

2020 Washington Comprehensive Emissions Inventory

Technical Support Document

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Contact Information

Air Quality Program
P.O. Box 47600
Olympia, WA 98504-7600
Phone: 360-407-6800

Washington State Department of Ecology — www.ecology.wa.gov

- | | |
|---------------------------------------|--------------|
| • Headquarters, Olympia | 360-407-6000 |
| • Northwest Regional Office, Bellevue | 425-649-7000 |
| • Southwest Regional Office, Olympia | 360-407-6300 |
| • Central Regional Office, Union Gap | 509-575-2490 |
| • Eastern Regional Office, Spokane | 509-329-3400 |

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List of Acronyms

ADT	Average Daily Traffic
ADVMT	Average Daily Vehicle Miles Traveled
AIRPACT	Air Indicator Report for Public Awareness and Community Tracking
AOP	Air Operating Permit
AQPPS	Air Quality Program Permitting System
CAA	Clean Air Act
CAP	Criteria Air Pollutant
CDL	Cropland Data Layer
CRO	Central Regional Office
DNR	Department of Natural Resources
ECY	Washington State Department of Ecology
EF	Emission Factor
EI	Emissions Inventory
EPA	Environmental Protection Agency
ERO	Eastern Regional Office
GIS	Geographic Information Systems
HAP	Hazardous Air Pollutant
HMS	Hazard Mapping System
HPMS	Highway Performance Monitoring System
ICI	Industrial, Commercial, and Institutional
MOVES	Motor Vehicle Emission Simulator
NAAQS	National Ambient Air Quality Standards
NEC	Not Elsewhere Classified
NEI	National Emissions Inventory
OFM	Office of Financial Management
OHU	Occupied Housing Units
ORVR	Onboard Refueling Vapor Recovery
PE	Precipitation Effectiveness

PM	Particulate Matter
POTW	Publicly Owned Treatment Works
SCC	Source Classification Code
SIP	State Implementation Plan
SMARTFIRE	Satellite Mapping Automatic Reanalysis Tool for Fire Incident Reconciliation
TPY	Tons Per Year
TRI	Toxics Release Inventory
ULSD	Ultra-Low Sulfur Diesel
UW	University of Washington
VMT	Vehicle Miles Traveled
VOC	Volatile Organic Compounds
VRS	Vapor Recovery System
WRAP	Western Regional Air Partnership
WRF	Weather Research and Forecasting Model
WSDOT	Washington State Department of Transportation
WSU	Washington State University
WWTP	Wastewater Treatment Plant

Table of Contents

1	Introduction	1
1.1	Purpose and Background	1
1.2	Pollutants and Emissions Sources	1
1.3	Spatial and Temporal Resolution	2
1.4	Emissions Calculated by EPA.....	2
2	Statistics Used Throughout the Inventory	4
2.1	County Demographics	4
3	Base Year 2020 Emissions Estimates	5
3.1	Point Sources	5
3.2	Onroad Mobile Sources	6
3.3	Construction Dust	12
3.4	Nonroad Mobile Vehicles and Equipment (NEC)	15
3.5	Locomotives	17
3.6	Silvicultural Burning (Prescribed Burning).....	19
3.7	Wildfires.....	21
3.8	Agricultural Burning	24
3.9	Municipal Solid Waste Burning	28
3.10	Publicly Owned Treatment Works (POTW).....	29
3.11	Residential Wood Combustion.....	31
3.12	Industrial and Commercial/Institutional (ICI) Fuel Use	38
3.13	Agricultural Harvesting Operations	41
3.14	Agricultural Tilling	44
3.15	Land clearing.....	48
3.16	Structure & Vehicle Fires	50
3.17	Natural/Biogenic	52
3.18	Emissions Calculated by EPA.....	54
4	Emissions Summaries	55

List of Tables

Table 1-1. Emissions Category Pollutant Checklist	2
Table 1-2. Emissions Category Notes	3
Table 2-1. Population and Occupied Housing Units	4
Table 3-1. Average Daily VMT for Rural Roads	7
Table 3-2. Average Daily VMT for Urban Roads	8
Table 3-3. Vehicle Population, 2020	9
Table 3-4. MOVES Model Parameters	10
Table 3-5. ADVMT on Unpaved Roads – Total of County and City Jurisdictions	11
Table 3-6. Precipitation Effectiveness Index Values	14
Table 3-7. Sectors Included in Ecology's Nonroad Mobile Category	15
Table 3-8. Boats Registered	16
Table 3-9. BNSF Switch Yard Locomotives Fuel Consumption (gallons)	17
Table 3-10. Switch Yard Locomotives Emission Factors (grams per gallon of fuel consumed)	18
Table 3-11. Silvicultural Burning Emission Factors (pounds per ton consumed)	19
Table 3-12. Silvicultural Burning Activity	20
Table 3-13. Wildfire Area Burned by County (acres)	22
Table 3-14. Largest Wildfires in Washington	23
Table 3-15. Average Fuel Loading for Agricultural Field Burns	25
Table 3-16. Agricultural Residue Burned (tons)	26
Table 3-17. Agricultural Burn Emission Factors (pounds per ton of material consumed)	27
Table 3-18. Emission Rates in Pounds Per Ton of Combustible Material Burned	28
Table 3-19. Public Wastewater Treatment Plant Throughput (millions of gallons)	30
Table 3-20. Surveys and Survey Groups	32
Table 3-21. County to Survey Assignments	32
Table 3-22. Device Usage (Percent of Occupied Housing Units)	34
Table 3-23. Amount of Wood Burned Per Device	35
Table 3-24. Tons of Wood Burned for Home Heating	36
Table 3-25. Pollutant Emission Factors in Pounds Per Ton Burned	37
Table 3-26. State Industrial and Commercial/Institutional Fuel Use	38
Table 3-27. Area of Crops Harvested (Acres)	42
Table 3-28. Agricultural Harvesting Emission Rates (lb/acre)	43
Table 3-29. Area of Farmland Tilled (Acres)	45
Table 3-30. Farming Practices and Silt Content	46
Table 3-31. Tilling Passes for Field Crops	47
Table 3-32. Land clearing tons burned by county	49
Table 3-33. Structure and Vehicle Fire Emission Factors (pounds per Ton consumed)	50
Table 3-34. Structure and Vehicle Fire Counts	51
Table 3-35. MEGAN Functional Plant Types	52
Table 3-36. MEGAN v2.1 Biogenic Emission Factors by Class Number ($\mu\text{g}/\text{m}^2/\text{hr}$)	53
Table 3-37. Emissions Source Types Calculated by EPA using Defaults	54
Table 4-1. Statewide Emissions in Tons per Year	55
Table 4-2. Annual Statewide Emissions Source Percentages by Pollutant	56
Table 4-3. County PM ₁₀ Emissions Estimates in Tons per Year	57
Table 4-4. County PM _{2.5} Emissions Estimates in Tons per Year	58
Table 4-5. County SO ₂ Emissions Estimates in Tons per Year	59
Table 4-6. County NO _x Emissions Estimates in Tons per Year	60
Table 4-7. County VOC Emissions Estimates in Tons per Year	61
Table 4-8. County CO Emissions Estimates in Tons per Year	62
Table 4-9. County NH ₃ Emissions Estimates in Tons per Year	63

1 Introduction

1.1 Purpose and Background

This document describes the methods and data sources employed to estimate emissions for the 2020 Washington Comprehensive Emissions Inventory. The emissions inventory (EI) is based on indicators of activity (e.g. population, registered vehicles, land use area) and scientifically developed emission rates that are specific to a source category. The EI is *not* based on ambient air quality monitor observations used by EPA to enforce the National Ambient Air Quality Standards (NAAQS), nor does it account for air pollution that originated outside the state boundaries (e.g. wildfire smoke from other states/countries).

The comprehensive EI includes emissions from point sources (e.g. large facilities that report their emissions annually), area sources (e.g. residential, agricultural, and commercial activities), mobile sources (e.g. cars, trucks, trains, boats), biogenic sources (e.g. vegetation and soil microbes), and event-driven sources (e.g. wildfires and prescribed burning) of air pollution. The Department of Ecology uses the EI as part of the overall air quality management program. This includes supporting air quality modeling, State Implementation Plan (SIP) attainment/maintenance planning, other air quality planning and rule efforts, public information, point source fee generation, and to meet federal air quality reporting requirements. The Department of Ecology compiles a comprehensive EI for every third year, which relies on coordination with EPA National Emissions Inventory (NEI) process. The next comprehensive EI will be for base year 2023.

Discretion should be used when comparing results between different EI years. What appear to be emissions changes may instead reflect: (1) changes in emissions estimation models, methodologies, and /or emission rates, (2) sources and/or pollutants included in the inventory, and (3) correction of errors in prior inventories.

1.2 Pollutants and Emissions Sources

The EI includes estimates of relevant criteria air pollutants (CAPs) for all sources inventoried. The Clean Air Act (CAA) defines CAPs as carbon monoxide (CO), lead (Pb), Ozone (O₃), nitrogen oxides (NO_x), particulate matter (PM), and sulfur dioxide (SO₂). Lead emissions are calculated by EPA for aircraft that use leaded fuel, but lead is not included in this EI. Ozone is a secondary pollutant formed in the atmosphere and is not directly emitted. NO_x and volatile organic compounds (VOCs) are ozone precursors and are included in this EI. PM is estimated for two size bins (PM₁₀ and PM_{2.5}), as specified in the NAAQS. Ammonia (NH₃) is technically not a CAP, but it is included in this EI because it is an important PM precursor and a Toxic Air Pollutant (TAP). Hazardous air pollutants (HAPs) are available from the NEI, as reported by Title V Major Sources and estimated from PM and VOC speciation profiles.

See Table 1-1 for information about the main pollutants included for each emissions category.

1.3 Spatial and Temporal Resolution

Emissions were estimated for each county. Total annual emissions were estimated. If seasonal or other shorter timeframe estimates are required for a project, temporal profiles or other information may be used to adjust the inventories to the needed temporal scale.

Table 1-1. Emissions Category Pollutant Checklist

Emissions Category	Abbr.	CO	NH ₃	NO x	PM ₁ 0	PM ₂ 5	SO ₂	VOC
Large point sources, usually with Title V AOP	POINT	X	X	X	X	X	X	X
Industrial/Commercial/Institutional fuel use	F_ICI	X	X	X	X	X	X	X
Residential non-wood fuel use (home heating)	F_RES	X	X	X	X	X	X	X
Residential wood combustion (home heating)	RWC	X	X	X	X	X	X	X
Residential open burning: yard waste, trash, land clearing	OB_RES	X	X	X	X	X	X	X
Agricultural open burning	OB_AG	X	X	X	X	X	X	X
Prescribed (Silvicultural) open burning	OB_RX	X	X	X	X	X	X	X
Wildfires	WF	X	X	X	X	X	X	X
Aircraft: military, commercial, general aviation	AIR	X		X	X	X	X	X
Recreational boats	BOAT	X	X	X	X	X	X	X
Railroad (locomotives)	RR	X	X	X	X	X	X	X
Ships (commercial marine vessels)	SHIP	X	X	X	X	X	X	X
Nonroad mobile equipment and vehicles (NEC)	NRM	X	X	X	X	X	X	X
Onroad mobile sources	ORM	X	X	X	X	X	X	X
Industrial, commercial, and consumer solvent use	SOLV							X
Gasoline storage and transport	PETROL							X
Paved and unpaved road dust	ROADS				X	X		
Construction Dust	CONST				X	X		
Dust from agricultural tilling and harvesting	TILL_HAR V				X	X		
Livestock	LIVE		X		X	X		X
Fertilizer application	FERT		X					
Food and kindred products	FOOD	X			X	X		X
Natural emissions from soil and vegetation	NAT	X		X				X
Miscellaneous	MISC	X	X	X	X	X	X	X

1.4 Emissions Calculated by EPA

In previous years, it was common for the Dept. of Ecology to estimate emissions for several non-point categories and submit them to EPA for inclusion in the NEI. Dept. of Ecology has typically used the same methods as EPA for calculations, but included updates to the input data assumptions for categories we calculate on our own. Recently, EPA has asked states to only submit new input data and allow EPA to make the emissions calculations. This ensures consistent methodology is used across the country and also allows for EPA to update methodology without need for States to recalculate and resubmit emissions. For the 2020 EI, emissions were calculated by EPA for many more categories than in previous years, but

Ecology submitted the input data for categories as needed. However, there are a few categories that Ecology calculated themselves that differ from the EPA NEI, which are noted in Table 1-2 as “False” in the ECY/EPA Match column. The technical support documents, data, and emission factors for the 2020 NEI are all available from EPA.¹ There are also Nonpoint Emissions Methodology documents (NEMOs) that have more methodology details, which can be provided upon request.

