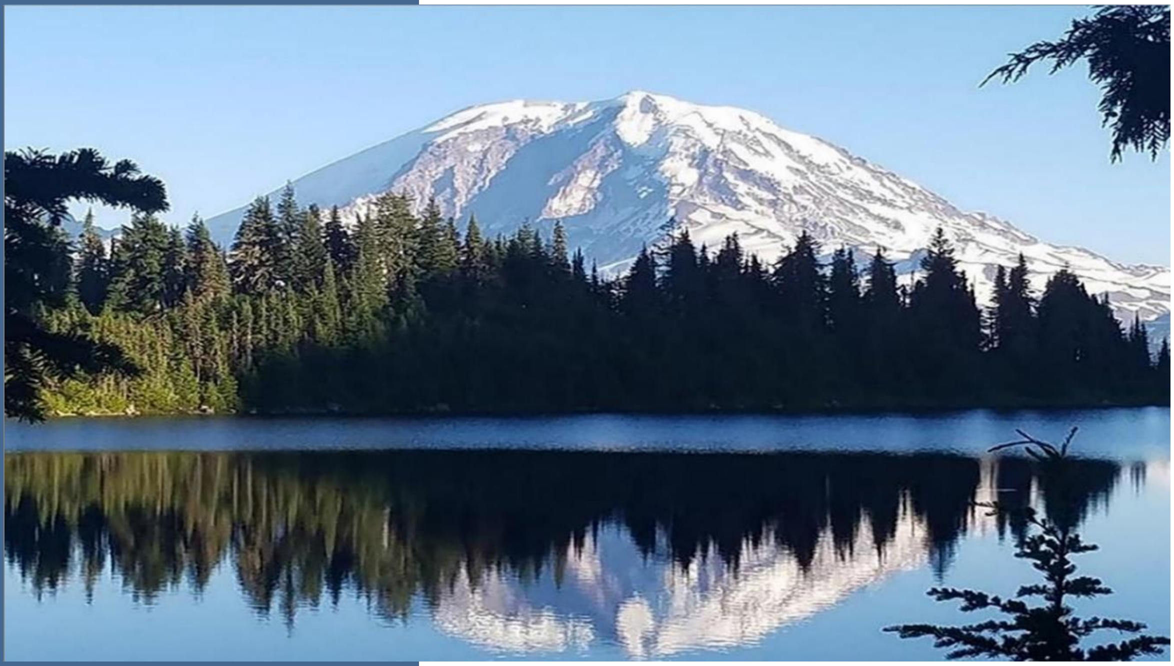

Washington State Greenhouse Gas Emissions Inventory: 1990–2019

Stacey Waterman-Hoey
Air Quality Program

Washington State Department of Ecology

Olympia, Washington

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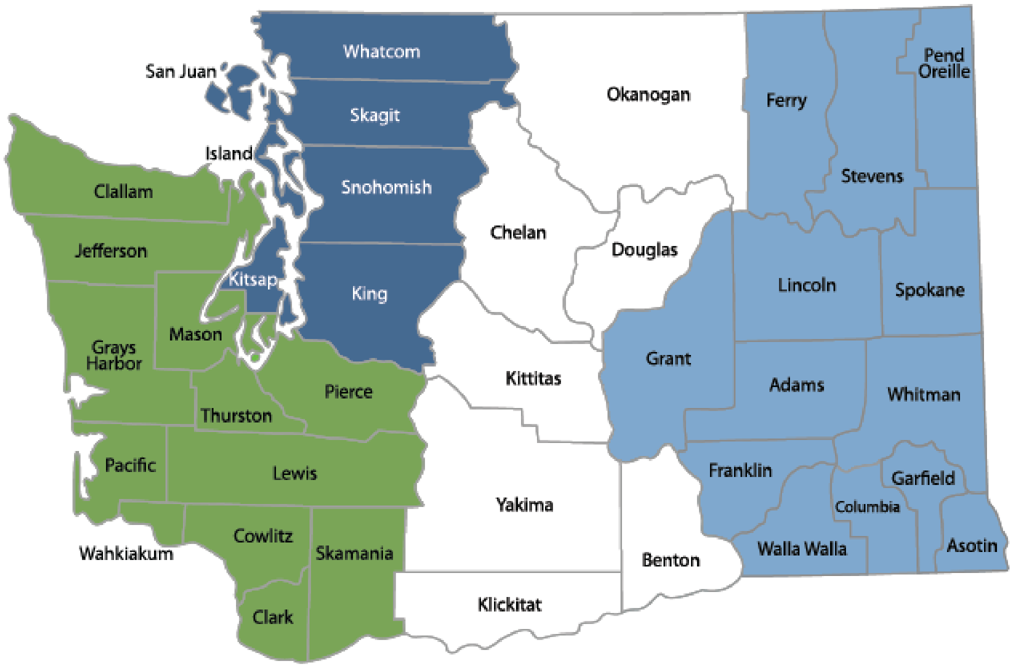
[1] www.ecology.wa.gov

Department of Ecology’s Regional Offices

Map of Counties Served



Southwest Region
360-407-6300

Northwest Region
425-649-7000

Central Region
509-575-2490

Eastern Region
509-329-3400

Region	Counties served	Mailing Address	Phone
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
Central	Benton, Chelan, Douglas, Kittitas, Klickitat, Okanogan, Yakima	1250 W Alder St Union Gap, WA 98903	509-575-2490
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
Headquarters	Across Washington	PO Box 46700 Olympia, WA 98504	360-407-6000

Washington State Greenhouse Gas Emissions Inventory 1990–2019

Report to the Legislature

Stacey Waterman-Hoey
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Washington State Department of Ecology

Olympia, Washington

DEPARTMENT OF
ECOLOGY
State of Washington

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Acknowledgements

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- Annie Smith, Washington State Department of Natural Resources.
- Austin Scharff, Washington State Department of Commerce.

Acronyms and Abbreviations

Acronym	Meaning
CH_4	Methane
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
EPA	U.S. Environmental Protection Agency
Ecology	Washington State Department of Ecology
GHG	Greenhouse Gas
GWP	Global Warming Potentials
HFC	Hydrofluorocarbon
IPCC	Intergovernmental Panel on Climate Change
MMT	Million Metric Tons
MWh	Megawatt hour
N_2O	Nitrous oxide
NCA	National Climate Assessment
NF_3	Nitrogen trifluoride
NWL	Natural and Working Lands Inventory
ODS	Ozone Depleting Substances
PFCs	Perfluorocarbons
RCI	Residential, Commercial and Industrial 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 the 1990 baseline established in law through to 2019, which is the most recent year of available data necessary to create this inventory. The report evaluates Washington's greenhouse gas emissions, shows where the emissions are coming from, and how those emissions are changing over time.

RCW 70A.45.020(2) states:

> *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. The department shall ensure the reporting rules adopted under RCW 70A.15.2200 allow it to develop a comprehensive inventory of emissions of greenhouse gases from all significant sectors of the Washington economy.*

Key findings from this report are that Washington's greenhouse gas emissions rose 6.9 percent from 2018 to 2019, reaching a total of 102.1 million metric tons carbon dioxide equivalent (MMT CO_2e). This was the highest total for the state since 2007. Emissions in 2019 were 8.7 MMT CO_2e (9.3 percent) higher than the 1990 baseline of 93.5 MMT CO_2e.

The greatest contributor to the 2018–2019 emissions increase is the mix of fuels used in the electricity sector. This sector's emissions rose from 16.5 MMT CO_2e in 2018 to 21.9 MMT CO_2e in 2019, an increase of 5.4 MMT CO_2e. The rise is in response to 2019 being a low water year, resulting in reduced hydropower generation and a corresponding increase in fossil fuel generation to meet demand. 2020 data is available for the electricity sector, and it shows that 2020 emissions in this sector fell 35 percent to 14.2 MMT CO_2e. This is 16 percent below the 1990 level (16.9 MMT CO_2e) for this sector.

Washington has made significant progress on two carbon intensity indicators. Relative to 2005, the metric tons of CO_2e per million dollars of economic output (GDP) declined 51 percent and the CO_2e per capita has declined 15 percent.

The transportation sector remained the largest source of emissions in the state at 40.3 MMT CO_2e in 2019. This is 4.8 MMT CO_2e over the 1990 baseline and a 2.8% increase over 2018 emissions for this sector. The transportation sector's share of statewide emissions, however, is reduced from 44.9 percent in 2018 to 39 percent in 2019 as the share from the electricity sector increased.

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, each including many complex and active systems. Each of these pools stores vastly different quantities of carbon, and each exchanges carbon at different rates.

In GHG inventories such as this report, the standard practice is to refer to these exchanges of emission sources and sinks as "carbon fluxes." Carbon fluxes can be positive ("carbon sources," which release more carbon to the atmosphere than they absorb) or negative ("carbon sinks," which absorb more carbon than they release). "Global carbon cycle" is the term for these combined systems of carbon fluxes. Table 1 shows the major global carbon pools and the amount of carbon they each store.[2]

Table 1. Global Carbon Pools, 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 (in various forms, such as carbon dioxide or methane) 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 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 plant life (also called the biosphere). This is measured in much shorter time units from a single year to decades. Left unperturbed, the fast and slow

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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, which is also equal to a petagram (Pg, 10^15 grams)

carbon cycles 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.

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

Because humans put carbon dioxide into the atmosphere more quickly than natural processes can remove it, the amount of carbon dioxide in the atmosphere is increasing. 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]

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 sink into the deep ocean or be absorbed by the land. Over time, the absorption of carbon will slow, and it will take much longer for the remaining half to be absorbed. Only after thousands of years will all of this carbon be absorbed, and at that point our biological systems will have experienced irreversible change.

Methane emitted today lasts about a decade in the atmosphere on average; however, it absorbs much more heat-trapping energy than CO_2.

These changes in the carbon cycle impact planetary functions and life on Earth. The carbon added to the atmosphere from fossil fuel use since 1880 has increased average global temperatures at least 1.1 degrees Celsius (1.9 degrees Fahrenheit), with most of the warming occurring since 1975.[6] These impacts are already severe enough to be experienced worldwide.

Effects of climate change

Increased carbon in the atmosphere and oceans is causing climate-related impacts that are evident across the globe and are well documented in Washington. Climate change impacts are changing the lives and livelihoods of people and the ecosystems that sustain life here. According to the University of Washington’s Climate Impacts Group:

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[4] NASA Earth Observatory, https://www.earthobservatory.nasa.gov/features/CarbonCycle

[5] NOAA https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

[6] NASA https://earthobservatory.nasa.gov/world-of-change/decadaltemp.php

> *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.*
>
> *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.* [7]

These impacts sometimes create feedback loops that result in additional carbon releases to the atmosphere, worsening the effects over time. For example, some of the increased CO_2 in the atmosphere is absorbed by oceans, which increases ocean acidity. This acidity is harming marine life, making it harder for some marine species to absorb carbon, and diminishing the ocean's ability to absorb carbon further.[8] This is keenly observed in Washington's shellfish industries, where the local oyster industry has been combating ocean acidification by adding sodium carbonate into hatchery waters to help support shell formation. This is a temporary solution that will become less effective as ocean acidity increases.

In addition to ocean impacts, altered weather and climate patterns are having visible impacts on forests and exacerbating conditions for forest fires, which release additional carbon into the atmosphere and harm human health.[9] The list of climate impacts in Washington continues to grow and includes increased flooding, sea level rise, erosion, impacts on water supply, forest health, fish and wildlife, human health, and the economy.

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[7] UW Climate Impacts Group https://cig.uw.edu/our-work/people-society/

[8] https://ecology.wa.gov/Air-Climate/Climate-change/Climate-change-the-environment/Ocean-acidification

[9] UW Climate Impacts Group, https://cig.uw.edu/our-work/forests-fire/

The Inventory in Context

Washington's annual statewide greenhouse gas (GHG) emissions inventory is an important tool for establishing historical emission trends and tracking Washington's progress in reducing GHGs. The complete inventory is shown in Table 4 of this report. The data presents estimates of anthropogenic (human-caused) sources occurring within Washington, as well as emissions associated with electricity consumed in the state, regardless of where the electricity was produced. An inventory of ecosystem carbon sources and removals is reported in this document in Appendix A. Ecosystem Carbon in Natural and Working Lands (NWL).[10] NWL are reported separately from anthropogenic emissions because the data available for this report has a relatively high level of uncertainty, and NWL are part of the biogenic carbon cycle which operates on vastly shorter time scales from fossil carbon sources.

This report follows methodology established in guidelines published by the Intergovernmental Panel on Climate Change (IPCC). This methodology defines a GHG 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 and biogenic sources.[11]

The inventory is the historical record of Washington's contribution to global climate change. It is the measure of our progress toward reducing greenhouse gas emissions and meeting statewide emission limits and uses 1990 as the base year.

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 GHGs that humans generate, carbon dioxide is the most significant, but other gases contribute to climate change as well.[12] These gases differ from each other in both their ability to absorb energy and how long they remain in the atmosphere. Table 2 lists the greenhouse gases that contribute the most to human-caused climate change.

Global warming potentials (GWPs) are a measure that allows comparison of the warming impacts of different gases. A GWP is a measure of 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 CO_2. Application of a GWP to a gas provides a conversion to normalized units of "carbon dioxide equivalent," or CO_2e. The emissions inventory shows greenhouse gases in millions of metric tons (MMT) of carbon dioxide

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[10] Sometimes also called the Land-use, Land-Use Change and Forestry (LULUCF) sector.

