22.6)*
Other land converted to forest land	*(3.0)*	*(3.0)*	*(3.0)*	*(3.0)*	*(3.0)*	*(3.0)*	*(3.0)*	*(3.0)*
Forest land converted to other land	*3.5*	*3.5*	*3.6*	*3.7*	*3.8*	*3.9*	*3.9*	*3.9*
Urban trees	(1.1)	(1.3)	(1.4)	(1.5)	(1.6)	(1.6)	(1.5)	(1.6)
Landfilled yard trimmings and food scraps	(0.5)	(0.3)	(0.2)	(0.3)	(0.2)	(0.3)	(0.3)	(0.3)
Forest fires (CH_4 and N_20)	1.2	0.3	2.5	2.6	31.4	4.5	27.8	18.9
N_2O from settlement soils	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Agricultural soil carbon flux	0.2	0.1	0.4	1.4	0.9	0.4	0.2	0.3

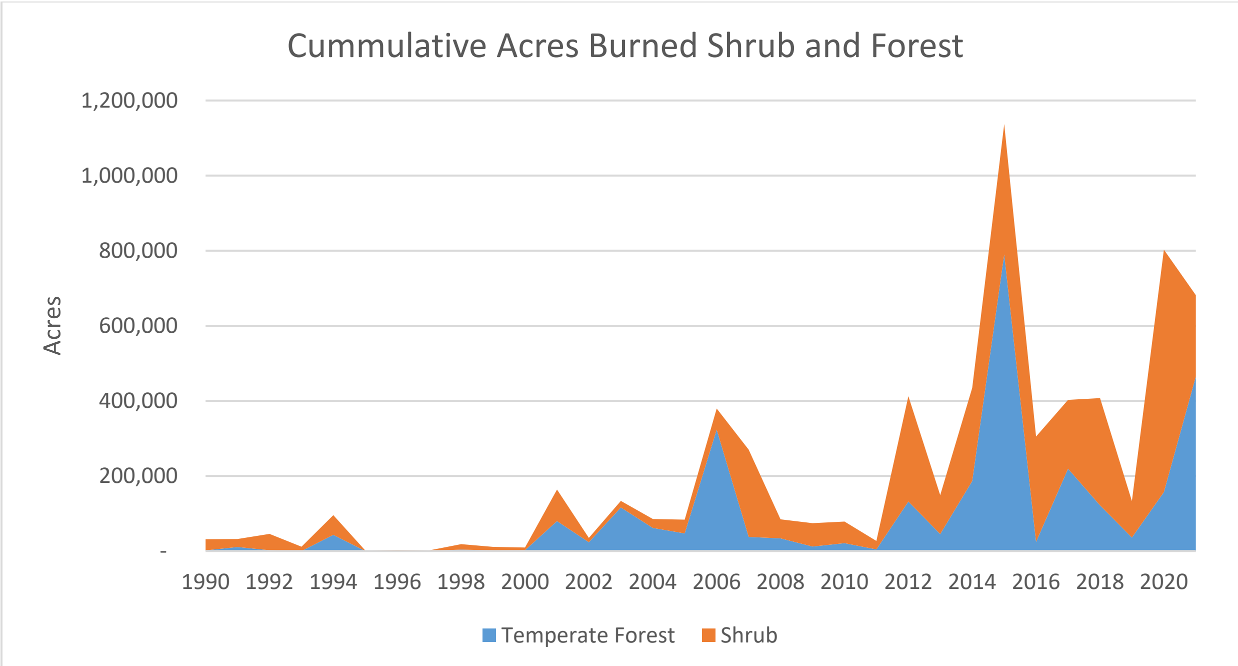

Figure 19. Acreage of forest and shrub consumed by wildfires in Washington.

Conclusion

In 2020, Washington satisfied the statutory requirement of reducing emissions to the 1990 baseline, however 2021 total emissions slightly exceeded the limit. Nevertheless, the 14.1% reduction in total emissions since 2000, the year of peak emissions, constitutes notable progress. Climate policies implemented since 2021 are likely to result in more rapid emissions reductions, which will be evident in future inventories.

The following trends in this report are notable:

- By the end of 2021, Washington's greenhouse gas emissions had declined 14.1% compared to their peak in 2000.
- In 2020, Washington's total greenhouse gas emissions fell 6% below the 1990 baseline.
- Washington's greenhouse gas emissions rose by 8.8% in 2021, putting the total 2.3% above the 1990 baseline.
- The rise and fall of emissions from 2019 to 2021 was likely driven by the pandemic.
- The transportation sector made up 86% of the post-pandemic emissions increase. Non-highway transportation (aviation, rail, marine) alone accounted for 79% of the post-pandemic rebound from 2020 to 2021.
- Electricity production within Washington's boundaries from fossil fuels shifted from reliance on coal to natural gas. Electricity imported to Washington from the Northwest Power Pool had a higher carbon intensity than electricity produced in Washington.
- Hydropower production dropped by approximately 10% over 20 years, presenting challenges for generating low carbon power in Washington.
- Residential, commercial, and industrial (building) emissions from on-site combustion of fossil fuels shifted from petroleum as the principal source to natural gas.
- Indirect emissions from residential and commercial electricity consumption remained relatively steady since 2000, while indirect emissions from industrial electricity consumption dropped significantly.
- When indirect emissions from electricity consumption are excluded, Agriculture, Industrial Processes, Waste Management, and Fossil Fuel Fugitive Emissions make up 17.3% of total emissions.
- Increasing forest and shrub fires have led to significant emissions in recent years, and to decreasing absorption of carbon by these systems over time.

This inventory relies predominantly on data provided by the US Environmental Protection Agency, which results in a time lag between data reporting to delivery due to quality control processes. Future inventories for Washington will seek data streams to reduce this lag and provide more timely analyses.