Table 1-2. Emissions Category Notes

Emissions Category	Abbr.	Final Calculation By	Ecology Activity Data	EPA/ECY Match
Large point sources, usually with Title V AOP	POINT	Ecology	N/A	True
Industrial/Commercial/Institutional fuel use [Industrial Wood]	F_ICI	Ecology	True	False
Industrial/Commercial/Institutional fuel use [all other]	F_ICI	EPA	True	True
Residential non-wood fuel use (home heating)	F_RES	EPA	False	True
Residential wood combustion (home heating)	RWC	EPA	True	True
Residential open burning [yard waste, trash]	OB_RES	EPA	True	True
Residential open burning [land clearing]	OB_RES	Ecology	True	True
Agricultural open burning	OB_AG	Ecology	True	True
Prescribed (Silvicultural) open burning	OB_RX	Ecology	True	True
Wildfires	WF	Ecology	True	True
Aircraft: military, commercial, general aviation	AIR	EPA	False	True
Recreational boats	BOAT	Ecology	True	False
Railroad (locomotives) [Line Haul]	RR	EPA	False	True
Railroad (locomotives) [Switch Yards]	RR	Ecology	True	True
Ships (commercial marine vessels)	SHIP	EPA	False	True
Nonroad mobile equipment and vehicles [NEC]	NRM	Ecology	False	False
Onroad mobile sources	ORM	Ecology	True	False
Industrial, commercial, and consumer solvent use	SOLV	EPA	False	True
Gasoline storage and transport [bulk operations]	PETROL	EPA	False	True
Gasoline storage and transport [vehicle refueling]	PETROL	Ecology	True	False
Paved and unpaved road dust [unpaved]	ROADS	Ecology	True	False
Paved and unpaved road dust [paved]	ROADS	EPA	True	True
Construction Dust	CONST	EPA	True	True
Dust from agricultural tilling and harvesting [Tilling]	TILL_HAR V	EPA	True	True
Dust from agricultural tilling and harvesting [Harvesting]	TILL_HAR V	Ecology	True	False
Livestock	LIVE	EPA	False	True
Fertilizer application	FERT	EPA	False	True
Food and kindred products	FOOD	EPA	False	True
Natural emissions from soil and vegetation	NAT	Ecology	N/A	False
Miscellaneous [Structure and Vehicle Fires]	MISC	Ecology	True	True
Miscellaneous [NEC]	MISC	EPA	False	True

2 Statistics Used Throughout the Inventory

2.1 County Demographics

Emissions estimation methods sometimes rely on surrogate parameters as indicators of activity. Population and occupied housing units (OHU) are two of the most common surrogates used. Estimates for 2020 below were obtained from the State Office of Financial Management (OFM).² The demographics are split into unincorporated and incorporated because rural/urban splits were not yet available for the 2020 Census.

Table 2-1. Population and Occupied Housing Units

County	Incorp. Population	Unincorp. Population	Total Population	Incorp. OHU	Unincorp. OHU	Total OHU
Adams	11,141	9,472	20,613	3,873	2,862	6,735
Asotin	8,365	13,920	22,285	3,795	6,239	10,034
Benton	170,317	36,556	206,873	67,266	12,810	80,076
Chelan	46,634	32,507	79,141	20,175	17,092	37,267
Clallam	31,319	45,836	77,155	15,343	22,587	37,930
Clark	270,263	233,048	503,311	110,468	84,568	195,036
Columbia	2,567	1,385	3,952	1,306	884	2,190
Cowlitz	62,391	48,339	110,730	26,229	19,195	45,424
Douglas	19,238	23,700	42,938	7,369	9,949	17,318
Ferry	992	6,186	7,178	531	3,528	4,059
Franklin	83,081	13,668	96,749	25,544	4,196	29,740
Garfield	1,389	897	2,286	713	481	1,194
Grant	54,136	44,987	99,123	20,948	17,687	38,635
Grays Harbor	46,643	28,993	75,636	23,137	12,921	36,058
Island	27,711	59,146	86,857	11,816	30,106	41,922
Jefferson	10,148	22,829	32,977	5,692	13,395	19,087
King	2,023,409	246,266	2,269,675	876,296	92,938	969,234
Kitsap	95,892	179,719	275,611	40,927	72,321	113,248
Kittitas	25,901	20,567	46,468	11,501	12,242	23,743
Klickitat	6,716	16,019	22,735	3,216	7,317	10,533
Lewis	32,688	49,461	82,149	13,665	21,747	35,412
Lincoln	5,586	5,290	10,876	2,611	3,121	5,732
Mason	10,371	55,355	65,726	3,887	29,382	33,269
Okanogan	16,161	25,943	42,104	7,405	14,315	21,720
Pacific	7,602	15,763	23,365	4,104	11,930	16,034
Pend Oreille	3,129	10,272	13,401	1,544	6,394	7,938
Pierce	490,882	430,248	921,130	203,036	156,453	359,489
San Juan	2,613	15,175	17,788	1,454	12,318	13,772
Skagit	76,917	52,606	129,523	31,492	24,252	55,744
Skamania	2,456	9,148	11,604	1,199	4,595	5,794
Snohomish	460,241	367,716	827,957	184,548	136,975	321,523
Spokane	380,815	158,524	539,339	162,826	61,193	224,019
Stevens	9,770	36,675	46,445	4,618	17,624	22,242
Thurston	149,937	144,856	294,793	63,854	57,584	121,438
Wahkiakum	560	3,862	4,422	308	1,881	2,189
Walla Walla	45,500	17,084	62,584	18,429	6,542	24,971
Whatcom	134,187	92,660	226,847	57,901	42,197	100,098
Whitman	42,044	5,929	47,973	18,168	2,754	20,922
Yakima	168,581	88,147	256,728	59,478	31,026	90,504
State Total	5,038,293	2,668,754	7,707,047	2,116,672	1,085,601	3,202,273

3 Base Year 2020 Emissions Estimates

To estimate emissions, four sub-tasks were completed for each source category. The four tasks were: 1) estimate the activity level for 2020, 2) if necessary, adjust/allocate the activity level (or emissions) spatially to the county level, 3) determine emission rates per the activity, and 4) estimate emissions in tons per year (TPY). The tasks are described below for each source category. Emissions estimates are listed in Section 4.

3.1 Point Sources

Industrial, commercial, or institutional stationary sources which emit criteria and/or hazardous air pollutants are called point sources. Major point sources are those with the potential to emit 100 tons per year or more of any one criteria pollutant or a combination of criteria pollutants, and/or point sources with the potential to emit 10 tons per year or more of any single Hazardous Air Pollutant, or 25 tons per year or more of a combination of Hazardous Air Pollutants (Section 112, CAA). Facilities with a major source potential-to-emit are included in Title V Air Operating Permit (AOP) programs unless a facility voluntarily adopts federally enforceable permit limits that reduce their potential-to-emit below the criteria and HAPs thresholds. Facilities that adopt these limits are called Synthetic Minor sources.

Local air agencies, Ecology regional offices, and Ecology's Industrial Section and Nuclear Waste Program (regulating authorities) regulate facilities in their jurisdictions according to state and local regulations and air operating permit programs. Emissions inventories are collected by Ecology annually from the facilities either directly or via the local air agency and EPA. All Title V sources (major) are included in the point source inventory.

EPA augments the point source data using a variety of sources including speciation profiles, the Toxics Release Inventory (TRI), airport reports, railyard estimates, landfill models, and other sources. Some of the augmented data was not accepted into Ecology's final inventory due to the possibility of double-counting emissions from sources. For instance, rail yards and airports were separated out of the EPA point source inventory. The final point source inventory is a combination of state, local, and federal estimates that represents a mutually exclusive list of point sources not represented in the other categories. The emissions for each individual point source in this category are available at:

<https://ecology.wa.gov/Air-Climate/Air-quality/Air-quality-targets/Air-emissions-inventory>

3.1.1 Activity Level

Individual facility throughputs and production rates determine the activity level for each facility.

3.1.2 Spatial Allocation

Point sources are allocated to counties based on their address or geographic coordinates.

3.1.3 Emission Rates and Estimates

Emissions estimates for each facility are calculated using a variety of emissions estimation methods: continuous emissions monitors, stack test data, mass balance, best professional judgment, manufacturer's specifications, speciation profiles, EPA emission factors (e.g., AP-42), and/or other state, manufacturer, or research group emission factors. Methods are selected considering permit conditions, data availability, and resource constraints.

3.2 Onroad Mobile Sources

Onroad mobile source emissions are those generated by operating vehicles on public roadways. Emissions from fuel combustion and evaporation, and brake and tire wear were estimated. VOC emissions due to spillage and vapor displacement during refueling were calculated as part of the onroad methodology, but are included as part of the Gasoline Storage and Transport category (PETROL).

EPA's Motor Vehicle Emission Simulator (MOVES) model version 3.0 with database version 20220105 was used to calculate emissions. MOVES combines basic vehicle activity information with information about vehicle and fuel characteristics, emissions control programs, meteorological information, and other parameters to estimate emissions. The basic activity data are vehicle miles traveled (VMT) and vehicle population.

VMT, vehicle population, and a brief description of the MOVES input parameters are described below. The MOVES Technical Guidance for SIP inventories and the MOVES Overview were used in developing many of the inputs to MOVES.^{3, 4} Detailed information about the MOVES input parameters is in a separate document.

Emissions were generated for the four seasons by choosing one month from the representative season to run – January for winter, April for spring, July for summer, and October for fall.

The MOVES3 default fleet includes no electric vehicles. MOVES3 allows users to input an appropriate fraction of electric vehicles. Ecology updated the fraction of electric vehicles as well as other vehicles based on the Washington State Department of Licensing registration data. It should be noted that there are no emission rates in MOVES3 for some vehicle types like electric motorcycles and electric motor homes. Emissions from those combinations are so small that can be negligible.

3.2.1 Vehicle Miles Traveled (VMT)

VMT are used in MOVES to calculate emissions while the vehicle is in motion or during short periods of idling. The source of county VMT data for 2020 used in this inventory was the Washington State Department of Transportation (WSDOT) under the national Department of Transportation's Highway Performance Monitoring System (HPMS).⁵ HPMS is a system of traffic counts collected over several urban and rural sampling areas. WSDOT makes estimates of county VMT by roadway (functional) classification using the HPMS data (see Table 3-1 for rural roads and Table 3-2 for urban roads).