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

[12] Water vapor is the most abundant GHG. Anthropogenic carbon emissions from fossil fuels are warming the atmosphere causing an increase in water vapor. Increased water vapor is a consequence of global warming rather than a cause of global warming.

equivalent (CO_2e) unless otherwise specified. Using carbon dioxide equivalent as a measurement allows us to capture the cumulative impacts of all greenhouse gases in a single number.

Table 2. Global warming potential factors for greenhouse gases[13]

Greenhouse Gas	100-year Global Warming Potential
Carbon dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous oxide (N_2O)	298
Hydrofluorocarbons (HFCs)	124–14,800
Perfluorocarbons (PFCs)	7,390–12,200
Nitrogen trifluoride (NF_3)	17,200
Sulfur hexafluoride (SF_6)	22,800

Greenhouse gas emission sources

Greenhouse gases are released from a wide variety of anthropogenic (made by humans) sources, which the IPCC categorizes as follows:

- *Stationary combustion*, which occurs at places that use equipment to produce electricity, steam, heat, or power (such as boilers or generators).
- *Mobile combustion*, which occurs when fuel is burned for transportation (such as in cars, trucks, ships, trains, and planes).
- *Industrial processes*, such as manufacturing cement, aluminum, ammonia, and other products where the process itself generates greenhouse gases.
- *Fugitive releases,* or unintentional releases from the production, processing, transmission, storage, or use of fuels and other substances that do not pass through a stack, chimney, vent, or exhaust pipe (such as the unintentional release of sulfur hexafluoride from electrical equipment, natural gas pipeline leakage, or emissions of nitrous oxide from fertilizers).

Greenhouse gas emission sectors

The GHG emission inventory is organized into the following internationally defined sectors:

- Energy

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[13] IPCC Fourth Assessment Report, 100-year time horizon. This data will be reviewed and updated as needed.

- Industrial processes
- Agriculture
- Waste

This report includes additional analyses on the following sectors:

- Electric power
- Transportation
- Building
- Industrial

Other emissions not included in the inventory are discussed in the Other Emissions section which includes international bunker fuels and ozone depleting substances.

Emission limits

Washington established statutory[14] GHG emission limits based on a review of scientific evidence of what is needed to avoid the worst impacts of climate change. Table 3 shows these limits, plus the statute's requirement to achieve net-zero greenhouse gas emissions by 2050.[15]

Table 3. Washington GHG emission limits

Year	2020 GHG Emission Limits
2020	Reduce to 1990 levels
2030	45% below 1990
2040	70% below 1990
2050	95% below 1990 and achieve net-zero emissions

Net-zero emissions are achieved when anthropogenic greenhouse gases to the atmosphere are balanced by anthropogenic removals over a specified period.[16]

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[14] https://apps.leg.wa.gov/rcw/default.aspx?cite=70A.45.020

[15] 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 2023. https://apps.ecology.wa.gov/publications/documents/1902031.pdf

[16] 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

RCW 70A.45.020(2) states that the inventory report shall include "emissions associated with leaked gas identified by the utilities and transportation commission." The Washington Utilities and Transportation Commission (UTC) began reporting leakage data for natural gas local distribution lines in 2020. The UTC data will be included in future publications of the inventory. Leakage data covering the natural gas transmission and storage system is not reported by the UTC.

Additionally, RCW 70A.45.020(2) states that the inventory report "must include greenhouse gas emissions from wildfires, developed in consultation with the department of natural resources." Estimated consistently with international carbon accounting guidelines, forest carbon emission sources and sinks are reported in Appendix A – Ecosystem Carbon in Natural and Working Lands. Trees are part of the biosphere; they capture carbon as they grow and emit carbon when they decay or burn.

Emissions from wood biomass, ethanol, and biodiesel consumption are also not included in the anthropogenic inventory. In line with 2006 IPCC Guidelines, biogenic carbon emissions are accounted for in the carbon flux of the natural and working lands where the land-use change occurred, not where the emissions occurred.[17]

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.[18] EPA reviews and updates this greenhouse gas emissions accounting tool annually and aligns it with data sources and methodologies used to develop the U.S. National Emissions Inventory.[19] Even when more accurate and current data is available for an individual state, the SIT is required to use data that is available consistently for all states. At this time, the most current data available from the SIT is through 2019.

Standard emissions accounting guidelines use production-based emissions, which are emissions occurring within state boundaries. There are several other ways to report emissions, all of which are useful for different purposes, and those are discussed further in Appendix B of this report. Washington's official inventory results shown in Table 4 depart from the production-based approach in one area, which is to report emissions associated with electricity *consumed* in our state in place of emissions associated with electricity *produced* in our state.

To make this substitution, in-state electric power generation emissions are replaced with Fuel Mix Disclosure program data provided by the Washington State Department of Commerce.[20]

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

[18] EPA State Inventory Tool: https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool

[19] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020, U.S. EPA, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2020

[20] https://www.commerce.wa.gov/growing-the-economy/energy/fuel-mix-disclosure/

This program requires each electric utility in Washington to report on the source of different fuels used to generate the electricity sold to Washington consumers. The department then uses this information to determine an aggregated fuel mix for the entire state and the CO_2 emissions associated with that electricity. Showing our consumption-based electricity emissions highlights the extent to which we rely on out-of-state fossil fuel-based generation and the extent to which power plants located in Washington are operated to provide electricity to other states. This approach is consistent with prior reports of state emissions. Data on in-state emissions associated with electricity production is provided in the Sector Analysis section.

Because the science underpinning GHG inventories is continually evolving, methodologies change over time, and this can affect inventory results. When methodologies change, we document those changes in detail and apply them to the entire data time series, if possible, to maintain consistency. This means that in future years, the numbers in this report may change because of methodology improvements.

Consultation with Department of Commerce

Ecology consulted with staff from the Washington State Department of Commerce to obtain the Fuel Mix Disclosure program data noted above and to ensure the accuracy of our calculations based on that program data.

Consultation with Department of Natural Resources

Ecology consulted with staff from the Washington State Department of Natural Resources to obtain the GHG emissions data from wildfires included in the Natural and Working Lands section of the inventory.

Inventory Results

The 2019 Washington State Greenhouse Gas Inventory results are shown in Table 4. Statewide total emissions were 102.1 MMT CO_2e, an increase of 6.9 percent over 2018 levels. This is 9.3 percent over the 1990 baseline, which is also the 2020 limit. The transportation sector represents the largest contributor, accounting for 39 percent of statewide emissions. The increase in total emissions from 2018 to 2019 was largely due to emissions associated with electricity consumption. Electricity sector emissions are the most volatile as they closely correlate to weather conditions—lower snowpack and extreme temperatures can result in reduced hydropower, and a corresponding increase in fossil fuel-based generation to meet demand.

Because the data for emissions from electricity consumption comes from a different source with a shorter lag time than the rest of the inventory, 2020 data for this sector is currently available. The 2020 electricity data shows emissions fell from 21.9 MMT CO_2e in 2019 to 14.2 MMT CO_2e. This is 16 percent below the 1990 level for this sector of 16.9 MMT CO_2e. Additional analysis of the electricity sector follows in the Sector Analysis section.

The combined residential, commercial, and industrial (RCI) sector emissions are from the energy used only for on-site fuel combustion, such as in furnaces, stoves, or to heat water. The electricity consumed by these sectors is counted separately in the electricity sector.

Table 4. Washington total annual GHG emissions (in MMT CO_2e)

Sector	1990	2000	2010	2015	2016	2017	2018	2019	2020
Electricity, net consumption-based	**16.9**	**23.3**	**20.9**	**19.2**	**17.1**	**16.9**	**16.5**	**21.9**	**14.2**
Coal	16.8	17.4	15.8	14.0	12.5	12.4	11.7	15.2	9.0
Natural gas	0.1	5.3	4.8	4.9	4.3	4.1	4.5	6.2	4.9
Petroleum	0.0	0.6	0.1	0.1	0.1	0.1	0.0	0.0	0.1
Biomass and waste (CH_4 and N_2O)	0.0	0.0	0.1	0.2	0.3	0.3	0.3	0.4	0.2
Residential, Commercial, and Industrial (RCI)	**25.3**	**28.9**	**23.5**	**23.8**	**24.3**	**25.0**	**24.8**	**25.3**	
Coal	0.6	0.3	0.3	0.2	0.2	0.1	0.1	0.1	
Natural gas	8.6	11.4	10.8	11.2	11.8	13.2	12.5	13.2	
Oil	16.1	17.3	12.4	12.5	12.3	11.6	12.1	12.0	
Wood (CH_4 and N_2O)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Transportation	**35.5**	**41.9**	**35.2**	**36.5**	**38.9**	**38.6**	**39.2**	**40.3**	

Sector	1990	2000	2010	2015	2016	2017	2018	2019	2020
Gasoline (Hwy)	15.6	19.8	16.1	15.5	15.3	16.1	17.0	16.9	
Non-Highway	16.6	16.7	11.8	14.1	17.7	16.4	15.4	16.7	
Diesel (Hwy)	3.4	5.4	7.3	6.9	5.9	6.2	6.9	6.6	
Alternative Fuel Vehicles	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	
Fossil fuel industry	**0.8**	**0.8**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**	
Natural gas industry (CH_4)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	
Coal mining (CH_4)	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
Oil industry (CH_4)	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
Industrial processes	**4.9**	**6.5**	**4.7**	**5.0**	**5.0**	**5.0**	**5.1**	**5.3**	
Carbon Dioxide Emissions	*2.2*	*3.3*	*1.4*	*1.3*	*1.2*	*1.1*	*1.2*	*1.3*	
Cement Manufacture	0.0	0.4	0.3	0.3	0.4	0.4	0.4	0.4	
Lime Manufacture	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.1	
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	0.0	0.0	0.0	0.0	0.0	0.0	
Aluminum Production, CO_2	2.0	1.7	0.5	0.4	0.2	0.2	0.2	0.3	
Iron & 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	0.2	0.1	0.1	0.2	0.2	
Urea Consumption	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Nitrous Oxide Emissions	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	
Nitric Acid Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Adipic Acid Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
HFC, PFC, NF_3, and SF_6 Emissions	*2.7*	*3.2*	*3.3*	*3.7*	*3.8*	*3.9*	*3.9*	*4.0*	
ODS Substitutes	0.0	1.1	2.3	2.9	2.9	3.0	3.0	3.2	
Semiconductor Manufacturing	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
Magnesium Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Sector	1990	2000	2010	2015	2016	2017	2018	2019	2020
Electric Power Transmission and Distribution Systems	0.8	0.4	0.1	0.1	0.1	0.1	0.1	0.1	
HCFC-22 Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Aluminum Production, PFCs	1.9	1.7	0.8	0.7	0.7	0.7	0.7	0.7	
Waste management	**3.1**	**2.9**	**3.5**	**2.4**	**2.4**	**2.5**	**2.4**	**2.4**	
Solid waste management	2.6	2.2	2.7	1.6	1.6	1.6	1.5	1.6	
Wastewater management	0.6	0.7	0.8	0.8	0.8	0.8	0.9	0.9	
Agriculture	**6.9**	**6.7**	**6.5**	**7.0**	**6.8**	**6.7**	**6.8**	**6.2**	
Enteric fermentation	2.7	2.7	2.4	2.6	2.6	2.6	2.7	2.7	
Manure management	0.9	1.2	1.3	1.5	1.5	1.5	1.5	1.5	
Agriculture soils	3.3	2.8	2.9	2.9	2.6	2.6	2.7	2.1	
Total gross emissions	**93.5**	**111.0**	**95.0**	**94.6**	**95.1**	**95.3**	**95.5**	**102.1**	

*Ozone Depleting Substance

Figure 1 shows Washington’s anthropogenic GHG emissions by inventory sector for 1990 through 2019.

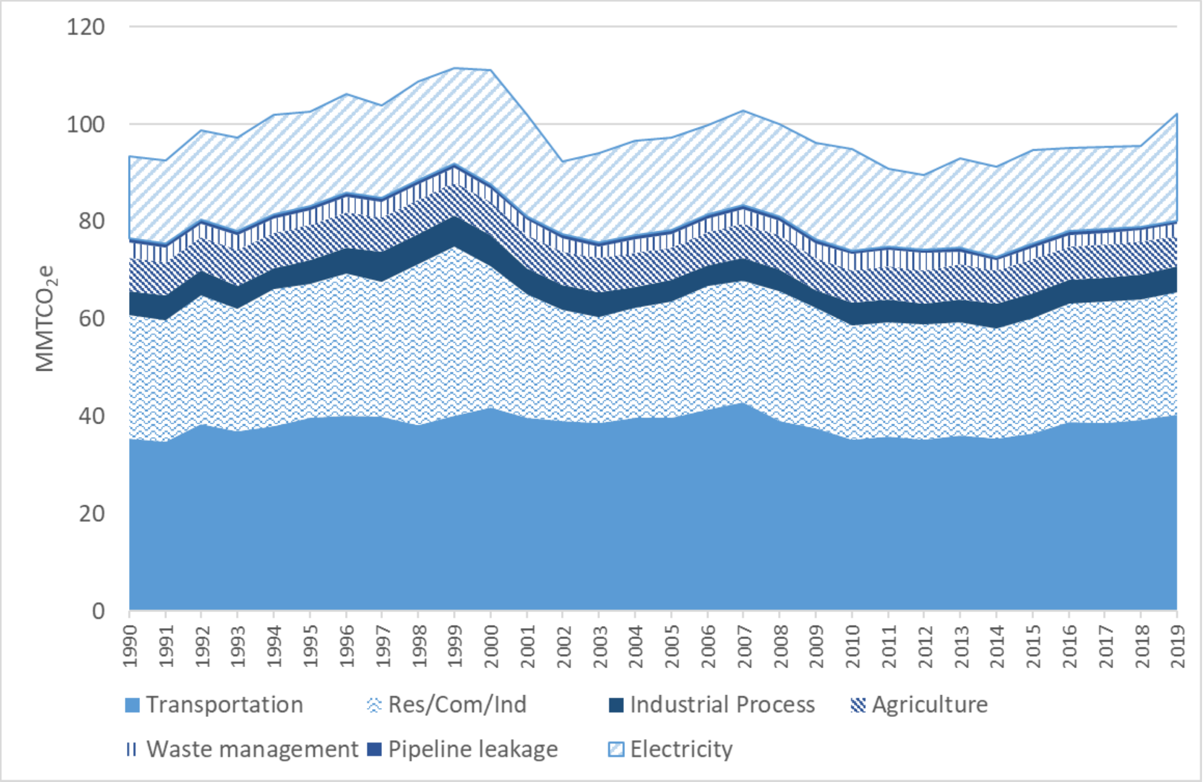

Figure 1. Washington’s total GHG emissions 1990-2019 in MMT CO_2e

Carbon Intensity Indicators

Washington has made significant progress on two carbon intensity indicators. Between 2005 and 2019, the state's population increased 20 percent and gross domestic product (GDP) increased 57 percent. Over this time, total CO_2e has remained relatively close to 2005 levels, though it increased by 4.9 percent in 2019.[21] In 2019, the CO_2e per capita was 13.5 MT, a 15 percent decrease relative to 2005. The CO_2e per GDP was 47.9 MT in 2019, 51 percent below 2005 levels.

Although the inventory does not provide the reasons for these changes specifically, there are several likely contributing factors. For example, since 2005, Washington has seen significant growth in economic activity from knowledge-based industries. The growth in the tech sector has been less energy-intensive than other vital economic sectors, such as manufacturing and agriculture, while still contributing to economic growth (GDP). Washington has also been a leader in adopting building and transportation sector energy efficiency measures. Decades of policies supporting renewable energy and energy efficiency adopted prior to 2019 have helped flatten the curve of energy use and emissions.

Figure 2 shows the changes in state GDP, population, and emissions from 2005 to 2019. 2019 appears to be an anomalous year for the electric power sector, as discussed in the following Sector Analysis section.

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[21] Population data from Washington Office of Financial Management. GDP data from U.S. Bureau of Economic Analysis.

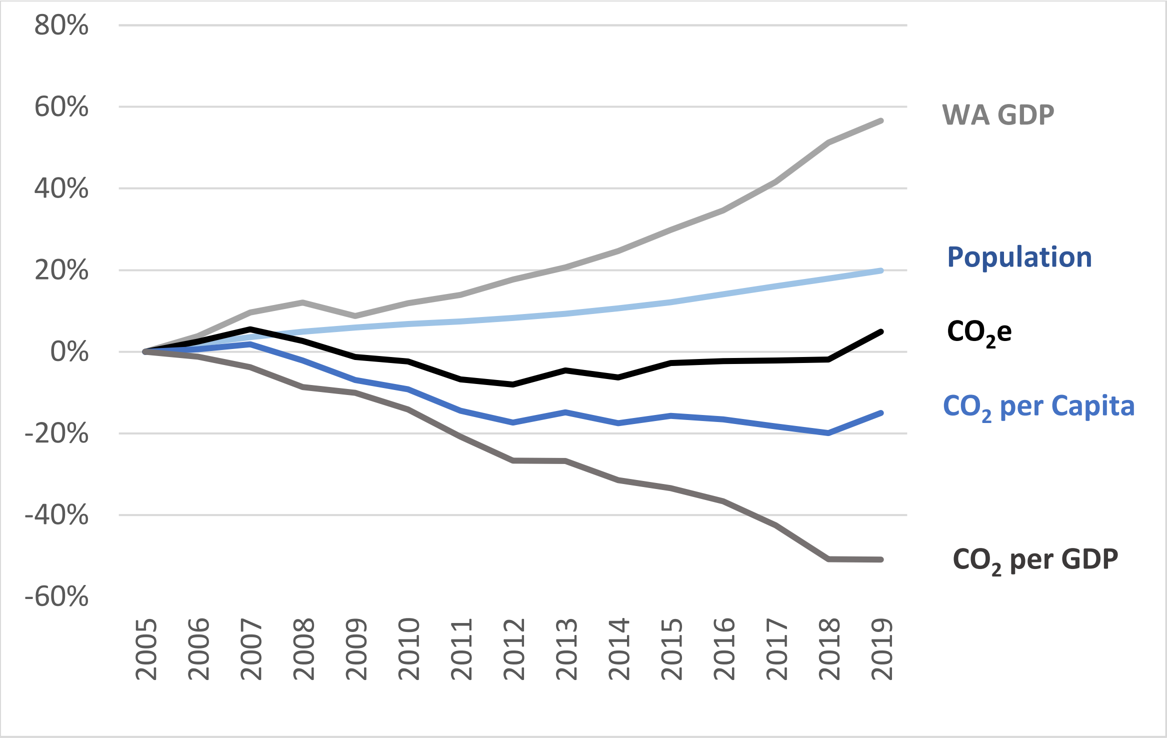

Figure 2. Change in Washington GDP, Population, and GHG Emissions Since 2005

Sector Analysis

The following sections provide overviews of trends in Washington's GHG emissions.

Electricity sector

The statewide inventory results in Table 4 include consumption-based electricity sector emissions. Consumption-based emissions are associated with electricity sold to consumers in Washington, even if the electricity was produced outside Washington's borders. For example, electric utilities serve Washington customers using electricity from the Colstrip coal-fired plant in Montana and the Jim Bridger coal-fired plant in Wyoming[22].

Electricity consumption in 2019 accounted for nearly 21 percent of statewide total GHG emissions. This is a 33 percent increase over 2018 and a 29 percent increase over 1990 for this sector. Electricity sector data is available through 2020 and it shows that emissions then dropped 35 percent to 16 percent below the 1990 emissions for the electricity sector. The 2019 increase was in response to reduced river flow and hydropower generation combined with an increase in demand due to extreme weather. The higher demand was met with more carbon intensive resources such as coal and natural gas. The decline in 2020 is a result of improved hydropower conditions, milder weather, and a decline in demand in response to the COVID-19 pandemic, which substantially affected the global economy and energy use.

Figure 3 shows consumption-based electricity sector emissions by fuel source. In 2019, coal was the largest share, representing 15.2 MMT CO_2e. This equals 70 percent of electricity sector emissions and 15 percent of total statewide emissions. Natural gas was 6.2 MMT CO_2e, or 28 percent of electricity sector emissions and 6 percent of the statewide total emissions. In 2020, the share of electricity sector emissions from coal dropped to 63 percent and natural gas increased to 34 percent.

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[22] https://www.commerce.wa.gov/wp-content/uploads/2021/03/FMD-Report-2019-FINAL.pdf

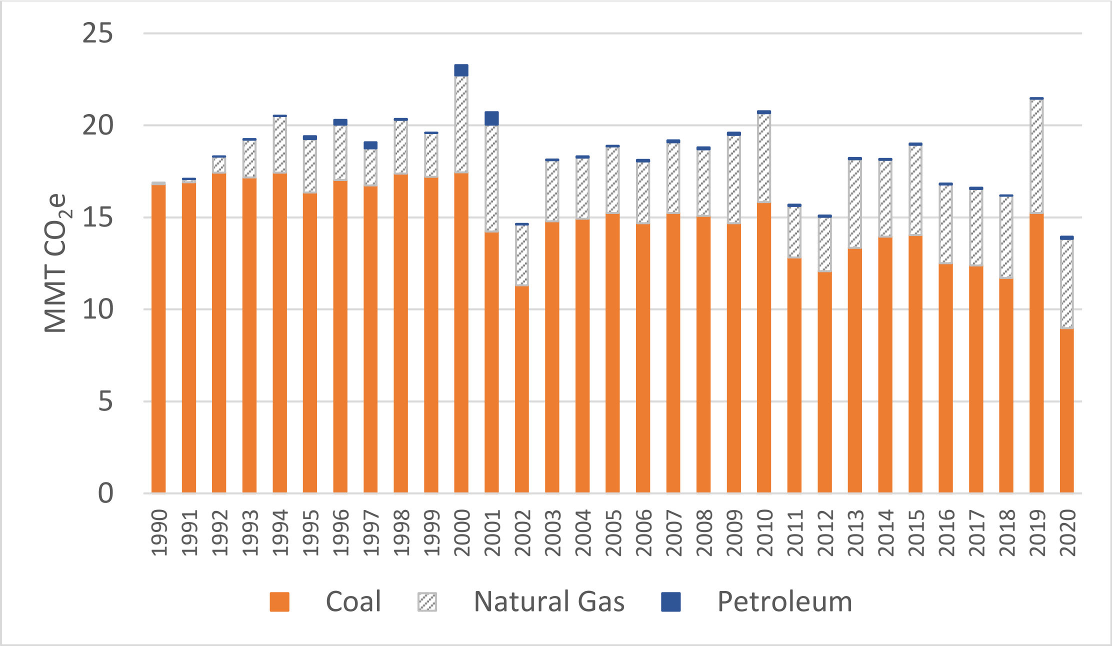

Figure 3. Electricity sector emissions by fuel source, 1990–2020 (consumption basis)

Figure 4 shows consumption-based electricity sector emissions compared to emissions from in-state production of electricity.[23] As Washington is part of an interconnected grid linking us to other western states, some of the electricity generated in-state is consumed here, but some is exported out of state. Washington is a net-exporter of electricity but is still reliant on electricity that flows back and forth from other states.

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[23] Data for in-state electric power generation is available through other sources, but the State Inventory Tool is only current through 2019

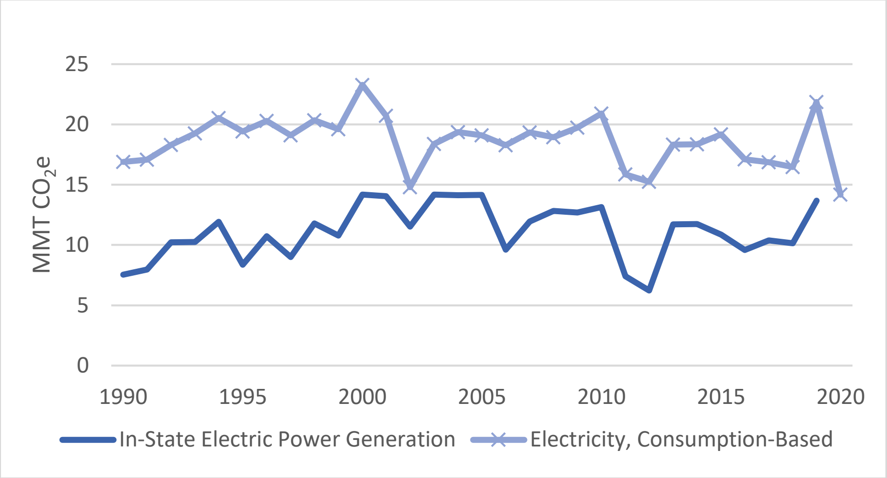

Figure 4. Electric power sector emissions: in-state production vs. consumption, 1990–2020

Table 5 shows the emissions associated with in-state electric power generation. The consumption-based emissions previously shown in Table 4 include emissions from all electricity consumed in Washington, which includes some in-state generation and some out-of-state generation sold to consumers in Washington. Table 4 does not report emissions from electricity generated in-state and sold to consumers out of state. Table 5 shows emissions only from in-state power generators. (Source: SIT)

Table 5. Emissions from in-state electric power generation by source and gas

Gas	1990	2000	2010	2015	2016	2017	2018	2019
CO_2 (MMT)								
Coal	7.5	9.8	8.8	5.4	4.9	5.8	5.7	7.6
Petroleum	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas	0.0	4.0	4.3	5.5	4.7	4.6	4.4	6.1
N_2O (MMT CO_2e)	**0.04**	**0.05**	**0.05**	**0.03**	**0.03**	**0.03**	**0.03**	**0.04**
CH_4 (MMT CO_2e)	**0.00**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
Total (MMT CO_2e)	**7.6**	**14.2**	**13.2**	**10.9**	**9.6**	**10.4**	**10.2**	**13.7**

Figure 5 shows electricity sector emissions allocated to end-use sectors in Washington from 1990–2020. This figure incorporates 2020 data for electricity sales to end-use sectors.[24] While volatile energy prices during 2001–2002 resulted in a reduction in electricity use across all

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[24] U.S. Dept of Energy Energy Information Administration, Electric Sales and Revenue Report https://www.eia.gov/electricity/sales_revenue_price/

sectors, the subsequent closure of many of the region's aluminum smelters also caused a dramatic decline in emissions from the industrial sector. Global economic closures following the COVID-19 pandemic caused a steep decline across all three of these end use sectors in 2020.