3.2.2 Vehicle Population

Vehicle population is used to calculate emissions while a vehicle is stationary. The emissions come from engine starts, extended idling, and some fuel evaporation processes. Vehicles are classified by age and type. There are thirteen vehicle types in MOVES within six broader categories: cars, motorcycles, light-duty trucks, heavy-duty single unit trucks, heavy-duty combination unit trucks, and buses.

Three sources were used to calculate vehicle population (see Table 3-3). The first was the Washington State Department of Licensing (DOL). DOL registers non-governmental vehicles annually.⁶ Government vehicles have a one-time registration. DOL does not register public transit and school buses each year, so alternate sources of information were used. Transit and intercity bus data came from the MOVES default database. School bus information for 2020

was obtained from the Washington State Office of the Superintendent of Public Instruction (OSPI).⁷

Table 3-1. Average Daily VMT for Rural Roads

(All Values in Thousands)

County	Interstate	Other Freeway / Expressway	Other Principal Arterial	Minor Arterial	Major Collector	Minor Collector	Local
Adams	592	478	0	0	151	42	89
Asotin	0	22	0	16	24	9	20
Benton	690	0	0	231	119	82	40
Chelan	0	238	339	235	163	38	57
Clallam	0	48	316	1	349	88	51
Clark	640	4	36	166	361	101	45
Columbia	0	0	74	0	56	9	30
Cowlitz	1,316	0	43	162	159	51	63
Douglas	0	148	178	45	74	30	101
Ferry	0	0	27	46	117	17	94
Franklin	0	533	0	0	208	55	55
Garfield	0	2	78	0	33	18	22
Grant	615	335	91	350	348	154	158
Grays	0	205	265	230	210	49	67
Island	0	18	358	128	105	100	33
Jefferson	0	140	300	113	88	88	57
King	1,117	295	325	485	480	293	54
Kitsap	0	157	228	63	255	54	25
Kittitas	2,176	0	169	5	165	77	99
Klickitat	0	28	252	69	180	27	82
Lewis	544	102	261	192	264	53	90
Lincoln	284	73	87	75	128	18	116
Mason	0	196	335	43	308	63	43
Okanogan	0	221	123	325	191	127	240
Pacific	0	15	178	168	167	24	56
Pend	0	45	71	111	44	27	63
Pierce	300	0	24	593	189	39	68
San Juan	0	0	0	0	88	41	17
Skagit	788	105	116	269	453	91	58
Skamania	0	19	164	42	61	22	41
Snohomish	609	101	278	506	311	149	64
Spokane	332	326	227	237	585	175	129
Stevens	0	142	273	100	258	68	189
Thurston	510	237	37	176	443	52	63
Wahkiakum	0	0	67	0	23	3	18
Walla Walla	0	135	223	112	135	28	41
Whatcom	346	18	76	179	657	127	65
Whitman	0	205	259	8	213	35	110
Yakima	731	27	188	157	623	150	249
State Total	11,589	4,616	6,067	5,635	8,787	2,674	2,963

Table 3-2. Average Daily VMT for Urban Roads*(All Values in Thousands)*

County	Interstate	Other Freeway/ Express	Other Principal Arterial	Minor Arterial	Major Collector	Minor Collector	Local
Adams	0	21	0	29	8	2	18
Asotin	0	6	42	85	26	0	20
Benton	567	580	601	616	320	25	317
Chelan	0	138	150	242	70	2	81
Clallam	0	60	263	80	123	20	82
Clark	1,799	1,133	1,241	1,007	393	33	689
Columbia	0	0	0	0	0	0	0
Cowlitz	562	84	263	283	112	2	148
Douglas	0	153	147	74	39	1	52
Ferry	0	0	0	0	0	0	0
Franklin	392	187	153	164	71	2	131
Garfield	0	0	0	0	0	0	0
Grant	101	126	117	173	51	7	94
Grays	0	228	297	82	122	20	110
Island	0	0	156	148	47	8	54
Jefferson	0	0	54	0	53	0	32
King	11,193	4,298	7,991	6,190	2,736	87	3,824
Kitsap	0	1,528	642	708	294	23	405
Kittitas	101	3	82	65	33	8	25
Klickitat	0	0	0	0	0	0	0
Lewis	799	0	111	161	47	7	59
Lincoln	0	0	0	0	0	0	0
Mason	0	44	127	9	62	0	30
Okanogan	0	21	0	49	4	9	21
Pacific	0	0	0	0	0	0	0
Pend Oreille	0	0	0	0	0	0	0
Pierce	2,905	2,750	3,825	2,892	967	9	1,741
San Juan	0	0	0	0	0	0	0
Skagit	392	161	317	352	160	6	170
Skamania	0	0	0	0	0	0	0
Snohomish	4,188	1,344	2,357	1,808	988	26	1,412
Spokane	1,904	285	2,669	1,298	410	37	821
Stevens	0	0	0	0	0	0	0
Thurston	1,636	356	742	928	284	4	486
Wahkiakum	0	0	0	0	0	0	0
Walla Walla	0	169	118	140	48	1	59
Whatcom	714	6	377	565	347	16	265
Whitman	0	0	99	43	36	8	24
Yakima	552	286	748	647	268	22	303
State Total	27,805	13,967	23,689	18,840	8,120	385	11,470

Table 3-3. Vehicle Population, 2020

County	Motorcycles	Cars	Light Trucks	Buses	Single Unit Trucks	Combination Unit Trucks	Total
Adams	388	8,867	10,861	174	730	115	21,135
Asotin	840	9,409	11,526	46	941	127	22,889
Benton	6,654	87,253	106,879	535	7,879	1,156	210,356
Chelan	3,402	36,332	44,503	239	3,214	447	88,137
Clallam	2,710	34,830	42,664	207	3,659	432	84,502
Clark	13,554	204,193	250,121	1,162	17,300	2,807	489,137
Columbia	158	1,872	2,293	23	169	24	4,539
Cowlitz	3,964	51,099	62,593	485	4,427	621	123,189
Douglas	1,615	18,784	23,009	149	1,727	246	45,530
Ferry	258	3,486	4,270	46	361	44	8,465
Franklin	1,960	39,721	48,654	318	3,306	544	94,503
Garfield	58	1,058	1,296	19	101	13	2,545
Grant	2,834	43,111	52,807	427	3,927	563	103,669
Grays Harbor	2,415	32,816	40,197	266	3,046	420	79,160
Island	4,538	42,010	51,459	157	3,697	481	102,342
Jefferson	1,419	16,277	19,939	106	1,657	181	39,579
King	42,761	790,405	968,183	4,471	69,536	12,709	1,888,065
Kitsap	11,678	116,758	143,019	579	10,591	1,531	284,156
Kittitas	2,165	20,658	25,304	301	2,056	271	50,755
Klickitat	948	11,248	13,778	125	949	128	27,176
Lewis	3,191	41,628	50,990	347	3,416	451	100,023
Lincoln	446	5,489	6,723	133	525	62	13,378
Mason	3,099	32,691	40,043	235	3,089	369	79,526
Okanogan	1,320	18,704	22,911	170	1,711	243	45,059
Pacific	774	11,020	13,498	114	1,039	123	26,568
Pend Oreille	557	6,850	8,391	64	670	77	16,609
Pierce	27,006	344,047	421,429	2,106	31,386	5,064	831,038
San Juan	856	9,381	11,491	22	734	98	22,582
Skagit	5,201	60,961	74,673	452	5,595	734	147,616
Skamania	497	6,064	7,429	47	534	69	14,640
Snohomish	26,192	326,827	400,337	1,844	28,748	4,668	788,616
Spokane	16,782	209,536	256,664	1,207	19,425	2,938	506,552
Stevens	1,978	23,216	28,438	210	2,119	258	56,219
Thurston	10,738	126,632	155,115	797	11,094	1,636	306,012
Wahkiakum	146	2,254	2,761	20	203	24	5,408
Walla Walla	2,105	24,468	29,971	176	2,323	351	59,394
Whatcom	7,143	96,322	117,986	522	9,804	1,282	233,059
Whitman	1,010	14,861	18,203	183	1,670	284	36,211
Yakima	5,406	110,813	135,737	712	9,517	1,452	263,637
State Total	218,766	3,041,951	3,726,145	19,196	272,875	43,043	7,321,976

3.2.3 MOVES Input Parameters

MOVES includes a default database that summarizes emissions relevant information for all counties in the United States. Default data may be replaced by local data to improve the estimates. Ecology developed local data for many of the parameters in MOVES.

Input parameters were developed that were characteristic of local conditions for each county and month. Some of the parameters presented here required local data. For others, EPA guidance recommended that local data be used. The parameters are shown in the table below. Note that Pierce County is known to have a transit bus system that uses Compressed Natural Gas, which was updated in the MOVES parameters. Also, Clark County fuel parameters were changed to use Oregon's fuel formulation.

Table 3-4. MOVES Model Parameters

MOVES Table	Parameter	Data Source	References
sourcetypeyear, avft	Vehicle population	DOL, OSPI, FTA	6, 7, 8
hpmsvtypeyear	VMT	WSDOT and MOVES	5, 8
hourvmtfraction, dayvmtfraction, monthvmtfraction	Temporal allocation to month, day, and hour	WSDOT and MOVES	9
moves3_levs_wa	California Emissions Standards	MOVES	10
fuelsupply, fuelformulation, fuelusagefraction	Fuel parameters	MOVES	N/A
zonemonthhour	Hourly temperatures and relative humidity	MOVES	N/A
roadtypedistribution	Road type distribution	WSDOT and MOVES	5, 8
sourcetypeagedistribution	Vehicle age distribution	DOL, OSPI, FTA	6, 7, 8
avgspeeddistribution	Speeds	MOVES Default	N/A
refuelingfactors	Vehicle refueling	MOVES Default	N/A

3.2.4 Road Dust

Dust emissions are generated as vehicles pass along roadways and disturb the layer of loose material on or near the road surface. This material contains particulate matter from soil, brake and tire wear, exhaust, and other substances. However, the road dust calculation excludes emissions from exhaust and brake and tire wear, which are estimated as part of the onroad mobile sources emissions. Road dust is not calculated by MOVES, but the calculations do use VMT inputs as the basis. Paved road VMT was obtained from a WSDOT HPMS report for 2020, which included rural/urban and functional road class categories, shown in the tables above. Note that the HPMS Average Daily VMT (ADVMT) estimate includes travel over both paved and unpaved roads; however, they are not distinguished from one another. A slight

overestimation of ADVMT does occur when using HPMS ADVMT as the paved road activity level. The overestimation is not significant, though, since unpaved ADVMT is only estimated to be 0.5% of the entire ADVMT. Unpaved road VMT was pulled forward from the 2017 Comprehensive EI (see Table 3-5). Both paved and unpaved VMT was submitted to EPA for calculations, which are explained in detail in the EPA NEI TSD¹. However, Ecology made an error in the VMT submittal to EPA and had to correct the emissions estimates which are not reflected in the NEI.