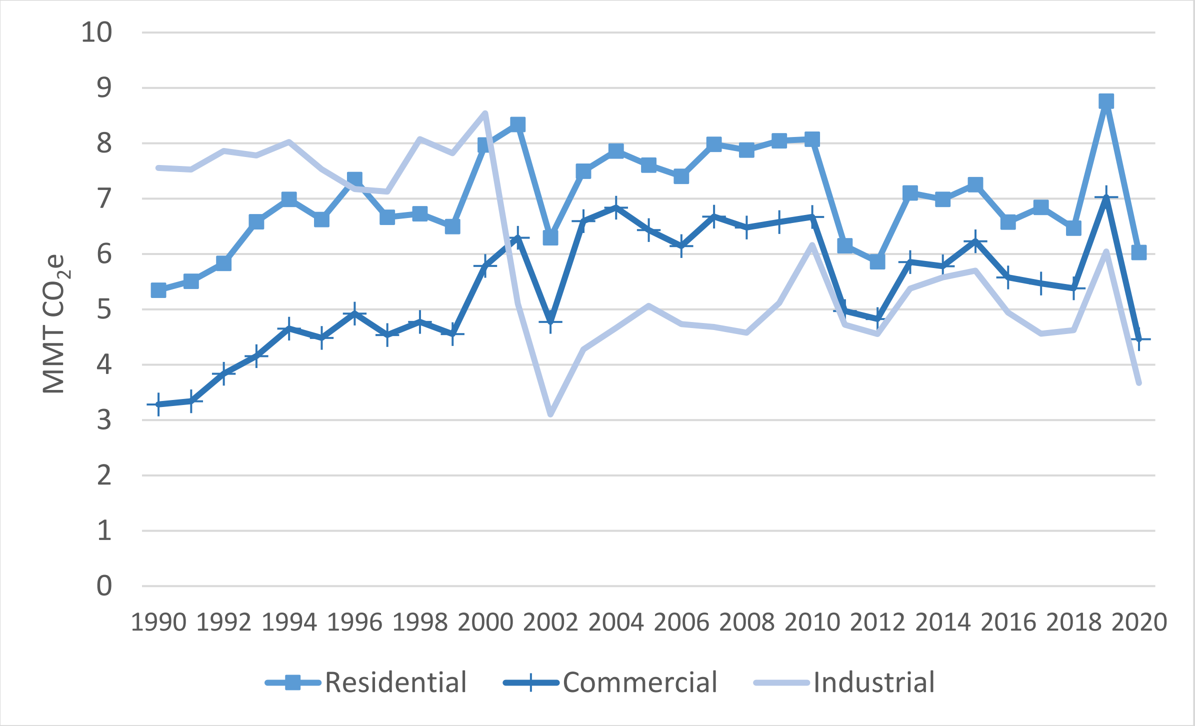

Figure 5. Electricity-sector emissions allocated to end-use sectors, 1990–2020

Figure 6 and Figure 7 show emissions for the electricity sector from different perspectives. In Figure 6, electricity generation is shown as a separate sector. In this view, the residential and commercial sector emissions only include space heating, cooking, and other direct combustion of fossil fuels. The industrial sector includes direct combustion of fuels (primarily for energy use) as well as emissions resulting from chemical processes.

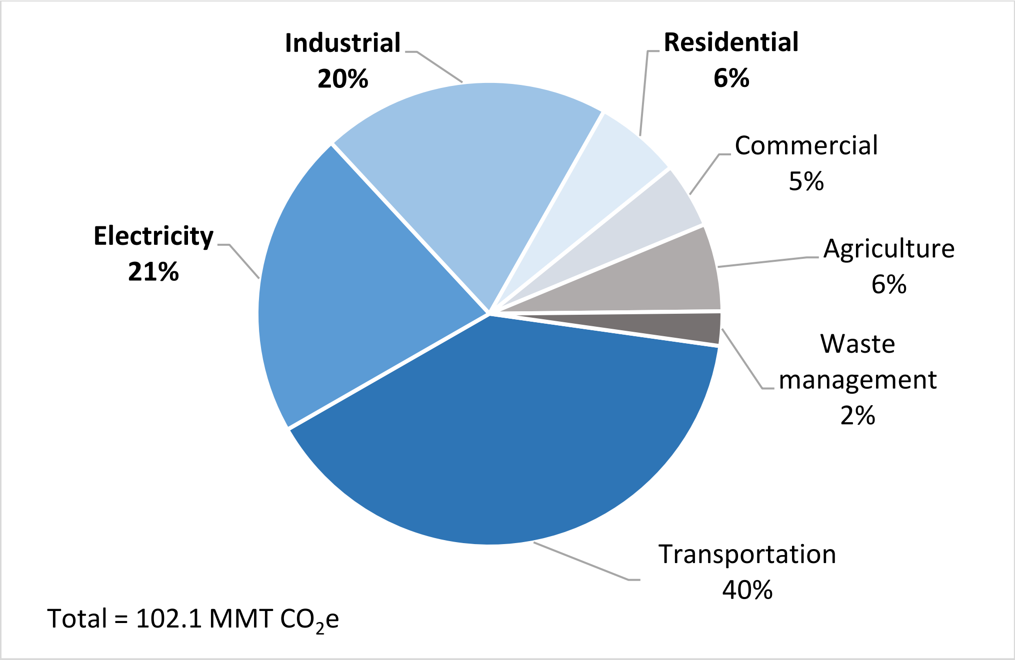

Figure 6. 2019 Emissions by sector, with electricity sector (%)

In contrast, Figure 7 shows the emissions from electricity use as assigned to the end-use sector where the electricity was ultimately consumed. In this view, electricity used for heating, lighting, air conditioning, and industrial processes are combined with the direct use of fossil fuels by each sector.

When electricity sector emissions are assigned to sectors based on their consumption of electricity, the residential sector's emissions rise from 6 percent of statewide emissions to 15 percent, the commercial sector rises from 5 percent to 11 percent, and the industrial sector rises from 20 percent to 26 percent.

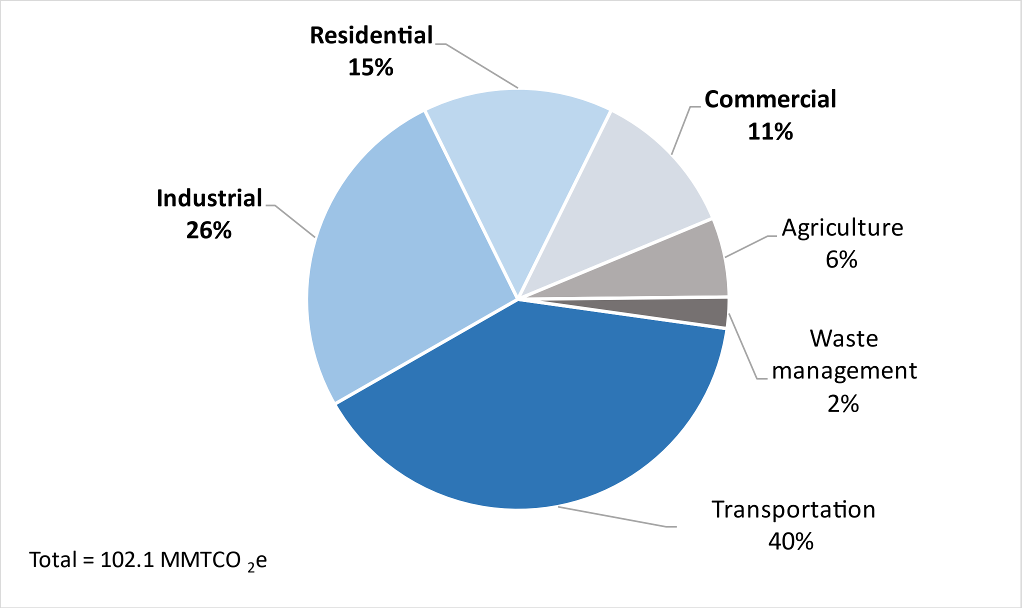

Figure 7. 2019 Emissions by sector with electricity allocated to end-use sector (%)

The influence of weather on electricity supply and demand is the most significant driver of fluctuation in statewide total emissions. Severe weather that causes extreme high or low temperatures causes electricity demand to increase. Utilities may satisfy this demand using generation from fossil fuel-fired power plants. Separately, the amount of water available for hydropower generation varies significantly from year to year, and this variation may result in increased generation from fossil fuel-fired power plants. Figure 8 shows the inverse relationship of hydropower generation, in megawatt hours (MWh, hatched line, right axis) and electricity sector emissions (MMT CO_2e, solid line, left axis).

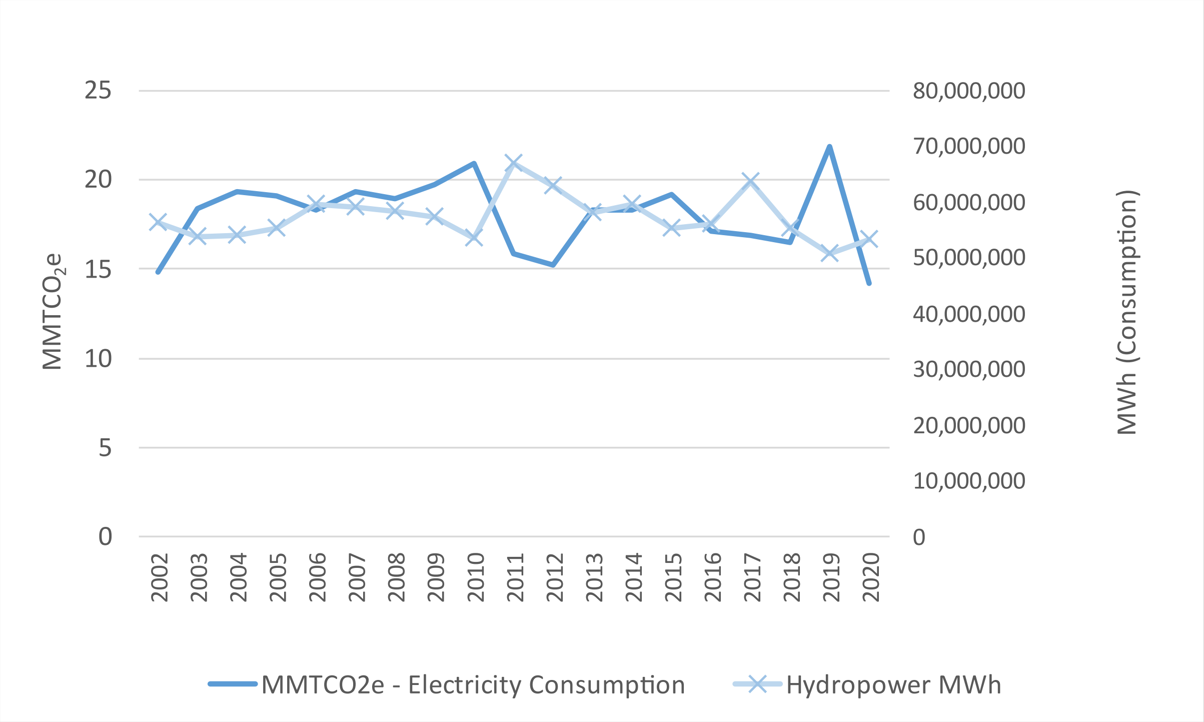

Figure 8. Electricity sector GHG emissions and hydropower generation (consumption basis), 2002–2020

Transportation sector

This section uses vehicle miles traveled (VMT) data to apportion total transportation sector emissions to different end uses and vehicle types and to estimate a more granular view of transportation emissions.[25]

The transportation sector represented 40.3 MMT CO_2e (39.5 percent) of statewide emissions in 2019. This sector represents the largest share of emissions in the state. Emissions in 2019 were 4 percent higher than the prior three-year average and 14 percent above the 1990 total of 35.5 MMT CO_2e. Figure 9 shows transportation sector emissions since 1990. It also shows the respective shares attributed to the highway use of gasoline, highway use of diesel, and non-highway use of both. Non-highway emissions are from fuels (primarily diesel) consumed by aviation, boats and ships, trains, and agricultural and construction equipment.

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[25] EPA's SIT modules provide aggregated transportation sector CO_2 emissions based on U.S. Dept. of Energy direct measurements of fuel consumption data. A different data source based on vehicle-miles-traveled (VMT) is used to derive an estimate for transportation sector CH_4 and N_2O. The VMT data, while more statistically uncertain, allow us to paint a more detailed picture of the transportation sector.

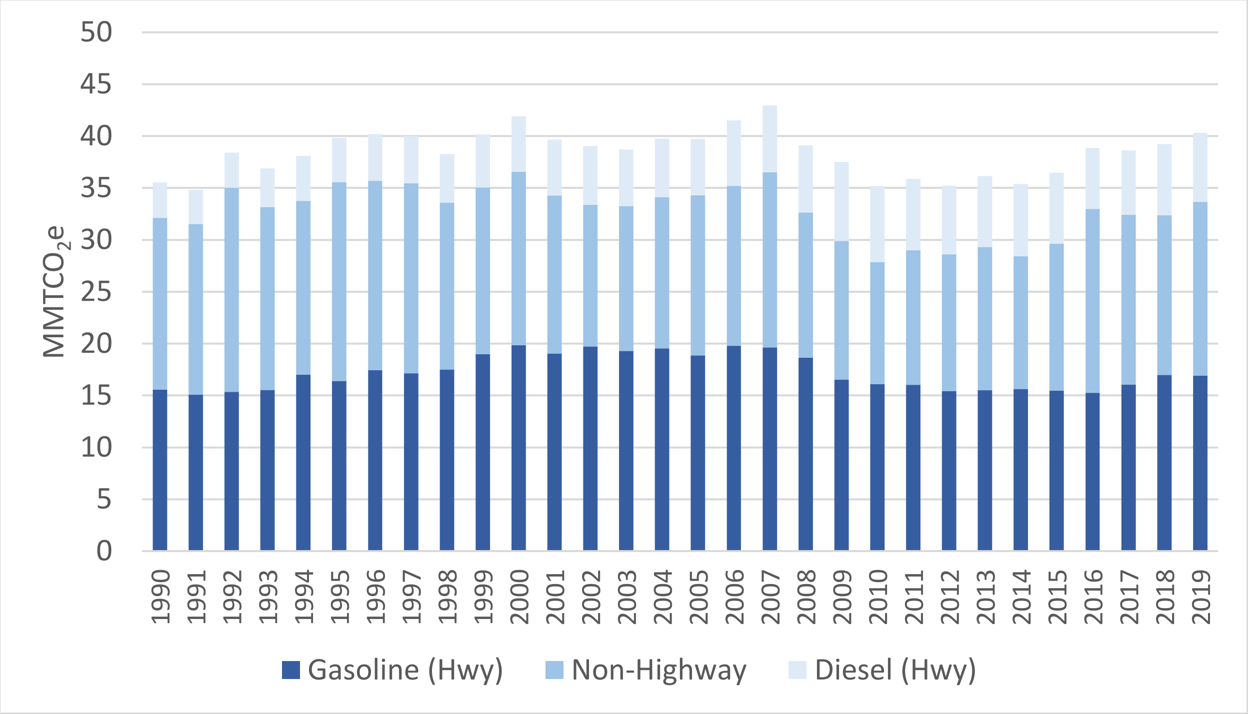


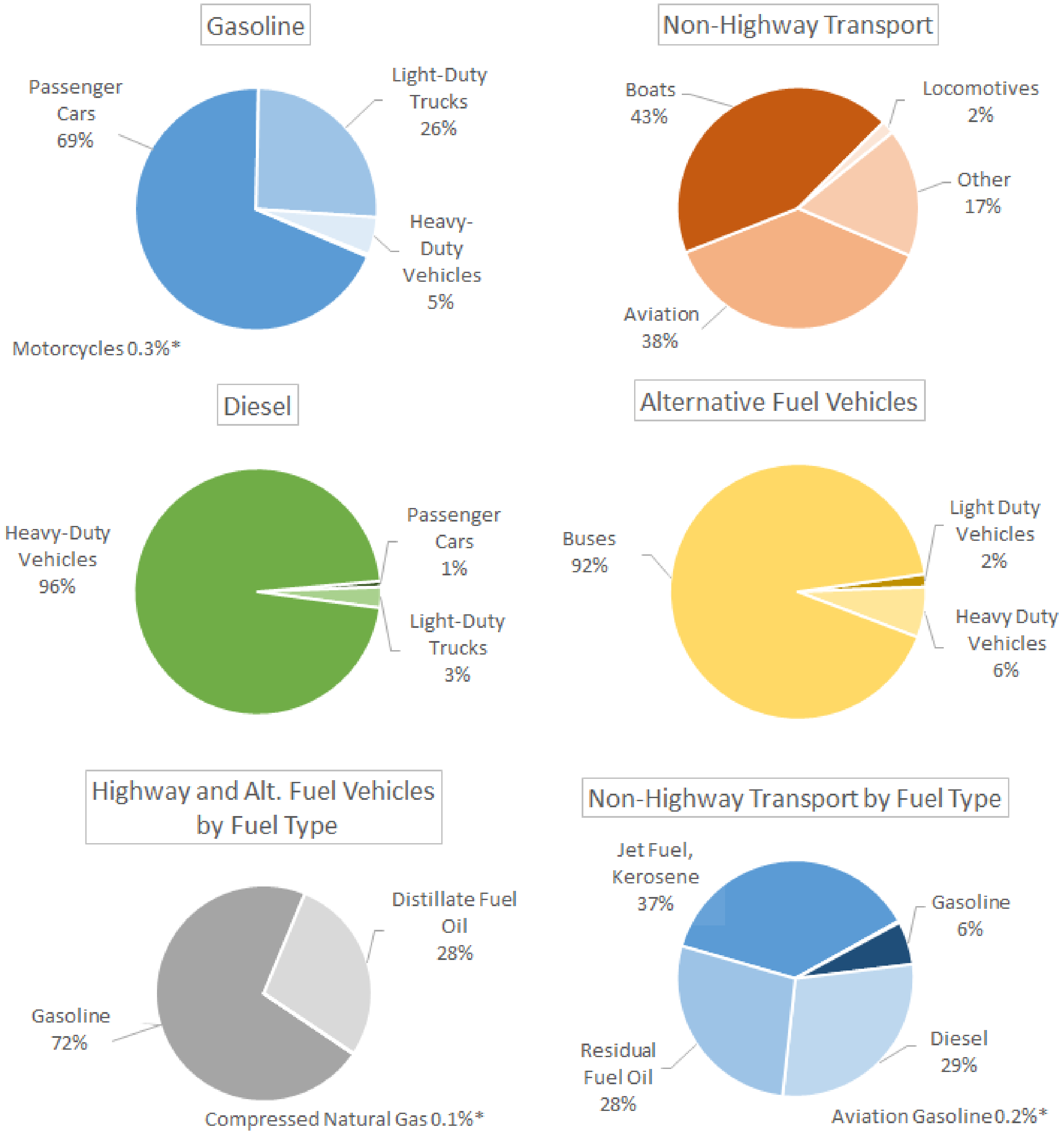
Figure 9. Transportation sector emissions by fuel type, 1990–2019

Emissions from gasoline increased from 15.6 MMT CO_2e in 1990 to 16.9 MMT in 2019, an increase of 1.4 MMT CO_2e (9 percent) over this time. Though a smaller share, highway diesel emissions have nearly doubled since 1990, increasing from 3.4 MMT CO_2e in 1990 to 6.6 MMT CO_2e in 2019. In 2019, gasoline-powered transportation made up 17 percent of the statewide total emissions, and diesel-powered highway transportation made up 7 percent of statewide emissions. Table 6 highlights the 2019 data shown above in Figure 9.

Table 6. 2019 Transportation sector emissions

	MMTCO₂e
Highway use of gasoline	16.9
Highway use of diesel	6.6
Non-highway use of both fuels for transportation	16.7
Alternative Fuel Vehicles	.02

In Figure 10, the data from Table 6 is allocated to various vehicle types based on vehicle-miles-traveled (VMT) data provided by the SIT. Figure 10 provides an estimate to compare the types of vehicles and fuels generating these emissions, but the actual quantities of these emissions are not estimated (so as to avoid implying certainty to these generalized estimates). These figures do reveal that passenger cars are the primary driver of emissions within the large category of gasoline use. Heavy-duty trucks are responsible for nearly all diesel emissions.



* Quantities too small to show in figure

Figure 10. 2019 Transportation sector emissions by fuel and vehicle type

Figure 11 shows a steady rise in highway vehicle miles traveled (VMT, right axis, dark blue line) and more variable, but slower-growing, emissions associated with highway driving (MTCO$_2$e, left axis, light blue line). The emissions data is available through 2019 but the VMT is available through 2020, showing a steep decline in driving during the first year of the COVID-19 pandemic.

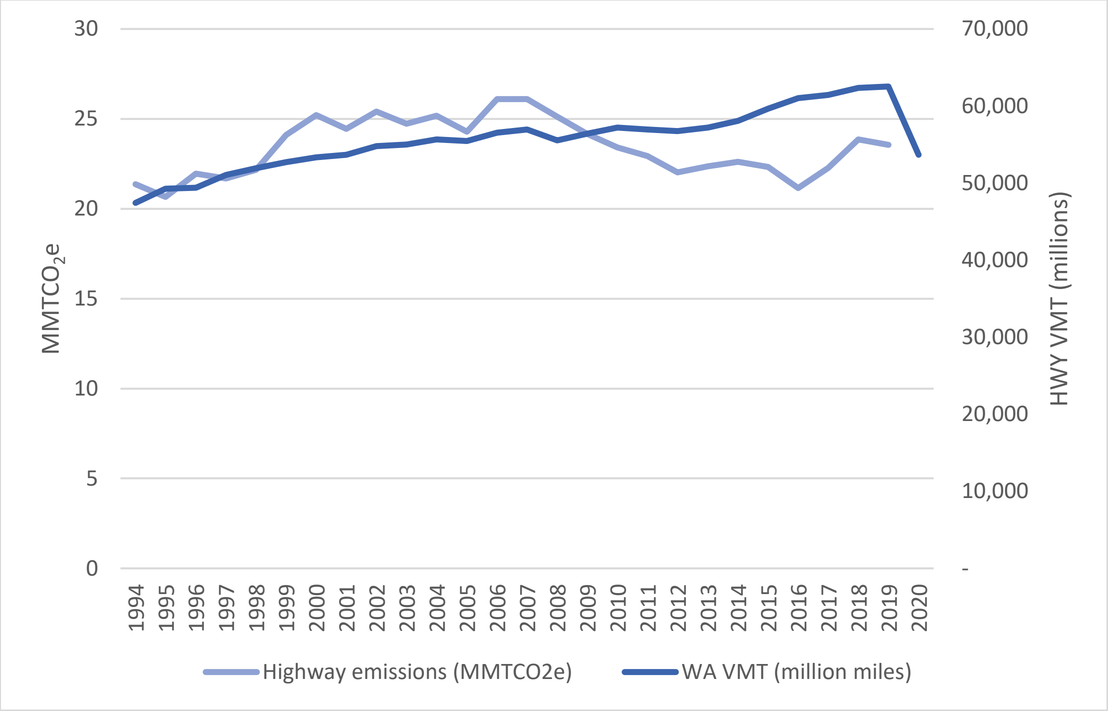


Figure 11. Highway emissions and highway VMT

Highway transportation is increasing in efficiency, meaning that as vehicle miles traveled increase, emissions have increased more slowly. However, as of 2019, we have yet to reduce highway emissions significantly in absolute terms. Increases in vehicle fuel economy and transportation demand management practices such as carpooling, transit and urban planning are likely driving these efficiency gains.

Buildings sector

This section estimates emissions associated with energy use in buildings in Washington. The analysis combines the emissions from the direct use of fossil fuels and emissions from electricity used in residential, commercial, and industrial buildings.

This analysis combines EPA SIT electricity end-use data (using consumption-based electricity inputs) and a 2006 point-in-time study that estimated natural gas used by equipment in buildings.[26] The 2006 equipment-use ratios were extrapolated to all years in

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[26] Energy End-Use Flow Maps for the Buildings Sector, D.B. Belzer, Pacific Northwest National Labs, September 2006

this estimate. Updated data on equipment end-uses would improve the results this analysis. The data does not include hydrofluorocarbon (HFC) emissions associated with space conditioning and refrigeration. HFCs are gases used in buildings for heating, cooling, and refrigeration that have no direct climate impact when used in a closed system, but that are powerful greenhouse gases if they leak into the atmosphere. Future publications of this report will include new HFC leakage data that is expected to become available in the coming years.

The result of this analysis, in Table 7 below, estimate emissions for the building sector by equipment usage. In 2019, emissions from buildings were estimated to represent 28% of statewide emissions. Within the buildings sector, residential buildings were estimated to be 52 percent of building sector emissions. Commercial buildings were 41 percent, and industrial buildings were the remaining 6 percent.

Space conditioning (heating, cooling, and ventilation) was responsible for an estimated 46 percent of emissions from buildings and 17 percent of statewide emissions.

Table 7. Estimated emissions from building energy use by sector, 1990–2019 (MMT CO_2e)

Application	1990	2000	2005	2010	2015	2016	2017	2018	2019
Residential - Total	**8.2**	**10.6**	**12.7**	**13.4**	**12.1**	**11.9**	**13.2**	**12.3**	**15.2**
Space heating	3.6	4.8	4.4	4.8	4.6	4.8	5.6	5.2	6.0
Air-conditioning*	0.4	0.4	1.0	0.9	0.9	0.8	0.9	0.8	1.1
Water Heating	0.9	1.4	1.6	1.7	1.8	1.8	2.0	1.9	2.3
Refrigeration*	0.7	0.8	1.0	1.0	0.6	0.6	0.6	0.6	0.8
Other Appliances and Lighting	2.6	3.0	4.5	4.8	3.9	3.6	3.8	3.5	4.8
Cooking	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3
Commercial - Total	**6.7**	**8.0**	**9.9**	**10.5**	**10.5**	**10.1**	**10.2**	**10.3**	**11.9**
Space heating	2.2	2.2	2.1	2.3	2.7	2.9	2.8	3.1	3.0
Air-conditioning*	0.4	0.6	0.8	0.8	0.7	0.6	0.6	0.6	0.8
Ventilation	0.4	0.5	0.8	1.0	1.0	0.9	0.9	0.9	1.1
Water Heating	0.5	0.6	0.6	0.6	0.5	0.6	0.6	0.6	0.7
Lighting	1.3	1.7	2.2	1.5	1.1	0.9	0.9	0.9	1.2
Cooking	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Refrigeration*	0.3	0.4	0.7	1.0	1.1	1.0	0.9	0.9	1.2

Application	1990	2000	2005	2010	2015	2016	2017	2018	2019
Office Equipment	0.1	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Computers	0.2	0.2	0.4	0.7	0.7	0.6	0.6	0.6	0.8
Other	1.1	1.4	1.8	2.0	2.0	2.0	2.1	2.0	2.4
Industrial buildings - Total	**1.9**	**1.8**	**1.5**	**1.9**	**1.8**	**1.7**	**1.6**	**1.6**	**1.9**
Facility HVAC*+	0.7	0.6	0.5	0.8	0.6	0.5	0.5	0.5	0.6
Facility Lighting	0.5	0.4	0.3	0.5	0.4	0.4	0.3	0.4	0.5
Other Facility Support	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Space Heating	0.6	0.7	3.6	3.9	0.6	0.7	0.7	0.7	0.7
Combined total all building types	**16.8**	**20.4**	**24.1**	**25.7**	**24.4**	**23.6**	**25.0**	**24.2**	**29.0**

* Emissions estimates shown are associated with electricity use only, however, some equipment in these categories also use HFCs. The data here likely underestimate the emissions due to HFC leakage from this equipment.