Table 3-5. ADVMT on Unpaved Roads – Total of County and City Jurisdictions

County	VMT
Adams	35,827
Asotin	6,599
Benton	12,410
Chelan	6,523
Clallam	806
Clark	1,049
Columbia	15,577
Cowlitz	281
Douglas	73,826
Ferry	19,040
Franklin	35,518
Garfield	18,463
Grant	62,617
Grays Harbor	3,733
Island	169
Jefferson	4,670
King	55,866
Kitsap	3,619
Kittitas	4,254
Klickitat	16,153
Lewis	2,173
Lincoln	49,632
Mason	2,969
Okanogan	30,731
Pacific	3,938
Pend Oreille	21,194
Pierce	3,270
San Juan	1,454
Skagit	2,821
Skamania	1,400
Snohomish	1,750
Spokane	108,113
Stevens	44,644
Thurston	4,813
Wahkiakum	743
Walla Walla	13,043
Whatcom	5,048

County	VMT
Whitman	51,997
Yakima	58,457
State Total	785,189

3.3 Construction Dust

Construction dust was estimated by the EPA Nonpoint Methods Advisory Committee (NOMAD) for road construction, residential construction, and nonresidential construction. Construction dust emissions are based on the total amount of soil disturbed. Additionally, each of the three categories had emissions corrected using silt content and soil moisture parameters. EPA used the National Cooperative Soil Survey to develop county-level silt content values and Ecology provided soil moisture parameters derived from 22 airport weather stations across the state.

3.3.1 Activity Level

Road construction activity was estimated by EPA using the Federal Highway Administration's Highway Statistics for New Construction, Relocation, Added Capacity, Major Widening, and Minor Widening. These categories were also differentiated according to the road type. The State expenditure data were then converted to new miles of road constructed using \$/mile conversions obtained from the Florida Department of Transportation (FLDOT) Cost Per Mile model for 2020. A conversion of \$9.6 million/mile is applied to the urban interstate expenditures and a conversion of \$4.8 million/mile is applied to the rural interstate expenditures. For expenditures on other urban arterial and collectors, a conversion factor of \$4.8 million/mile is applied. For expenditures on other rural arterial and collectors, a conversion factor of \$2.6 million/mile is applied. The new miles of road constructed are used to estimate the acreage disturbed due to road construction. The total area disturbed in each state is calculated by converting the new miles of road constructed to acres using an acres disturbed/mile conversion factor for each road type which ranges from 6.6 to 11.4 acres disturbed per mile of constructed road.

Residential construction activity was estimated by EPA using acres of surface soil disturbed and volume of soil removed for basements. Surface soil disturbed was estimated using the 2020 *New Privately Owned Housing Units Started by Purpose and Design*.¹¹ dataset from the US Census Bureau. The amount of soil removed were assumed to be ¼ acre, 1/3 acre, and ½ acre for 1-unit, 2-unit, and apartment structures, respectively. To calculate basement soil removal, the 2020 table of *Characteristics of New Single-Family Houses Completed, Foundation*.¹² was used by EPA to estimate the percentage of 1 unit structures that have a basement (on the regional level). The county level estimate of number of 1-unit starts was multiplied by the percent of 1 unit houses in the region that have a basement to get the number of basements in a county. Basement volume was calculated by assuming a 2000 square foot house has a basement dug to a depth of 8 feet (making 16,000 ft³ per basement). An additional 10% is added for peripheral dirt bringing the total to 17,600 ft³ (651.85 yd³) per basement.

Non-residential construction activity was estimated by EPA using acres disturbed and were estimated by multiplying the value of non-residential construction put in place (obtained from the US Census Bureau) by the number of acres disturbed per million dollars. EPA used a factor of 0.84 acres/\$1 million to convert from dollars to acres disturbed.

3.3.2 Spatial Allocation

Building permits were used by EPA to allocate the state-level acres disturbed by road construction to the county level. A ratio of the number of building starts in each county to the total number of building starts in each state was applied to the state-level acres disturbed to estimate the total number of acres disturbed by road construction in each county.

Residential construction activity data was already at the county level, so no spatial adjustment was needed.

The national value of non-residential construction put in place was allocated to counties using county-level non-residential construction employment data obtained from the US Census Bureau.

3.3.3 Emission Rates

Initial PM₁₀ emissions from construction of roads were calculated by EPA using an emission factor of 0.42 tons/acre-month. This emission factor represents the large amount of dirt moved during the construction of roadways, reflecting the high level of cut and fill activity that occurs at road construction sites. The duration of construction activity for road construction is assumed to be 12 months.

Initial PM₁₀ emissions from construction of residential structures were calculated using emission factors that ranged from 0.032 tons PM₁₀/acre-month (1-unit structures without basements) to 0.11 tons PM₁₀/acre-month (apartments). The duration of construction activity for houses was assumed to be 6 months and the duration of construction for apartments was assumed to be 12 months.

Initial PM₁₀ emissions from construction of non-residential buildings were calculated by EPA using an emission factor of 0.19 tons/acre-month. The duration of construction activity for non-residential construction is assumed to be 11 months.

Regional variances in construction emissions were corrected using soil moisture level and silt content. To account for the silt content, the PM₁₀ emissions are weighted using average silt content for each county. EPA used the National Cooperative Soil Survey Microsoft Access Soil Characterization Database to develop county-level, average silt content values for surface soil. To account for the soil moisture level, the PM₁₀ emissions were weighted using a county-specific 30-year average precipitation-effectiveness (PE) value calculated by Ecology. Table 3-6 shows the PE Index values submitted by Ecology.

3.3.4 Emissions Estimates

The equation for PM₁₀ emissions corrected for soil moisture and silt content is:

$$Corrected E_{PM10} = Initial E_{PM10} \times \frac{24}{PE} \times \frac{S}{9\%}$$

where:

Corrected E_{PM10} = PM₁₀ emissions corrected for soil moisture and silt content,
PE = precipitation-evaporation value for each county,
S = % dry silt content in soil for area being inventoried.

Once PM₁₀ adjustments were made, PM_{2.5} emissions were set to 10% of PM₁₀.

Table 3-6. Precipitation Effectiveness Index Values

County	PE-Index
Adams	17.6
Asotin	28.2
Benton	14.5
Chelan	18.9
Clallam	87.5
Clark	92.5
Columbia	41.5
Cowlitz	99.7
Douglas	18.9
Ferry	41.7
Franklin	14.5
Garfield	28.2
Grant	17.6
Grays Harbor	182.9
Island	96.5
Jefferson	87.5
King	113.2
Kitsap	159.5
Kittitas	20.2
Klickitat	37.6
Lewis	99.7
Lincoln	17.6
Mason	216.4
Okanogan	41.7
Pacific	182.9
Pend Oreille	41.7
Pierce	113.2
San Juan	22.3
Skagit	96.5
Skamania	92.5
Snohomish	96.5
Spokane	48.4
Stevens	41.7
Thurston	142.5
Wahkiakum	99.7
Walla Walla	41.5
Whatcom	87.7
Whitman	60.3
Yakima	18.0

3.4 Nonroad Mobile Vehicles and Equipment (NEC)

Nonroad mobile emissions estimates account for exhaust from nonroad mobile vehicles and equipment that combust fuel. However, nonroad mobile emissions for commercial ships, seaport support equipment, locomotives, and aircraft are estimated separately and thus not included here. Each nonroad sector includes multiple equipment types and horsepower classes. The sectors included in Ecology's nonroad mobile category and corresponding examples are listed in the table below. Note that recreational marine vessels are discussed here but their emissions are listed separately in the BOAT category.

Table 3-7. Sectors Included in Ecology's Nonroad Mobile Category

Sector	Examples
Agricultural Equipment	Tractors, Combines, Tillers, etc.
Airport Support Equipment	Ground Support, Servicing Aircraft
Commercial Equipment	Pumps, Compressors, Welders, etc.
Construction Equipment	Crushers, Pavers, Backhoes, etc.
Industrial Equipment	Forklifts, Scrubbers, Tractors, etc.
Lawn and Garden Equipment	Chainsaws, Blowers, Lawn Mowers, etc.
Logging Equipment	Chainsaws, Shredders, etc.
Oil Field Equipment	Pumps, Tanks, Pipelines, etc.
Pleasure Craft	Pleasure Craft, Personal Boats
Railroad Maintenance Equipment	Railway Maintenance Equipment
Recreational Equipment	Snowmobiles, ATVs, Golf Carts, etc.
Underground Mining Equipment	Trucks, Loaders, Shovels, etc.

EPA's Motor Vehicle Emission Simulator (MOVES) model version 3.0 with database version 20220105 was used to estimate nonroad emissions. MOVES combines basic nonroad activity information with information about equipment, vehicle and fuel characteristics, emissions control programs, meteorological information, and other parameters to estimate emissions.

3.4.1 MOVES Input Parameters

MOVES includes a default database that summarizes emissions-relevant information for all counties in the United States. Default data may be replaced by local data to improve the estimates. Default data was used for all parameters except the recreational marine vessel spatial surrogate. Note that despite using the same defaults as EPA, and EPA using the updated spatial surrogates, Ecology values do not exactly match EPA NEI since Ecology simulated seasons.

The default surrogate for recreational marine vessels is water surface area. Water surface area can overestimate recreational boat usage in counties with large areas of open water (e.g., Clallam). Spatial allocation from state to county was not based on defaults (water area) and

instead based on county boat registrations. Boat registrations for 2017 were provided by the Washington Department of Licensing¹³, shown in Table 3-8.

3.4.2 Emission Rates

Emissions were generated by the model for the four seasons by choosing one month from the representative season to run – January for winter, April for spring, July for summer, and October for fall.

Table 3-8. Boats Registered

County	Inboard	Outboard
Adams	15	436
Asotin	23	812
Benton	402	6,696
Chelan	339	3,869
Clallam	655	2,748
Clark	809	11,119
Columbia	5	142
Cowlitz	310	4,235
Douglas	105	1,985
Ferry	29	353
Franklin	111	2,469
Garfield	4	94
Grant	172	4,288
Grays Harbor	198	2,219
Island	1,127	4,196
Jefferson	853	1,647
King	10,090	34,574
Kitsap	2,621	7,412
Kittitas	121	1,473
Klickitat	53	593
Lewis	221	2,290
Lincoln	102	980
Mason	539	3,768
Okanogan	85	1,464
Pacific	166	800
Pend Oreille	30	998
Pierce	3,433	19,238
San Juan	1,168	1,385
Skagit	1,844	5,165
Skamania	35	398
Snohomish	4,112	19,291
Spokane	661	14,215
Stevens	198	3,124
Thurston	1,328	7,141
Wahkiakum	63	346
Walla Walla	71	1,447
Whatcom	2,200	5,515

County	Inboard	Outboard
Whitman	37	920
Yakima	245	4,628
State Total	34,580	184,473

3.5 Locomotives

Emissions from Class I line-haul and switch yard locomotives were estimated using EPA guidance and information from the railroads. U.S. Class I railroads are line-haul freight railroads with operating revenue in excess of \$250 million or more after applying the revenue deflator formula which adjusts for inflation using the Railroad Freight Price Index relative to 1991 (\$900.0 million in 2020).^{14, 15, 16, 17, 18} The Class I railroads that operate in Washington are Burlington Northern Santa Fe Railway (BNSF) and Union Pacific Railroad (UP). Amtrak passenger train emissions were also included in this inventory. Note that EPA estimated Class I, 2 and 3 line-haul locomotive emissions as part of the 2020 NEI, which was accepted by Ecology. Ecology calculated switch yard locomotive emissions.

3.5.1 Activity Level

Activity level is measured in gallons of diesel consumed by locomotives. BNSF provided 2020 fuel use for switch yard locomotives by location, summarized in Table 3-9.¹⁹ Amtrak and UP have switch yards in King and Pierce County, but did not provide fuel use data. Ecology used EPA's switch yard locomotive fuel estimates for King and Pierce counties, which included all three railroads.

Table 3-9. BNSF Switch Yard Locomotives Fuel Consumption (gallons)

County	Fuel Consumption (gallons)
Benton	4870
Chelan	13840
Clark	195,020
Cowlitz	35,590
Franklin	723,330
Grant	1230
King	1,156,246
Klickitat	4390
Lewis	23,040
Lincoln	2880
Pierce	1,099,596
Skagit	1,980
Skamania	1400
Snohomish	195,910
Spokane	438,150
Stevens	2,270
Walla Walla	2,260
Whatcom	18,380
Yakima	185,250
State Total	4,105,632

3.5.2 Emission Rates

Emission factors (shown in Table 3-10) were taken from EPA documentation.²⁰

Table 3-10. Switch Yard Locomotives Emission Factors (grams per gallon of fuel consumed)

Pollutant	Emission Factor (g/gal)
Volatile Organic Compounds	12.97662
Carbon Monoxide	27.816
Nitrogen Oxides	199.83548
PM _{2.5}	5.0870182
PM ₁₀	5.2443486
Sulfur Dioxide	0.0939
Ammonia	0.0833

3.5.3 Emissions Estimates

For switch yard locomotives emissions calculated with emission factors, the equation used was:
$$TPY = (\text{fuel use in gallon}) \times (\text{emission factor in g/gal of fuel}) \times 1.1\text{E-}6 \text{ tons/gram}$$

3.6 Silvicultural Burning (Prescribed Burning)

Silvicultural burning, also discussed as prescribed burning, includes rangeland burns, logging debris burns and forest health burns. It does not include land clearing nor agricultural burns. Silvicultural burning is done by the Department of Natural Resources (DNR), Department of Fish & Wildlife (WDFW), U.S. Forest Service (USFS), Bureau of Indian Affairs (BIA), Bureau of Land Management (BLM), US Fish and Wildlife Service (USFWS), and private industry.

3.6.1 Activity Level and Emission Rates

Prescribed burns are conducted either as pile burns, understory burns, or broadcast burns. Activity for pile burns is reported as tons of material burned while understory and broadcast burns are reported as “acres burned” and have a corresponding fuel loading (tons/acre) from which tons of material burned is calculated. Emissions for silvicultural burns were calculated using historical emission factors that were applied to the tonnage burned.

The amount and type of material burned was primarily obtained from the DNR completed burns database. Burn permits were not available for prescribed burns done by the BIA. Furthermore, the DNR completed burns database was incomplete and contained errors, for which some gap-filling was done based on DNR planned burn database and HMS satellite hot-spot detects. Some prescribed burn location data was also obtained from EPA, based on HMS satellite detected hot-spots, Forest Service Activity Tracking System (FACTS) database, and the USFWS database. The HMS locations and prescribed burn data from EPA was spatiotemporally cross-checked against the DNR data to avoid double-counting. All HMS and EPA data added to the prescribed burn database were assumed to be 100 tons (the maximum burn size allowed without a DNR permit).

Table 3-11. Silvicultural Burning Emission Factors (pounds per ton consumed)

Pollutant	EF
PM ₁₀	15.5
PM _{2.5}	13.5
CO	76
NO _x	4
VOC	19
SO ₂	0.1

3.6.2 Spatial Adjustments

No spatial adjustments were necessary. All burns were identified either by their coordinates or by county and Public Land Survey System (PLSS) legal description (i.e. section-township-range).

3.6.3 Emissions Estimates

Prescribed burn emissions were calculated assuming 100% combustion completeness:

$$TPY = (\text{tons burned}) \times (\text{pollutant lb/T}) \times (1 \text{ T}/2000 \text{ lb})$$

Table 3-12. Silvicultural Burning Activity

County	Forest Burns (Tons)	Rangeland Burns (Tons)
Adams		400
Asotin	100	
Benton		2,000
Chelan	2,824	
Clallam	16,654	
Clark	1,893	
Columbia	319	
Cowlitz	5,879	
Douglas	1,898	300
Ferry	43,138	
Franklin		100
Garfield		
Grant		600
Grays Harbor	23,917	
Island	130	
Jefferson	11,207	
King	756	
Kitsap		
Kittitas	1,320	1,000
Klickitat	30,259	200
Lewis	17,878	
Lincoln	700	200
Mason	3,750	
Okanogan	9,654	
Pacific	6,571	
Pend Oreille	14,173	
Pierce	9,010	
San Juan	216	
Skagit	15,601	
Skamania	3,775	
Snohomish	6,956	
Spokane	11,498	
Stevens	41,481	
Thurston	1,130	
Wahkiakum	811	
Walla Walla		600
Whatcom	12,924	
Whitman		100
Yakima	15,941	900
State Total	312,363	6,400

3.7 Wildfires

Wildfire emissions were initially estimated for the 2020 EPA NEI by an EPA contractor. The Satellite Mapping Automatic Reanalysis Tool for Fire Incident Reconciliation (SMARTFIRE) v2 was used to estimate fire location and size, while the BlueSky Pipeline modeling framework was used to estimate the resultant emissions. The EPA effort used SMARTFIRE v2 to combine fire locations reported by the following sources: Incident Command Summary (ICS-209) reports, the National Oceanic and Atmospheric Administration (NOAA) Hazard Mapping System (HMS), the National Wildfire Coordinating Group (NWCG) National Incident Feature Service (NIFS), the US Fish and Wildlife Service (USFWS) prescribed burn database, and the Department of Interior (DOI) Integrated Reporting of Wildland Fire Information (IRWIN) database. All fire locations detected by HMS that were within the boundaries of the USDA Cropland Data Layer (CDL) were classified as agricultural burns, except for pasture land. All remaining fire locations detected by HMS were classified as wildfire if they occurred between July 6 and September 20 and there was no other information available.

3.7.1 Activity Level

Ecology reviewed the EPA's wildfire and prescribed fire emissions estimates and found many errors with fire type, location, and size. Some of these errors occurred presumably due to complications with SMARTFIRE, which was not developed to handle many sources of input. Other errors occurred because EPA removed data sources: HMS fire locations were removed if snow was on the ground, the National Interagency Fire Center (NIFC) perimeters were not used, and all HMS fire locations were moved to agricultural fire if they occurred on cropland. The EPA wildfire emissions data was corrected after crosschecking against InciWeb reports, the WildCAD online system, DNR prescribed burn reports, HMS fire locations, and perimeters from NIFC. The county level estimate of wildfire area burned is shown in Table 3-13. Washington's largest wildfires in 2020 are shown in Table 3-14.

3.7.2 Spatial Adjustments

No spatial adjustments were necessary. All fire locations were identified by their coordinates.

3.7.3 Emissions Estimates

The BlueSky modeling framework incorporates a variety of modeling components to determine emissions. This effort simulated emissions in BlueSky using the following model pathway: the Fuel Characteristic Classification System (FCCS) v3 to determine fuel loading, the Consume v5 model to estimate the percentage of fuels consumed, and the Fire Emission Production Simulator (FEPS) v2 to estimate total emissions by pollutant type. EPA used the BlueSky default fuel moisture settings, so emissions scale linearly with area burned for each fuel type. The EPA BlueSky emissions were used for kept locations and to derive emission factors (lbs/acre burned by fuel type) to be used for additional fire locations. Fire locations that weren't in the original EPA dataset were assigned a representative fuel type for the region of interest, so that emissions could be calculated.

Table 3-13. Wildfire Area Burned by County (acres)

County	Area Burned
Adams	801
Asotin	57
Benton	5,419
Chelan	14,230
Clallam	91
Clark	274
Columbia	501
Cowlitz	102
Douglas	231,514
Ferry	21,679
Franklin	23,010
Garfield	0
Grant	9,636
Grays Harbor	6
Island	0
Jefferson	29
King	132
Kitsap	3
Kittitas	19,298
Klickitat	488
Lewis	35
Lincoln	125,884
Mason	13
Okanogan	223,489
Pacific	3
Pend Oreille	168
Pierce	1,840
San Juan	1
Skagit	15
Skamania	24,209
Snohomish	5,716
Spokane	1,298
Stevens	559
Thurston	645
Wahkiakum	2
Walla Walla	394
Whatcom	106
Whitman	34,822
Yakima	96,707
State Total	843,177

Table 3-14. Largest Wildfires in Washington

Fire Name	Area Burned (Acres)	Counties
Anglin	1,992	Okanogan
Apple Acres	5,752	Chelan
Babb-Malden	15,269	Spokane, Whitman
Beverly Burke	920	Grant
Big Hollow	24,995	Skamania
Chief Timothy	1,400	Whitman
Chikamin	2,151	Chelan
Cold Springs	189,923	Okanogan
Colockum	2,967	Chelan
Customs Road	2,208	Ferry
Downey Creek	3,166	Snohomish
Evans Canyon	75,817	Kittitas, Yakima
Green	1,480	Okanogan
Greenhouse	5,320	Okanogan
Inchelium Highway	7,120	Ferry
Kahlotus	22,000	Franklin
Kewa Field	11,797	Ferry
Konnowac	1,083	Yakima
Lower Coyote Creek	2,582	Okanogan
Manning Rd.	2,685	Whitman
North Brownstown 2	884	Yakima
North Brownstown 3	5,981	Yakima
Palmer	17,988	Okanogan
Paterson	1,460	Benton
Pearl Hill	223,730	Douglas
Road 11	9,330	Douglas
Saddle Mountain	8,063	Grant
Taylor Pond	24,892	Yakima
Tule Road	702	Yakima
Whitney	127,430	Lincoln

3.8 Agricultural Burning

Agricultural burning in Washington is defined as "the burning of vegetative debris from an agricultural operation necessary for disease or pest control, necessary for crop propagation and/or crop rotation, or where identified as a best management practice by the agricultural burning practices and research task force established in RCW [Revised Code of Washington] 70.94.650 or other authoritative source on agricultural practices."²¹ All agricultural burning in Washington requires a permit by law, but compliance is not 100%. In addition to the agricultural burn permits obtained, satellite-detected hot-spot data for agricultural land was obtained from NOAA HMS. The burn data for agricultural land from HMS was spatiotemporally cross-checked against the permit data for redundancy. Duplicate HMS locations from the same date and location were removed. It is noted here that in Chelan, Douglas, Kittitas, Klickitat, and Okanogan Counties some orchards are removed but not replanted and thus do not qualify for agricultural burning permits. Emissions from these tear-outs are not consistently included in the inventory due to lack of permits and dependence on satellite detection.

3.8.1 Activity Level

The activity level for agricultural burning is the amount of residue consumed. The general equation and sources of each parameter are described below.

$$\begin{aligned} \text{tons consumed} &= \text{acres burned} \times \text{fuel loading (tons/acre)} \times \text{combustion completeness} \\ \text{or} \\ \text{tons consumed} &= \text{tons burned} \times \text{combustion completeness factor} \end{aligned}$$

Acres or Tons Burned

Department of Ecology Central and Eastern Regional Offices (CRO, ERO)

The Department of Ecology maintains the Air Quality Program Permit System (AQPPS) database. The permits include crop type, general location (legal description), and permit issue date. Pile burn permits include the amount of material burned in tons while field burn permits include acreage and fuel loading estimates.²² Permits issued in 2020 were selected for this inventory.

Yakima Regional Clean Air Agency (YRCAA) Permits

AQPPS does not contain information for counties outside of Ecology air jurisdiction. Permit information was obtained for Yakima County from YRCAA, but fuel type and location were not included, so general crop-type emission factors were used.

Satellite-Detected Hot-Spots

Satellite hot spot detects from NOAA HMS that were added to the agricultural burning data were assumed to be a 120-acre burn (EPA default). The 2020 Washington State Department of Agriculture Land Use GIS data was used to determine crop type for locations acquired from HMS.