+ HVAC: heating, ventilation, and air conditioning.

Industrial sector

As shown in the inventory results in Table 4, industrial sector emissions are presented in three separate categories:

- On-site combustion of fuels for industrial sector energy use is counted in the residential, commercial, and industrial sector (or "RCI").
- Industrial process emissions.
- Industrial sector consumption of electricity is bundled within the electricity sector.

In Figure 12, emissions from these three categories are combined to create a single representation of the industrial sector, with total emissions of 26.0 MMT CO_2e, representing 25 percent of statewide emissions.

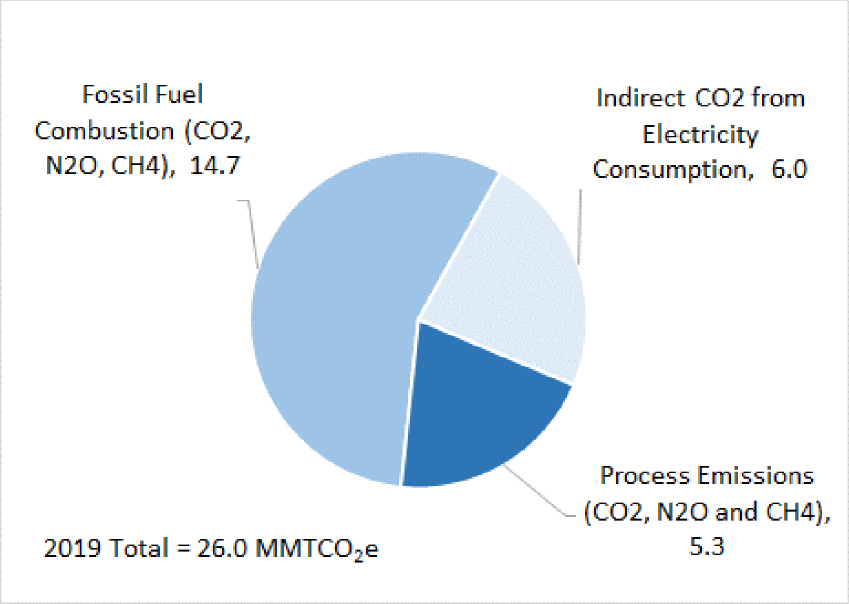

Figure 12. 2019 Industrial sector emissions by category, MMT CO_2e

Figure 13 shows CO_2 emissions from the industrial sector's direct combustion of fossil fuels for energy use from 1990–2019. In 2019, fossil fuel combustion emissions in this sector totaled 14.5 MMT CO_2, of which, 68 percent were from petroleum, 31 percent from natural gas, and 1 percent from coal. These levels have held relatively steady over the past decade and are 4 MMT below 1990 levels.

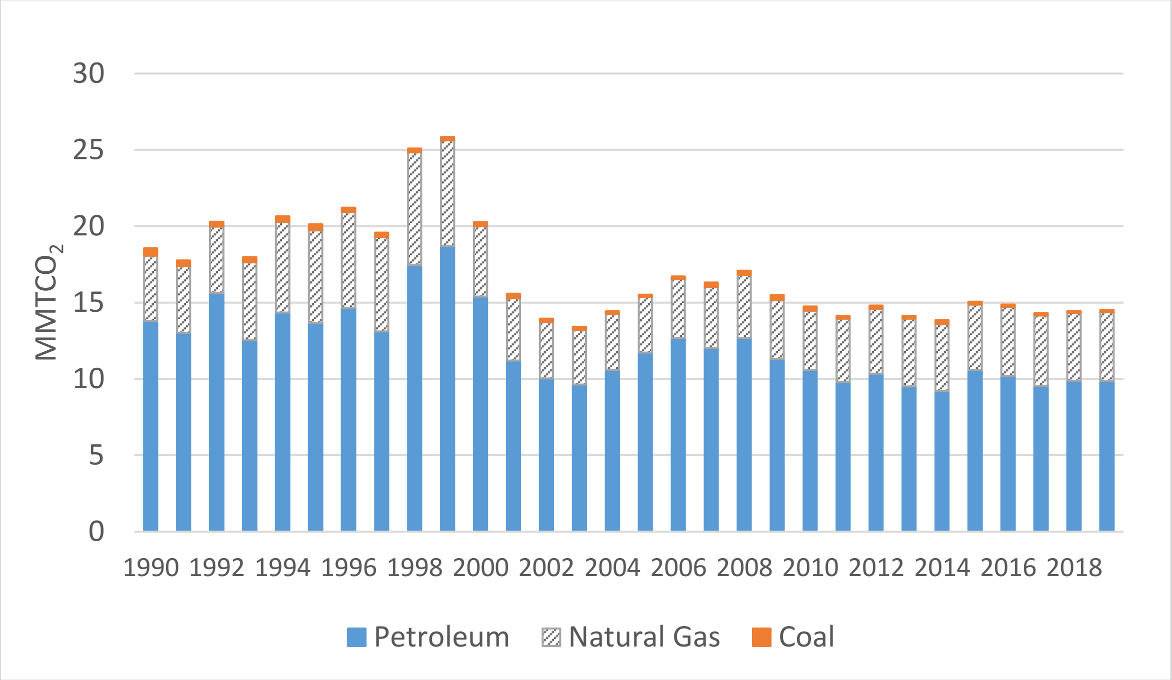

Figure 13. Industrial sector fossil fuel combustion (CO_2 only), 1990–2019

Emissions from the industrial sector declined significantly when the aluminum industry largely closed operations in the state following the volatility of energy markets during 2000-2001.

Table 8 shows an estimate of the emissions from electricity generation consumed by the industrial sector. The table breaks out the electrical end-use equipment at industrial facilities. (Source: SIT)

Table 8. Industrial Sector Emissions from Electricity Consumption, MMT CO_2e

Application	1990	2020	2010	2017	2018	2019
Indirect Uses-Boiler Fuel	**0.0**	**0.0**	**0.0**	**0.1**	**0.1**	**0.1**
Conventional Boiler Use	0.0	0.0	0.0	0.1	0.1	0.1
CHP* and/or Cogeneration Process	0.0	0.0	0.0	0.0	0.0	0.0
Direct Uses-Total Process	**4.9**	**4.2**	**4.7**	**3.5**	**3.5**	**4.6**
Process Heating	0.6	0.5	0.6	0.4	0.3	0.4
Process Cooling and Refrigeration	0.4	0.4	0.4	0.4	0.5	0.6
Machine Drive	3.2	2.8	2.8	2.2	2.3	3.0

Application	1990	2020	2010	2017	2018	2019
Electro-Chemical Processes	0.6	0.5	0.6	0.3	0.3	0.3
Other Process Use	0.0	0.0	0.3	0.2	0.2	0.3
Direct Uses-Total Non-process	**1.3**	**1.1**	**1.3**	**1.0**	**1.0**	**1.3**
Facility HVAC	0.7	0.6	0.7	0.5	0.5	0.6
Facility Lighting	0.5	0.4	0.4	0.3	0.4	0.5
Other Facility Support	0.2	0.1	0.1	0.1	0.1	0.1
Onsite Transportation	0.0	0.0	0.0	0.0	0.0	0.0
Other Non-process Use	0.0	0.0	0.0	0.0	0.0	0.1
Other	**0.3**	**0.3**	**0.1**	**0.1**	**0.0**	**0.1**
Total	**6.5**	**5.6**	**6.2**	**4.6**	**4.6**	**6.0**

*Combined heat and power

Washington State has another source of industrial sector GHG emissions data: the Greenhouse Gas Reporting Program (GHGRP).[27] The GHGRP provides detailed emissions reports from entities that emit more than 10,000 MT CO_2e per year. The data reported through this program differ from the data provided in the EPA SIT in their definitions, categorization, and threshold for reporting for some industrial subsectors. Plans for future publications of the inventory include integrating GHGRP data into the industrial sector.

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[27] Washington State Greenhouse Gas Reporting Program https://ecology.wa.gov/Air-Climate/Climate-change/Tracking-greenhouse-gases/Greenhouse-gas-reporting/Facility-greenhouse-gas-reports

Other emissions

This section discusses emissions not included in the inventory results in Table 4.

International bunker fuels

International bunker fuels are used in marine and aviation transport originating in the United States with international destinations. In 2019, international bunker fuels sold within Washington resulted in emissions totaling 6.8 MMT CO_2e. Following the emissions accounting standards and the U.S. National Inventory methodology, emissions from international transport are reported separately and are not included in the statewide inventory total. Figure 14. International bunker fuels 1990-2019 shows the international bunker fuels sold in Washington from 1990 through 2019.

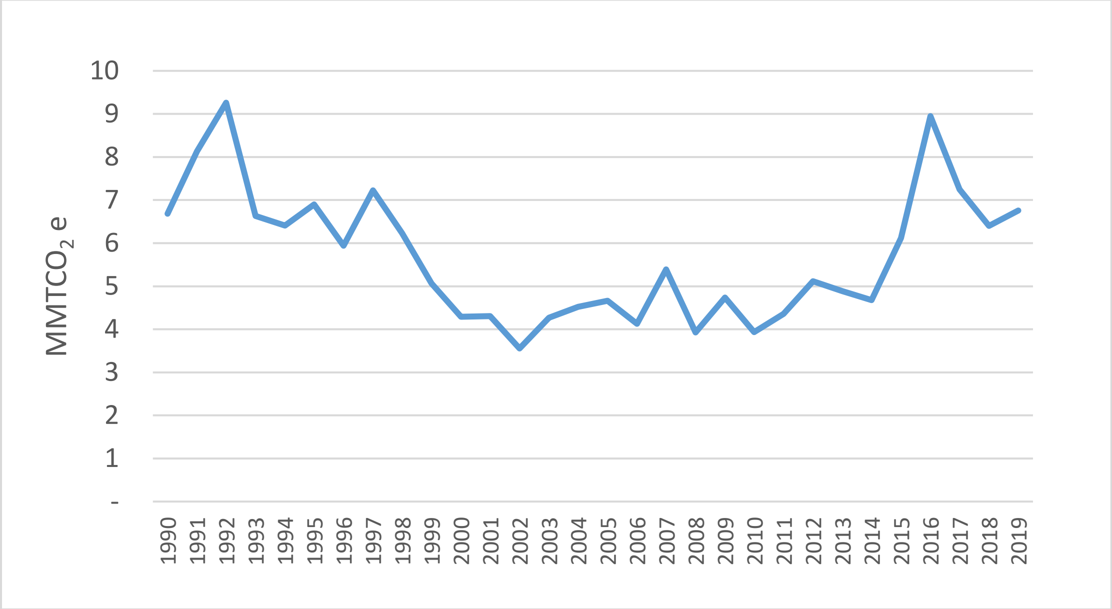

Figure 14. International bunker fuels 1990-2019 (MMT CO_2e)

Ozone depleting substances

Ozone Depleting Substances (ODS) are chemicals commonly used in air conditioning and refrigeration, in producing insulating foams, and as propellants. These greenhouse gases are thousands of times more powerful than carbon dioxide. In Table 4 they are included under Industrial Process emissions. This is because they are generally tracked at the manufacturer level as an industrial product from chemical factories. However, these chemicals are consumed in residential, commercial, industrial and transportation sectors. In future publications, we plan to incorporate additional data and more detailed analysis of ODS end uses.

Planned Improvements

The current inventory relies on data which typically lags three or four years and cannot be disaggregated beyond what is presented in this report. The subsector analyses we present here are generalized estimates that, in some cases, have high levels of uncertainty. Some data presented here are apportioned national emissions that are allocated to states based on factors such as GDP or population, which means actions to reduce these emissions at the state level will not necessarily be reflected in Washington's inventory.

To address these limitations, Ecology is planning future changes to this inventory to improve the timeliness, accuracy, and detail. Where possible, Ecology plans to link to data sets that are more relevant to Washington State. These data sets would supplement or replace the nationally-aggregated data from EPA that is used in this report. There are multiple data sources available to Washington that may provide more detailed, state-specific, accurate, and timely GHG emissions information. These include data sets from several Washington state agencies which collect data that could improve this inventory. In future years, Ecology is planning to identify and integrate such data into the inventory, substituting for EPA data, as we are able.

Ecology has submitted a budget request to the Governor, requesting additional resources to support this effort. The budget request would also support hiring additional data analysts with industry sector experience, who could use this knowledge to improve the accuracy of the relevant data models and projections. This work would help improve the Washington-specific data.

Finally, we also plan to make more data accessible on the Ecology website.