Fuel Loading

The overall average loading factor for wheat field burns was 4.2 tons/acre. This is comparable to the 4 tons/acre average found in a special study performed by Air Sciences Incorporated.²³ Air Sciences Incorporated performed a field study funded by Ecology, the Washington Association of Wheat Growers, and the US EPA-Region 10 to measure emissions and develop emission rates for wheat stubble field burning. The loading factor was 0.7 tons/acre higher than the wheat field loading factor of 3.2 tons/acre in AP42 (adjusted for fuel consumption).

The agricultural burn permit database included a loading factor for each field burn. For burns detected by satellite, the default fuel loading of 1.9 tons/acre was used, except for corn (4.2 tons/acre). Overall average fuel loading and combustion completeness for field burns is shown in the table below for the following crop groups: barley; beans; corn; fallow land; hay, grass, pasture and Conservation Reserve Program (CRP) land; potatoes, wheat (including triticale), and all other field crops.

Table 3-15. Average Fuel Loading for Agricultural Field Burns

Crop Group	Fuel Loading (Tons/Acre)	Combustion Completeness
Barley	3.1	85%
Beans	1.8	85%
Corn	3.7	75%
Fallow	1.9	75%
Hay, Grass, Pasture, CRP	2.2	85%
Other	2.5	85%
Potatoes	1.9	85%
Wheat	4.2	85%

All field and pile burns were summed together to generate the total tons of agricultural residue burned in 2020, shown in Table 3-16. Note that Yakima permit data did not include crop type or location, so they were grouped in the “Other” category.

3.8.2 Emission Rates

Emission rates were taken from EPA's AP42 (VOC, CO, NO_x), a San Joaquin Valley study (NO_x)²⁴, the Air Sciences Incorporated report (PM₁₀, PM_{2.5}, CH₄)²³, and the 2014 NEI Agricultural Burning Emission Factors spreadsheet (NH₃)²⁵. Emission rates for NH₃ are based on the NO_x/NH₃ emissions ratio in the 2002 NEI and the NO_x emissions rate from McCarty et al. (2011)²⁶.

3.8.3 Emissions Estimates

Emissions estimates were calculated with the equation below.

$$TPY = (\text{tons consumed}) \times (\text{pollutant lb/T}) \times (1 \text{ T}/2000 \text{ lb})$$

Table 3-16. Agricultural Residue Burned (tons)

County	Wheat	Corn	Tree Plantations, Orchards, & Vineyards	Grass, Hay, Pasture, CRP, and Fallow	Other or Unknown
Adams	3,423	2,688	1,313	4,480	2,257
Asotin					35
Benton	1,824	4,536	912	5,244	2,964
Chelan	228		8,190		
Clallam				228	
Columbia	92,061	137	6	12,547	1,170
Douglas	228		12,763	1,716	15
Franklin	5,470	4,091	9,040	4,885	2,471
Garfield	25,670			1,405	355
Grant	7,303	7,622	18,615	7,997	5,438
Grays Harbor		1,008			
Island				684	
King		1,512		228	228
Kittitas			4	1,596	1,410
Klickitat	684		6,734	1,824	481
Lewis		1,008		228	
Lincoln	2,533		4	1,433	100
Okanogan			7,217	912	
Pend Oreille				249	
San Juan				456	
Snohomish		504			
Spokane	684			1,140	1,140
Stevens				474	20
Thurston				1,140	
Walla Walla	104,229	504	5,272	3,179	16,001
Whatcom		1,008		456	228
Whitman	72,690			4,683	2,841
Yakima	4,560	10,584	456	23,940	26,043
State Total	321,586	35,201	70,526	81,123	63,196

Table 3-17. Agricultural Burn Emission Factors (pounds per ton of material consumed)

Crop	Burn Season	CO	NO_x	PM₁₀	PM_{2.5}	SO₂	VOC	NH₃
Barley	spring	67	5.1	6.8	6.8	0.1	5.3	12.52
Barley	fall	117	5.1	12.3	12.3	0.1	12	12.52
Wheat and triticale	spring	67	4.3	6.8	6.8	0.9	5.3	33.73
Wheat and triticale	fall	117	4.3	12.3	12.3	0.9	12	33.73
Corn	all	108	3.3	13.8	13.2	0.4	12	19.32
CRP, grass, pasture	all	101	4.5	15.7	15	0.6	15	12.52
Hay - Alfalfa	all	106	4.5	44.3	42.2	0.6	28	12.52
Hay - Other	all	139	4.5	31.5	30	0.6	17	12.52
Apple	all	42	5.2	3.9	3.7	0.1	3	12.52
Apricot	all	49	5.2	5.9	5.6	0.1	6	12.52
Cherry	all	44	5.2	7.9	7.4	0.1	8	12.52
Mixed fruit trees	all	42	5.2	3.9	3.7	0.1	3	12.52
Peach	all	42	5.2	5.9	5.6	0.1	4	12.52
Pear	all	57	5.2	8.8	8.3	0.1	7	12.52
Berries	all	117	5.2	20.7	19.7	0.1	18	12.52
Beans, legumes, lentils	all	186	5.2	42.3	40.3	0.1	36	39.76
Peas	all	147	5.2	30.5	29.1	0.1	29	12.52
Potatoes	all	117	4.5	20.7	19.7	0.6	18	12.52
Vineyards	all	117	5.2	20.7	19.7	0.1	18	12.52
Other Crops	all	117	5.2	20.7	19.7	0.1	18	12.52
Limbs & Brush	all	140	4.3	16.3	14.5	0.1	19	12.52
Willow	all	140	5.2	16.3	14.5	0.1	19	12.52

3.9 Municipal Solid Waste Burning

Municipal Solid Waste Burning is outdoor burning of household waste. The EPA calculated this category.

3.9.1 Activity Level

The measure of activity for residential trash burning is the amount of material burned. The EPA method assumes that 0.42 tons of waste are generated per person per year and that 0.354 tons of that waste is combustible or “burnable”. This assumes that a person burning RHW in their yard is more likely to be a non-recycler than an avid recycler. Open burning of trash is generally not practiced in urban areas, so only the rural population in each county is assumed to practice open burning. The EPA default assumes that 24% of the rural population burns trash. Trash burning is illegal in Washington, but compliance is not 100%. Ecology asked EPA to consider that municipal waste burning is banned, but 25% of the original emissions is still assumed to occur.

The amount of residential trash burned was estimated using the following equation:

$$\text{Rural Population} \times 0.354 \text{ (tons/person/year)} \times 28\% \times 25\%.$$

3.9.2 Emission Rates

Emissions factors for open burning of municipal solid waste are listed in the table below. The emissions factors for CO, NOX, PM, SO₂, and VOC are from AP-42²⁷ and the EPA report *Evaluation of Emissions from the Open Burning of Household Waste in Barrels*²⁸. Emission factors were applied to the combustible waste burned.

3.9.3 Emissions Estimates

Emissions estimates were calculated with the equations below.

$$\text{TPY} = (\text{tons burned}) \times (\text{pollutant lb/T}) \times (1 \text{ T}/2000 \text{ lb})$$

Table 3-18. Emission Rates in Pounds Per Ton of Combustible Material Burned

Pollutant Name	Pollutant Code	Emission Rate (lbs/ton)
Carbon Monoxide	CO	100.7
Nitrogen Oxides	NOX	7.1
PM10	PM10-PRI	38
PM2.5	PM25-PRI	34.8
Sulfur Oxides	SO2	1.18
VOC	VOC	7.409

3.10 Publicly Owned Treatment Works (POTW)

Emissions from publicly owned wastewater treatment plants (WWTPs) are included in the POTW category. POTWs are distinct and separate from industrial wastewater treatment.

3.10.1 Activity Level

Activity for POTWs is measured in gallons of wastewater treated, which was obtained from the Permit and Reporting Information System (PARIS)²⁹ Discharge Monitoring Reports (DMRs)³⁰. Reports for 2020 were selected from Municipal National Pollutant Discharge Elimination System Individual Permits (NPDES IP), Municipal to ground State Waste Discharge Permits (SWDP), and Reclaimed Water Individual Permits. The amount of wastewater treated at POTWs is shown in Table 3-19.

3.10.2 Emission Rates

An ammonia emission factor of 0.169 pounds per million gallons was obtained from a report to EPA,³¹ while the VOC emission factor of 0.85 pounds per million gallons was based on a study from a California-based Technical Advisory Committee (Tri-TAC).³²

3.10.3 Spatial Allocation

WWTPs were allocated to counties based on their geographical coordinates.

3.10.4 Emissions Estimates

Annual emissions for each county were calculated according to the following equation:

$$\text{TPY} = (\text{million gallons treated}) \times (\text{pollutant lb/million gallons}) \times (1 \text{ T}/2000 \text{ lb})$$

Table 3-19. Public Wastewater Treatment Plant Throughput (millions of gallons)

County	Wastewater Treated
Adams	816
Asotin	312
Benton	12,359
Chelan	1,615
Clallam	1,390
Clark	11,512
Columbia	87
Cowlitz	3,888
Douglas	632
Ferry	36
Franklin	3,947
Garfield	49
Grant	2,001
Grays Harbor	2,706
Island	134
Jefferson	380
King	65,950
Kitsap	4,031
Kittitas	2,532
Klickitat	316
Lewis	2,240
Lincoln	199
Mason	884
Okanogan	442
Pacific	717
Pend Oreille	213
Pierce	17,832
San Juan	150
Skagit	3,068
Skamania	89
Snohomish	21,784
Spokane	16,826
Stevens	667
Thurston	5,086
Wahkiakum	33
Walla Walla	2,089
Whatcom	6,460
Whitman	1,361
Yakima	4,696
State Total	199,530

3.11 Residential Wood Combustion

Residential wood combustion (RWC) consists of home heating and recreational use of wood-burning equipment. Emissions from woodstoves, fireplaces, fireplace inserts, pellet stoves, indoor furnaces, and outdoor hydronic heaters are included. Other outdoor wood burning devices, such as fire pits, are part of the residential outdoor burning category for the 2020 EI.

3.11.1 Activity Level

The measure of activity for residential wood combustion is the amount of wood burned. EPA estimated RWC emissions based on the 2018 Commission on Environmental Cooperation (CEC) nationwide survey. EPA supplemented the CEC survey with information from the 2015 Energy Information Administration (EIA) Residential Energy Consumption Survey (RECS) and the state of Minnesota's 2014/2015 residential wood survey.

Ecology replaced some EPA assumptions with data from other surveys conducted by WSU, the National Research Center, and Kittitas County. Specifically, Ecology replaced appliance fractions of woodstoves and fireplace inserts for predominantly urban counties (King, Pierce, Snohomish, Spokane, Clark, Yakima, Thurston, Kitsap, Benton, and Whatcom) and replaced burn rates of woodstoves and fireplace inserts for all counties. Ecology also replaced the estimate of occupied housing units with OFM 2020 demographic data.

EPA originally had Ecology's values for appliance fractions as their defaults (pulled forward from 2017), so Ecology did not submit new appliance fractions. However, EPA later replaced the appliance fraction defaults, rendering the EPA NEI values unusable for Ecology. Ecology subsequently calculated emissions for this Comprehensive EI, which significantly lowered emissions relative to EPA NEI. Note that despite using the same appliance fractions and burn rates used in 2017, EPA changed many other assumptions that caused dramatic increases in emissions estimates relative to 2017: wood density factors increased by more than 25% and some pollutant emission factors for certified devices increased by 33% to 67%.

The residential wood combustion activity data replaced by Ecology was taken from the three residential wood combustion surveys previously used for our state. The first Washington survey was conducted by Washington State University in 2001 (WSU2001).³³ It divided the state into regions and compiled results for each region. The WSU survey had 749 completed surveys for WA. The second Washington survey was conducted by the National Research Center in 2007 (NRC2007).^{34, 35} It covered seven geographic areas in the central Puget Sound region and consisted of 1,015 completed surveys. The third Washington survey was conducted by the Kittitas County Health Department in 2014 and 2015. It covered Kittitas County and consisted of 1174 responses. The surveys solicited complete information to conduct an inventory. The Washington survey areas are listed in Table 3-20. The Washington surveys were used for each county group as shown in Table 3-21.

The EPA and Washington surveys were used to determine the percentage of households using wood burning devices and the annual amount of wood burned per device for fireplaces, woodstoves, inserts, and pellet stoves. For woodstoves and fireplace inserts, EPA used distribution profiles based on a combination of data from RECS and Minnesota surveys such that 31% of devices in western states are uncertified, 41% are certified noncatalytic, and 28% are certified catalytic. For central heaters, EPA used distribution profiles based on the CEC survey such that 1% are indoor pellet boilers, 3% are indoor pellet furnaces, 23% are indoor cordwood boilers, 37% are indoor cordwood furnaces, and 36% are outdoor cordwood boilers. The percentage of occupied households using wood burning devices are shown in Table 3-22.

Table 3-20: Surveys and Survey Groups

Survey	Survey Group	Geographic Area
Kit2014-15	Ellensburg and other areas	Kittitas County occupied housing unit weighted average
NRC2007	PS_King	King County total
NRC2007	PS_Kitsap	Kitsap County total
NRC2007	PS_PieN	Pierce County Non-Urban Growth Area
NRC2007	PS_PieU	Pierce County Urban Growth Area
NRC2007	PS_SnoD	Snohomish County - Darrington
NRC2007	PS_SnoM	Snohomish County - Marysville, Lake Stevens, North Everett
NRC2007	PS_SnoO	Snohomish County - All other areas
WSU2001	Eastern WA_Range	Adams, Asotin, Benton, Franklin, Garfield, Grant, Lincoln, Whitman Counties
WSU2001	Eastern WA Forested	Chelan, Columbia, Douglas, Ferry, Kittitas, Klickitat, Okanogan, Pend Oreille, Spokane, Stevens, Walla Walla, Yakima

Table 3-21. County to Survey Assignments

County(ies)	Survey Group
Kittitas	Kittitas
King	PS_King
Kitsap	PS_Kitsap
Pierce	PS_Pierce = Household weighted average of PS_PieN and PS_PieU
Snohomish	PS_Snohomish = Household weighted average of PS_SnoD, PS_SnoM, and PS_SnoO
Adams, Asotin, Benton, Franklin, Garfield, Grant, Lincoln, Whitman	EWA_Range
Chelan, Columbia, Douglas, Ferry, Klickitat, Okanogan, Pend Oreille, Spokane, Stevens, Walla Walla, Yakima	EWA Forested
Clallam, Clark, Cowlitz, Grays Harbor, Island, Jefferson, Lewis, Mason, Pacific, San Juan, Skagit, Skamania, Thurston, Wahkiakum, Whatcom	PS_KitPieSno = Household weighted average of all the PS survey areas except King Co.*

To calculate emissions using emission factors in lb/ton burned, the weight of the wood burned was estimated. Pellets are sold in 40-lb sacks, and fire logs were estimated at 8 lb per log. The amount of wood burned per device is shown in Table 3-23. The weight of a cord of wood varies with moisture content and species type. EPA calculated the weight of wood burned using wood density factors (e.g. for hardwood and pine) from the US Forest Service³⁶, which varied from

2268 to 2992 pounds per cord for counties in Washington, a significant increase from previous years.

Table 3-22. Device Usage (Percent of Occupied Housing Units)

County	Fireplaces	Woodstoves	Fireplace Inserts	Central Heaters	Pellet Stoves	Wax Logs
Adams	3.8%	11.1%	5.3%	1.4%	3%	0%
Asotin	7.4%	7.8%	4.3%	1%	2.5%	0%
Benton	3.9%	5%	3%	1%	2.4%	0%
Chelan	6%	16.7%	7.6%	3.5%	3%	0%
Clallam	7.7%	15.5%	9.2%	2.3%	3.2%	0%
Clark	10.3%	12.3%	8.1%	1.5%	2.5%	0%
Columbia	4.7%	15.9%	8.0%	2.3%	3.5%	0%
Cowlitz	9.5%	14.4%	9%	2.3%	2.9%	0%
Douglas	3.3%	13.6%	6.4%	2%	2.8%	0%
Ferry	6.5%	25.9%	9.6%	6.8%	4.5%	0%
Franklin	4.8%	9.1%	5.2%	1%	2.6%	0%
Garfield	3.6%	20.1%	7.5%	3.6%	4.6%	0%
Grant	2.9%	11.9%	6.1%	1.4%	2.6%	0%
Grays Harbor	9.5%	15%	8.8%	2.5%	3.2%	0%
Island	5.3%	12.6%	6.4%	1.7%	3.6%	0%
Jefferson	9.3%	18.8%	10.4%	3.3%	3.9%	0%
King	11.1%	5.9%	5.9%	1%	1.8%	1.9%
Kitsap	8.5%	15.3%	12.9%	1.2%	2.6%	0%
Kittitas	6.4%	14.8%	5.9%	3.4%	3.1%	0%
Klickitat	5.6%	14.2%	6.8%	2.1%	3.7%	0%
Lewis	9.5%	17.3%	9.5%	3.2%	3.5%	0%
Lincoln	4.2%	18.5%	6.1%	3.6%	4.7%	0%
Mason	9.1%	19.1%	10%	3.5%	4%	0%
Okanogan	5.2%	20.4%	8.4%	4.1%	4.1%	0%
Pacific	6.3%	17.8%	9.1%	2.9%	3.7%	0%
Pend Oreille	8.8%	25%	10.5%	6.7%	4.2%	0%
Pierce	10.7%	11.2%	6.7%	1.3%	2.3%	1.2%
San Juan	4.3%	18.6%	7.6%	2.8%	5.1%	0%
Skagit	12.5%	10.9%	6.2%	1.9%	3.1%	0%
Skamania	10.1%	25.1%	10%	7.6%	4.3%	0%
Snohomish	12.2%	12.4%	8%	1.4%	2.4%	0%
Spokane	7.6%	11.5%	5.2%	1.7%	2.5%	0%
Stevens	8.4%	20.8%	8.1%	5.3%	4.1%	0%
Thurston	10.7%	12.3%	8.1%	1.3%	2.7%	0%
Wahkiakum	8.2%	23%	10.5%	4.6%	4.8%	0%
Walla Walla	5.4%	8.4%	4.5%	1%	2.7%	0%
Whatcom	10.2%	12.3%	8.1%	2.5%	2.7%	0%
Whitman	3.6%	7.4%	3.3%	1.1%	2.1%	0%
Yakima	6.7%	11.5%	5.2%	1.3%	2.8%	0%

Table 3-23. Amount of Wood Burned Per Device

County	Fireplaces (Cords)	Woodstoves (Cords)	Fireplace Inserts (Cords)	Central Heaters (Cords)	Pellet Stoves (Tons)	Wax Logs (Tons)
Adams	0.42	1.40	1.30	2.61	0.40	0.78
Asotin	0.36	1.40	1.30	2.57	0.34	0.78
Benton	0.36	1.40	1.30	2.57	0.36	0.78
Chelan	0.34	2.70	1.70	3.02	1.27	0.78
Clallam	0.35	2.03	1.98	2.82	0.90	0.78
Clark	0.27	2.03	1.98	2.43	0.87	0.78
Columbia	0.39	2.70	1.70	2.77	0.64	0.78
Cowlitz	0.32	2.03	1.98	2.82	1.05	0.78
Douglas	0.38	2.70	1.70	2.78	0.58	0.78
Ferry	0.41	2.70	1.70	3.11	1.76	0.78
Franklin	0.38	1.40	1.30	2.59	0.34	0.78
Garfield	0.47	1.40	1.30	2.78	0.73	0.78
Grant	0.41	1.40	1.30	2.69	0.47	0.78
Grays Harbor	0.35	2.03	1.98	2.78	0.94	0.78
Island	0.37	2.03	1.98	2.51	0.53	0.78
Jefferson	0.37	2.03	1.98	2.86	1.11	0.78
King	0.23	1.31	1.35	1.92	0.91	0.78
Kitsap	0.29	1.94	1.57	2.39	0.65	0.78
Kittitas	0.36	2.00	2.10	2.94	1.05	0.78
Klickitat	0.41	2.70	1.70	2.64	0.56	0.78
Lewis	0.36	2.03	1.98	2.87	1.18	0.78
Lincoln	0.47	1.40	1.30	2.79	0.66	0.78
Mason	0.38	2.03	1.98	2.84	1.12	0.78
Okanogan	0.41	2.70	1.70	2.90	1.06	0.78
Pacific	0.39	2.03	1.98	2.83	0.93	0.78
Pend Oreille	0.37	2.70	1.70	3.15	2.04	0.78
Pierce	0.28	1.42	1.70	2.58	0.77	0.78
San Juan	0.47	2.03	1.98	2.61	0.56	0.78
Skagit	0.35	2.03	1.98	2.65	0.65	0.78
Skamania	0.38	2.03	1.98	3.14	2.30	0.78
Snohomish	0.29	2.86	2.29	2.61	0.74	0.78
Spokane	0.32	2.70	1.70	2.75	0.67	0.78
Stevens	0.38	2.70	1.70	3.04	1.45	0.78
Thurston	0.31	2.03	1.98	2.52	0.64	0.78
Wahkiakum	0.42	2.03	1.98	2.86	1.18	0.78
Walla Walla	0.38	2.70	1.70	2.52	0.32	0.78
Whatcom	0.32	2.03	1.98	2.89	1.00	0.78
Whitman	0.37	1.40	1.30	2.58	0.42	0.78
Yakima	0.36	2.70	1.70	2.60	0.49	0.78

Table 3-24. Tons of Wood Burned for Home Heating

County	Fireplaces	Woodstoves	Fireplace Inserts	Central Heaters	Pellet Stoves	Wax Logs	TOTAL
Adams	107	1,047	464	246	81	0	1,945
Asotin	267	1,096	561	258	85	0	2,267
Benton	1,124	5,605	3,123	2,058	692	0	12,602
Chelan	760	16,804	4,815	3,939	1,420	0	27,738
Clallam	1,022	11,935	6,909	2,460	1,092	0	23,419
Clark	5,424	48,699	31,280	7,109	4,242	0	96,753
Columbia	40	940	298	140	49	0	1,467
Cowlitz	1,381	13,278	8,095	2,946	1,383	0	27,083
Douglas	217	6,359	1,884	963	281	0	9,705
Ferry	108	2,838	662	858	321	0	4,789
Franklin	542	3,789	2,010	770	263	0	7,375
Garfield	20	336	116	119	40	0	632
Grant	459	6,437	3,064	1,455	472	0	11,887
Grays Harbor	1,199	10,980	6,283	2,506	1,085	0	22,052
Island	822	10,723	5,312	1,789	800	0	19,446
Jefferson	657	7,284	3,930	1,801	826	0	14,499
King	24,745	74,912	77,199	18,609	15,876	14,364	225,706
Kitsap	2,792	33,614	22,936	3,248	1,914	0	64,504
Kittitas	547	7,028	2,942	2,373	773	0	13,663
Klickitat	242	4,038	1,218	584	218	0	6,300
Lewis	1,211	12,436	6,661	3,252	1,463	0	25,023
Lincoln	113	1,485	455	576	178	0	2,806
Mason	1,150	12,899	6,587	3,307	1,490	0	25,434
Okanogan	463	11,963	3,102	2,583	944	0	19,055
Pacific	394	5,794	2,889	1,316	552	0	10,944
Pend Oreille	258	5,358	1,417	1,675	680	0	9,389
Pierce	10,770	57,173	40,946	12,057	6,367	3,365	130,678
San Juan	278	5,200	2,072	1,006	393	0	8,951
Skagit	2,439	12,334	6,843	2,807	1,123	0	25,546
Skamania	222	2,952	1,147	1,383	573	0	6,278
Snohomish	11,375	114,025	58,903	11,748	5,710	0	201,762
Spokane	5,448	69,558	19,803	10,473	3,752	0	109,035
Stevens	710	12,491	3,063	3,584	1,322	0	21,170
Thurston	4,028	30,322	19,476	3,978	2,098	0	59,903
Wahkiakum	75	1,022	455	288	124	0	1,964
Walla Walla	512	5,663	1,910	629	216	0	8,931
Whatcom	3,267	24,993	16,054	7,232	2,703	0	54,249
Whitman	279	2,168	898	594	185	0	4,122
Yakima	2,183	28,101	8,001	3,059	1,242	0	42,586
State Total	87,655	683,681	383,783	125,780	63,029	17,729	1,361,657