Conclusion

Washington's greenhouse gas emissions rose 6.9 percent in 2019, from 2018 levels, reaching a total of 102.1 MMT CO_2e. This is 8.7 MMT CO_2e (9.3 percent) higher than the 1990 baseline. The increase in 2019 is largely attributed to emissions from electricity, which rose from 16.5 MMT CO_2e in 2018, to 21.9 in 2019. Electricity sector data for 2020 is available and shows that emissions from this sector dropped to 14.2 MMT CO_2e in 2020, a reduction of 35 percent from 2019. Electricity emissions in 2020 were 2.7 MMT CO_2e (16 percent) below the 1990 level for this sector. This is the only sector for which 2020 data is currently available. This decline is due to a decrease in energy demand in response to the COVID-19 pandemic, improved conditions for hydropower generation, and temperate weather conditions.

Although the share of statewide emissions from the transportation sector declined in 2019, it remains the largest source of emissions in the state at 40.3 MMT CO_2e, or 39 percent of the statewide total. This is a 2 percent increase over 2018 emissions for this sector.

In 2019, the total emissions from all sources of the industrial sector were 26.0 MMT CO_2e, representing 25 percent of statewide emissions. Emissions from buildings were estimated to represent 28 percent of statewide emissions.

Washington has broken the historic trend of economic growth leading to rising emissions. Evidence that the economy is decarbonizing is seen in Washington's incredible growth in GDP and population since 2005, while emissions largely flattened.

Future planned improvements to the inventory include incorporating data from the Greenhouse Gas Reporting Program and other state data sources which will enable more detailed and timely analysis.

Appendix A. Ecosystem Carbon in Natural and Working Lands

Natural and working lands (NWL) refer to the variety of land uses that make up our natural environment: forests and woodlands, grassland and shrub land, cropland and rangeland, wetlands, and urban green spaces. NWL provide us with the food and fiber we use every day. NWL ecosystems continuously exchange carbon between the biosphere, atmosphere, and the ocean, playing a key role in the global carbon cycle. These ecosystems are unique in their ability to both contribute GHGs to the atmosphere and to remove it.

The carbon stored in NWL is part of the biogenic carbon pool (also called the biosphere or ecosystem). As discussed in the Global Carbon Cycle section of this report, biogenic carbon circulates over a much shorter timescale than ancient, fossil carbon. Fossil carbon accumulates in deep geologic structures over millions of years.[28]

Prior to the industrialized era, biogenic carbon emissions from fire, plant decay, and other natural sources were balanced by carbon sequestered in growing plants and soils across the biosphere. For the past three million years, relatively minimal change occurred in the total concentration of atmospheric carbon. Emissions from fossil-fuel combustion are causing greenhouse gases to accumulate in the atmosphere and oceans, threatening the balance of natural cycles. They are also contributing to a feedback loop for forests and other lands: as carbon accumulates in the atmosphere and Washington experiences more warming, extreme heat events, and droughts, the risk and intensity of fires also increases. This, in turn, pushes the biogenic carbon cycle further out of balance.

Although NWL can store carbon, they are not always a carbon sink—land use change, wildfires, insect infestations, and extreme weather are among the many factors that can release carbon stored in NWL. Washington is historically a net carbon sink due to the large amount of carbon stored in our forests. However, in recent years there have been fire seasons large enough to emit more carbon than all the forests and other lands in our state sequester in a year. At these times, our forests become a source of emissions contributing to climate change.

NWL inventories, often categorized as the “land use, land use change and forestry sector,” estimate carbon stocks and fluxes across specific land use categories. While stocks reveal the *quantity* of carbon in each land use category, fluxes reveal *net exchange* of carbon between

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[28] The exception is peat, which formed over thousands of years. The carbon in peat has remained largely isolated from the active carbon cycle since their formation. Peat is categorized with the fossil fuels because it is involved in cycles with longer time scales than living plants and is not renewable on policy-relevant time scales. (EPA 2011 *Accounting Framework For Biogenic Co2 Emissions From Stationary Sources)* (https://www.epa.gov/sites/default/files/2016-08/documents/biogenic-co2-accounting-framework-report-sept-2011.pdf)

land use categories. When a flux is negative for a category, it is absorbing more carbon from the atmosphere than it emits, making it a carbon sink. Carbon flux is an important measurement of how carbon stores are changing in the landscape.

Table 9 presents carbon flux in Washington's NWL. The numbers are positive or negative relative to the atmospheric carbon pool. Positive numbers represent a source of carbon moving from the land to the atmosphere. The net emissions are determined by summing all the NWL sources and sinks.

The trends for the carbon stored in these land use categories are dynamic as all are both managed by humans and subject to climate impacts and feedback loops.

Table 9. Washington net CO_2 flux (carbon stock change) from natural and working lands (MMT CO_2e)

Land-Use Category	1990	2005	2015	2016	2017	2018	2019
Forest Land Remaining Forest Land	**(10.3)**	**(15.2)**	**(19.1)**	**(18.7)**	**(18.2)**	**(17.8)**	**(17.3)**
Changes in Forest Carbon Stocks[a]	(10.3)	(15.2)	(19.1)	(18.7)	(18.2)	(17.8)	(17.3)
Land Converted to Forest Land	**(3.0)**	**(3.0)**	**(3.0)**	**(3.0)**	**(3.0)**	**(3.0)**	**(3.0)**
Changes in Forest Carbon Stocks[b]	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)	(3.0)
Cropland Remaining Cropland	**(0.5)**	**(0.3)**	**(0.4)**	**(0.7)**	**(0.7)**	**(0.6)**	**(0.6)**
Changes in Soil Carbon Stocks	(0.5)	(0.3)	(0.4)	(0.7)	(0.7)	(0.6)	(0.6)
Land Converted to Cropland	**0.5**	**0.6**	**0.7**	**0.6**	**0.6**	**0.6**	**0.6**
Changes in Ecosystem Carbon Stocks[c]	0.5	0.6	0.7	0.6	0.6	0.6	0.6
Grassland Remaining Grassland	**(0.0)**	**0.1**	**0.3**	**0.2**	**0.2**	**0.2**	**0.2**
Changes in Ecosystem Carbon Stocks	(0.0)	0.1	0.3	0.2	0.2	0.2	0.2
Land Converted to Grassland	**0.2**	**(0.0)**	**0.3**	**0.1**	**0.1**	**0.1**	**0.1**
Changes in Ecosystem Carbon Stocks[c]	0.2	(0.0)	0.3	0.1	0.1	0.1	0.1
Wetlands Remaining Wetlands	**(0.1)**	**(0.1)**	**(0.1)**	**(0.1)**	**(0.1)**	**(0.1)**	**(0.1)**
Changes in Organic Soil Carbon Stocks in Peatlands	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Changes in Ecosystem Carbon Stocks in Coastal Wetlands	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)
Land Converted to Wetlands	**0.0**	**0.0**	**(0.0)**	**(0.0)**	**(0.0)**	**(0.0)**	**(0.0)**

Land-Use Category	1990	2005	2015	2016	2017	2018	2019
Changes in Ecosystem Carbon Stocks[d]	0.00	0.00	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
Settlements Remaining Settlements	**(2.6)**	**(2.7)**	**(2.9)**	**(2.9)**	**(2.9)**	**(2.9)**	**(2.9)**
Changes in Organic Soil Carbon Stocks	0	0	0	0	0	0	0
Changes in Settlement Tree Biomass Carbon Stocks[e]	(2.2)	(2.6)	(2.9)	(2.8)	(2.8)	(2.8)	(2.8)
Changes in Yard Trimmings and Food Scrap Carbon Stocks in Landfills	(0.5)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)
Land Converted to Settlements	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Changes in Ecosystem Carbon Stocks	2	2	2	2	2	2	2
LULUCF Net CO_2 Flux	**(13.8)**	**(18.2)**	**(21.8)**	**(22.0)**	**(21.6)**	**(21.1)**	**(20.6)**

Totals may not sum due to independent rounding.

a Includes the net changes to carbon stocks stored in all forest ecosystem pools. Harvested wood products are not estimated in the SIT at this time. This includes the net CO2 flux from drained organic soils in both Forest Land Remaining Forest Land and Land Converted to Forest Land.

b Includes the net changes to carbon stocks stored in all forest ecosystem pools, but emissions from drained organic soils are included in the flux from Forest Land Remaining Forest Land because it is not possible to separate the activity data at this time.

c Includes changes in mineral and organic soils from all lands converted to Croplands/Grasslands, and the above- and below-ground biomass, dead wood, and litter from Forest Lands Converted to Croplands/Grasslands.

d Includes carbon stock changes for land converted to vegetated coastal wetlands.

e Includes Lands Converted to Settlements.

Table 10 presents methane (CH_4) and nitrous oxide (N_2O) emissions. Sources of methane in NWL include wildfires and wetlands. Sources of nitrous oxide include urban soils, wildfires, wetland, and drained peat soils.[29]

Table 10. Washington methane and nitrous oxide emissions from natural and working lands (MMT CO_2e)

Gas/Land-Use Sub-Category	1990	2005	2015	2016	2017	2018	2019
CH_4	**0.1**	**0.2**	**3.2**	**0.2**	**1.6**	**0.8**	**0.8**

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[29] Agricultural soils also produce CO_2, CH_4 and N_2O, but these emissions are classified as part of the agricultural sector of the anthropogenic GHG inventory, rather than as part of NWL.

Gas/Land-Use Sub-Category	1990	2005	2015	2016	2017	2018	2019
Forest Land Remaining Forest Land: Forest Fires	+	0.1	3.1	0.1	1.5	0.7	0.7
Wetlands Remaining Wetlands: Coastal Wetlands Remaining Coastal Wetlands[b]	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Grassland Remaining Grassland: Grassland Fires	+	+	+	+	+	+	+
Land Converted to Wetlands: Land Converted to Coastal Wetlands[b]	+	+	+	+	+	+	+
Forest Land Remaining Forest Land: Drained Organic Soils	+	+	+	+	+	+	+
Wetlands Remaining Wetlands: Peatlands Remaining Peatlands	+	+	+	+	+	+	+
N_2O	**0.0**	**0.2**	**2.1**	**0.1**	**1.1**	**0.6**	**0.6**
Forest Land Remaining Forest Land: Forest Fires	+	0.1	2.0	+	1.0	0.5	0.5
Settlements Remaining Settlements: Settlement Soils	+	0.1	+	+	+	+	+
Forest Land Remaining Forest Land: Forest Soils	+	+	+	+	+	+	+
Grassland Remaining Grassland: Grassland Fires	+	+	+	+	+	+	+
Wetlands Remaining Wetlands: Coastal Wetlands Remaining Coastal Wetlands[a]	+	+	+	+	+	+	+
Forest Land Remaining Forest Land: Drained Organic Soils	+	+	+	+	+	+	+
Wetlands Remaining Wetlands: Peatlands Remaining Peatlands	+	+	+	+	+	+	+
LULUCF CH_4 & N_2O Emissions	**0.1**	**0.4**	**5.3**	**0.3**	**2.6**	**1.4**	**1.4**

Notes: Totals may not sum due to independent rounding. EPA is using 100-year Global Warming Potentials (GWP) from IPCC's Fourth Assessment Report, as required in reporting annual inventories to the UNFCCC.

"+" Value does not exceed 0.005 MMT CO2e
a Net N2O flux from aquaculture are not available at the State-level.

Figure 15 shows the gross emissions for the top source of land use emissions (Land Converted to Settlements) and three top sinks for 2019.

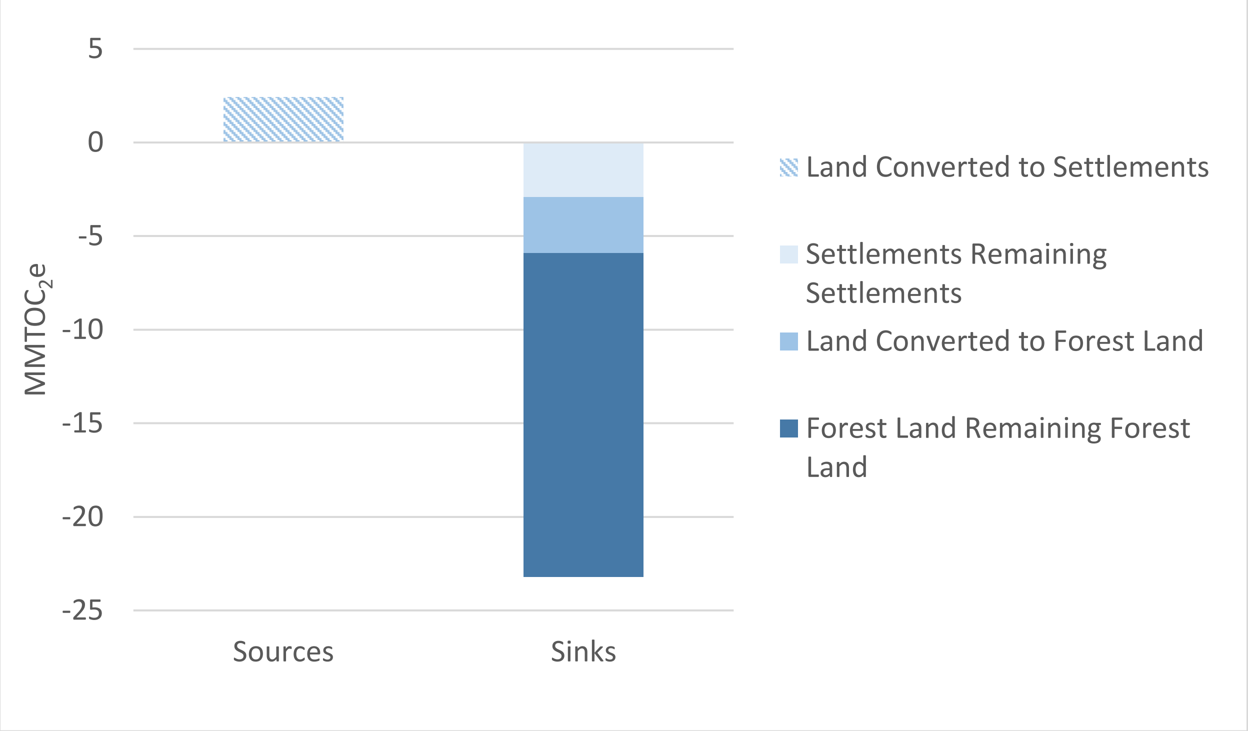

Figure 15. 2019 Washington NWL gross GHG emissions by largest sources and sinks, MMT CO_2e

Forest Land Remaining Forest Land is overwhelmingly the largest carbon sink in Washington, representing an estimated 63% of all carbon exchanged within the ecosystem and 72 percent of the carbon sink. Land Converted to Settlements is consistently the largest source of emissions in this sector.

The second largest carbon sink is Land Converted to Forest Land (afforested land). The natural lands categorized as Settlements Remaining Settlements are a carbon sink largely due to the biomass of urban trees. Changes in carbon stocks from yard trimmings and food scrap in landfills are included within this category as well.

Wildfire emissions

Figure 166 shows wildfire emissions (indicated by a short dash) and acres burned (indicated by a vertical bar). The emissions vary depending on the carbon intensity of the landscape that burned. The dense forests of Western Washington and the eastern slopes of the Cascades hold significant carbon stores. Wildfires in grassy, non-forested regions of Eastern Washington may burn vast acreage yet result in lower carbon emissions. Recent years have seen a dramatic increase in both total emissions and acres burned in wildfires.

Wildfires convert carbon stored in forests to atmospheric carbon. In the NWL inventory, this reduces the carbon stored in the category of Forest Land Remaining Forest Land.[30] Following a fire, if the land is reforested, the land use category Lands Converted to Forest Land will show increasing carbon stores over time.

This data comes from Department of Natural Resources Forest Resilience Division. The 2014–2021 data is available in *Wildfire Emissions 2014 – 2021*.[31]

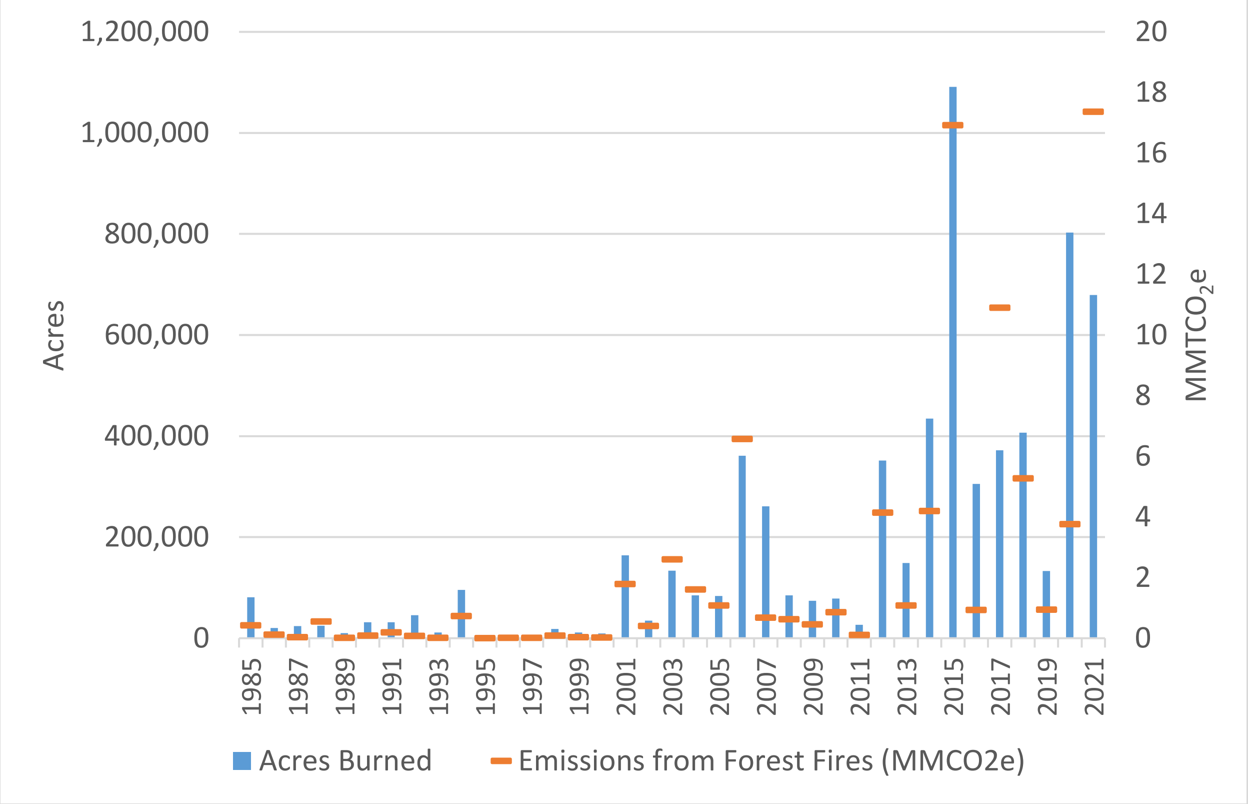

Figure 16. Wildfire emissions, 1985–2020 MMT CO_2e

Natural and working lands data in context

The NWL data were provided by EPA and intended to be an accessible tool for states and to provide consistency with the U.S. National Inventory methodology. This data is a starting point

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[30] Note that the underlying data measurements for Forest Land Remaining Forest Land provided by EPA are averaged across multiple years which means the resulting GHG flux estimates cannot be attributed to a specific year or cause, such as wildfire.

[31] DNR Forest Resilience Division, Forest Health Strategic Plan https://www.dnr.wa.gov/ForestHealth

for constructing a state NWL inventory, but it has limitations that are important to document and to provide context for their use.

- Some of the data sources underlying the NWL inventory is old. The forest carbon data is only available through 2014, and the wood products data date from 1997. Other years are extrapolated from those years. More current data is available for Washington.
- Data for "blue carbon," such as wetlands, impoundments, shorelines, and coastal water is currently underestimated in the EPA NWL data set. Washington has some of the most advanced scientific research in this field, however, as it is not yet available for the country as whole, it is not included in the EPA data set. This is potentially a large number for Washington.
- EPA does not report the margin of error (uncertainty) around its state-level estimates.
- EPA uses statistical extrapolation from field-based measurements to estimate GHG fluxes in NWL. Ten percent of the plots are measured each year, so the entire land mass is measured every 10 years and the intermittent years are extrapolated. This means the estimates are not spatially explicit (i.e., cannot be mapped) and cannot be attributed to a specific year or cause, such as wildfire or cover crop adoption.
- Some GHG fluxes are double counted (like some urban trees that are also classified as "forest") or omitted altogether (such as trees in agricultural lands or terrestrial wetlands).

EPA is working to improve the national and state-level data; however, they recommend that more sophisticated inventory methods be used to effectively inform state policymaking or establish benchmarks. Additional research would be needed to identify and incorporate improved state data sources to track the flow of carbon in our natural and working lands and to quantify the uncertainty estimates for Washington's NWL inventory.

Natural and Working Lands Summary

In 2019, Washington's natural and working lands were estimated to contribute 3.4 MMT CO_2e in emission sources and 24 MMT CO_2e in emission removals for an estimated net sink of 20.6 MMT CO_2e. The largest source of emissions from this sector is the Land Converted to Settlements category. Forest Land Remaining Forest Land is the largest sink and the primary reason Washington's NWL are a net sink. Wildfires reduce the carbon stores in this category, and, in some recent years, have converted this category to a net source of emissions.

Appendix B. Additional Methods for Estimating Emissions

The Washington Greenhouse Gas Emissions Inventory is primarily a production-based emissions inventory (PBEI). This means the reported emission sources and sinks occur within the state's boundaries, except for the electricity sector emissions. The methodology for PBEIs is fairly standardized globally with formal guidelines established by the IPCC and US EPA. PBEIs represent emissions most directly under the authority of Washington.

One critique of PBEIs is that they may give an incomplete picture of a state's carbon footprint because they do not include emissions that occur outside a state's boundaries that are driven by in-state consumption. This can obscure progress toward reducing emissions. Climate policy based solely on production-based emissions may promote geographic carbon leakage, meaning the shifting of emissions from within the state to outside the state. Production may concentrate in states or countries with less stringent carbon-reduction policies, leading to an increase in global emissions. This "carbon loophole"—greenhouse gas emissions linked to the production of goods that are then traded across state and national borders—accounts for nearly 25 percent of the world's total greenhouse gas emissions.[32]

Additional methods for measuring and regulating carbon emissions have emerged to provide a more holistic understanding of a jurisdiction's carbon footprint and to help mitigate the risk of carbon leakage.

Consumption-based emissions inventory (CBEI) – A CBEI quantifies emissions associated with consumption of materials, goods, and services within a boundary—what are often referred to as "embodied emissions." CBEIs complement traditional PBEIs by linking consumer goods and services to the emission sources where the goods and services originate. Rather than using direct measurements, they are typically based on economic input-output models that link to environmental data from the point of origin of the good or service. Section 5 of the 2021 Washington State Energy Strategy recommends that the state conduct an inventory of the embodied carbon of goods and services purchased by Washingtonians.[33] Examples of CBEIs can be found in the State of Oregon and King County, Washington.[34,35] These analyses suggest that the carbon footprint of Washington's economic activity may be much larger than what is captured by the state's PBEI. For example, King County's 2015 CBEI reported emissions more

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[32] Moran, Daniel, Ali Hasanbeigi, and Cecilia Springer. 2018. The Carbon Loophole in Climate Policy: Quantifying the Embodied Carbon in Trade Products. https://www.climateworks.org/wp-content/uploads/2018/09/Carbon-Loophole-in-Climate-Policy-Final.pdf

[33] Washington State Dept. of Commerce State Energy Strategy https://www.commerce.wa.gov/wp-content/uploads/2020/12/Washington-2021-State-Energy-Strategy-December-2020.pdf

[34] Oregon's CBEI: https://www.oregon.gov/deq/mm/Pages/Consumption-based-GHG.aspx

[35] King County CBEI: https://kingcounty.gov/services/environment/climate/actions-strategies/strategic-climate-action-plan/emissions-inventories.aspx

than 2.5 times its PBEI.[36] At the same time, emissions associated with products manufactured in Washington for export would not be attributed to Washington in a CBEI. The U.S. EPA is currently working with states to develop state-level guidance for conducting a CBEI.

Product life-cycle assessment (LCA) – A comprehensive product life-cycle assessment focuses on all emissions associated with manufacturing a single product, regardless of where those emissions occur. Product LCAs often focus on cradle-to-gate emissions: raw material extraction; transport to the manufacturing site; and manufacturing.[37] These are the emissions that manufacturers control, including emissions embodied in the product's supply chain. As a result, cradle-to-gate product LCAs can be a valuable tool for designing policies that incentivize manufacturers to produce lower-carbon products or in making procurement decisions. Regulating products, rather than manufacturing facilities, also helps mitigate the risk of carbon leakage by removing the incentive to move production offshore.[38] LCAs can provide detailed information for the product being assessed and help identify opportunities for efficiencies and alternatives, but they are challenging to scale to other products.

Environmental product declarations (EPD) – EPDs are a standardized tool for reporting a product's environmental life-cycle performance.[39] Similar to a nutrition label on food, EPDs report the carbon and other environmental impacts of a product.[40] The product life cycle assessments reported in an EPD are based on specific product category rules (PCRs) that define the rules and requirements for producing an EPD for that particular product. Product-specific Type III EPDs are the most thorough. They cover one individual product from a manufacturer and are third-party verified. Product-specific Type III EPDs are a useful tool for comparing the carbon intensity of products within a product category.[41] EPDs are increasingly common in the building sector to facilitate procurement of low-carbon products. In addition to product-specific EPDs, there are also industry-wide EPDs that report averages for a product across multiple manufacturers. The International EPD System provides a catalogue of environmental performance data for a wide range of products and services.[42]

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[36] https://www.commerce.wa.gov/wp-content/uploads/2020/12/Washington-2021-State-Energy-Strategy-December-2020.pdf

[37] Product LCAs can also be cradle-to-grave, which covers all life cycle stages from extraction to end of life. Cradle-to-grave product LCAs come with some assumptions. For example, a manufacturer that produces a soda has no way of knowing whether that can is recycled or ends up in a landfill. As a result, cradle-to-grave product LCAs are less appropriate than cradle-to-gate product LCAs for policies intended to incentivize manufacturers to produce lower-carbon products or promote low-carbon procurement. However, they can be valuable in designing other types of decarbonization policies.

[38] https://www.climateworks.org/report/build-clean-industrial-policy-for-climate-and-justice/

[39] International Organization for Standardization (ISO) series 14040

[40] In addition to global warming potential, EPDs may also report other environmental impacts such as smog creation, ozone depletion, and water pollution.

[41] https://carbonleadershipforum.org/guidance-on-embodied-carbon-disclosure/

[42] The International EPD System https://www.environdec.com/home