3.11.2 Emission Rates

Emissions factors for RWC (see Table 3-25) come primarily from AP-42 ³⁷ and Houck and Eagle (2006) ³⁸, but also from Houck et al. (2001) ³⁹. Emissions factors for wax fire logs are from Li and Rosenthal (2006) ⁴⁰. Additional emission factors are taken from Aurell et al. (2012) ⁴¹. Note that EPA significantly changed the emission factors used for certified woodstoves and certified fireplace inserts, which now use the AP-42 values. Note that the new factors for PM are 67% larger than the factors used in previous EIs. Emission factor values from the 2017 EI are shown in parentheses for comparison in Table 3-25.

3.11.3 Spatial Allocation

Spatial allocation was not necessary since occupied housing units were available by county.

3.11.4 Emissions Estimates

Annual emissions for each county and wood burning device were calculated according to the following equation:

$$TPY = (OHU) \times (\text{usage fraction}) \times (T \text{ burned/device-yr}) \times (\text{pollutant lb/T}) \times (T/2000 \text{ lb})$$

where OHU= number of occupied housing units in the county

Table 3-25. Pollutant Emission Factors in Pounds Per Ton Burned

Pollutant	Fireplaces	Certified Catalytic Inserts & Woodstoves	Certified Non-Catalytic Inserts & Woodstoves	Uncertified Inserts & Woodstoves	Pellet Stoves	Wax Logs
Ammonia	1.8	0.67	0.67	1.7	0.3	
Carbon Monoxide	149	92.3	122.6	230.8	15.9	125.1
Nitrogen Oxides	2.6	2 (1.49)	1.69	2.8	3.8	7.7
Primary PM10	23.6	16.2 (9.72)	14.6 (8.76)	30.6	3.06	29.3
Primary PM2.5	23.6	16.2 (9.72)	14.6 (8.76)	30.6	3.06	28.4
Sulfur Dioxide	0.4	0.4 (0.3)	0.4 (0.3)	0.4	0.32	
VOCs	18.9	15 (11.2)	12 (8.88)	53	2.20	39.6

3.12 Industrial and Commercial/Institutional (ICI) Fuel Use

Industrial and Commercial/Institutional (ICI) fuel combustion sources include emissions from boilers, engines, and other combustion sources from the industrial, commercial, and institutional sectors that are *not* reported as large point sources. This category includes emissions from combustion of coal, distillate fuel oil, residual fuel oil, kerosene, liquefied petroleum gas (LPG), natural gas, and wood.

The calculations for estimating emissions from the ICI sectors include estimating the total fuel consumption by sector in each state, using data from the Energy Information Administration (EIA) State Energy Data System (SEDS). Total fuel consumption is adjusted to account for fuel consumed by mobile sources in each sector and fuel used as an input to industrial processes but is not combusted. Washington submitted state-level fuel consumption data from point sources in these sectors to EPA, using information from the WEIRS database and as reported by local clean air agencies. The state-level point source fuel consumption was subtracted from the total fuel consumption to estimate the fuel consumption from nonpoint sources, and EPA calculated the subsequent emissions. An adjustment was made to the nonpoint estimate of industrial wood combustion, since it was unreasonably high. After consultation with a senior Ecology engineer, and consistent with the previous EI, it was decided to estimate nonpoint industrial wood combustion at 25% of the total point source value. However, that value was not submitted to EPA in time for inclusion in the NEI.

3.12.1 Activity Level

The activity data for this source category is total fuel consumption in the industrial and commercial/institutional sectors. The default data for this category are obtained from the total 2020 state-level fuel consumption in each sector from EIA SEDS ⁴² for all fuel types except distillate. Distillate fuel consumption is taken from EIA's Form 821 data ⁴³, which reports distillate sales by state and sector for 2020. Note that EPA makes small adjustments to some of the SEDS data.

Table 3-26. State Industrial and Commercial/Institutional Fuel Use

Sector	Fuel	Units	State	Point	Nonpoint
Commercial	Coal	Tons	0	0	0
Commercial	Distillate	Thousand Gallons	526	106	420
Commercial	Kerosene	Thousand Gallons	168	0	168
Commercial	LPG	Thousand Gallons	48,459	147	48,312
Commercial	Natural Gas	Million Cubic Feet	55,548	1,175	54,373
Commercial	Residual	Thousand Gallons	0	0	0
Commercial	Wood	Million BTU	4,520,000	0	4,520,000
Industrial	Coal	Tons	81,100	61,380	19,720
Industrial	Distillate	Thousand Gallons	15,594	107	15,487

Sector	Fuel	Units	State	Point	Nonpoint
Industrial	Kerosene	Thousand Gallons	0	0	0
Industrial	LPG	Thousand Gallons	28,903	546	28,357
Industrial	Natural Gas	Million Cubic Feet	74,263	36,153	38,110
Industrial	Residual	Thousand Gallons	0	2,460,637	0
Industrial	Wood	Million BTU	64,453,000	13,383,698	3,346,925

3.12.2 Spatial Allocation

The estimated state-level nonpoint source activity data in each state is distributed to the county level based on employment in the industrial or commercial sector from the Census Bureau's County Business Patterns⁴⁴. The adjusted nonpoint fuel consumption in each state is distributed to the county based on the proportion of employment in each county in each sector to the total employment at the state level in each sector.

3.12.3 Emission Rates and Emissions

Emissions were calculated as:

$$E = A \times EF$$

where A is the amount of fuel used, and EF is the emission rate in lbs/unit. The emission factors are discussed in the Section 25 of the 2020 NEI EPA TSD.

3.13 Agricultural Harvesting Operations

The Western Regional Air Partnership (WRAP) published a handbook for calculating dust emissions which includes harvesting operations. Harvesting emissions are generated by three different operations: crop handling by the harvest machine, loading of the harvested crop into trailers or trucks, and transport by trailers or trucks in the field. Emissions from these operations are in the form of solid particulates composed mainly of raw plant material and soil dust that is entrained into the air.⁴⁵ The WRAP Handbook recommended the methodology and emission rates used by the California Air Resources Board (CARB). Note that emissions for this category have not been adjusted since 2017, due to lack of updated activity data.

3.13.1 Activity Level and Spatial Adjustments

Acres harvested by crop type are the measure of activity. Every 5 years an extensive national census is made. The USDA National Agricultural Statistics Service (NASS) published the USDA/WSDA crop data and Census data on-line for query and download.⁴⁶ Statistics from the 2017 census were obtained for several major crop and fruit types. “Acres Harvested” statistics were used for most crops, except for fruit statistics that are reported as “Acres Bearing”. The data included individual county acreage estimates for several crop types, but individual county acreage was considered confidential in some instances. State totals were used to evenly apportion remaining crop acreage to individual counties when county estimates were withheld.

Harvested acreage by county is shown in Table 3-27, with similar crop types grouped as follows:

Beans & Peas: Dry Beans, Lima Beans, Snap Beans, Lentils, Dry Peas, Green Peas
Fruit: Apples, Apricots, Berries, Cherries, Grapes, Nectarines, Peaches, Pears, Plums
Grains: Barley, Canola, Corn, Wheat
Hay & Haylage: Alfalfa Hay, Hay, Alfalfa Haylage, Haylage
Potatoes: Potatoes
Other Crops: Hops, Oats, Onions

Table 3-27. Area of Crops Harvested (Acres)

County	Beans & Peas	Fruit	Grains	Hay & Haylage	Potatoes	Other Crops
Adams	11,460	4,435	280,403	9,141	21,780	1,279
Asotin	2	305	26,751	5,229	0	119
Benton	12,207	41,294	143,454	11,204	42,046	25,289
Chelan	505	20,293	305	2,220	2	1
Clallam	2,066	276	5,648	4,647	9	126
Clark	1,882	1,302	796	16,190	10	122
Columbia	15,205	169	71,399	3,361	384	119
Cowlitz	471	1,540	5,588	4,206	384	119
Douglas	1,723	11,495	165,733	5,331	1	119
Ferry	506	55	4,640	9,995	384	1
Franklin	8,974	16,584	96,359	84,585	29,983	3,757
Garfield	207	95	101,972	1,960	0	119
Grant	41,327	66,532	219,903	138,569	47,052	7,230
Grays Harbor	2,323	553	4,395	10,173	6	1
Island	8	528	5,083	5,532	3	4
Jefferson	1	116	1	3,103	2	2
King	1,974	469	1,764	8,519	20	42
Kitsap	11	102	4	8,110	11	6
Kittitas	2,563	1,001	2,925	41,195	384	44
Klickitat	2,460	2,700	57,092	36,587	4	10
Lewis	852	543	6,718	38,359	2	107
Lincoln	3,366	1,138	364,578	26,610	384	287
Mason	4	1,002	89	8,409	2	1
Okanogan	218	19,408	12,267	30,485	6	217
Pacific	142	1,285	0	6,698	3	1
Pend Oreille	0	60	0	16,155	0	0
Pierce	435	535	5,021	5,751	5	9
San Juan	1,854	251	4,909	3,994	5	2
Skagit	2,525	2,446	16,813	17,668	9,896	10
Skamania	141	321	0	974	384	0
Snohomish	40	833	6,021	11,686	979	74
Spokane	41,351	503	155,112	62,233	384	1,165
Stevens	1,946	249	5,429	39,985	384	395
Thurston	11	1,246	311	15,038	13	15
Wahkiakum	1	1,419	0	4,078	1	1
Walla Walla	24,538	14,498	205,165	17,261	10,223	1,647
Whatcom	1,877	11,953	13,005	36,486	1,635	130
Whitman	181,807	1,034	573,641	20,502	1	120
Yakima	74	90,393	75,075	45,948	1,027	29,161
State Total	367,055	318,964	2,638,369	818,177	167,801	71,849

3.13.2 Emission Rates

Emission rates were adapted from the WRAP Handbook. The handbook assumed that PM_{2.5} was 15% of the PM₁₀. No control measures were assumed.

Table 3-28. Agricultural Harvesting Emission Rates (lb/acre)

Crop	PM ₁₀	PM _{2.5}
Apples	0.08	0.012
Apricots	0.08	0.012
Barley	5.80	0.870
Beans, other	1.68	0.252
Beans, snap	0.17	0.026
Berries	0.08	0.012
Canola	5.80	0.870
Cherries	0.08	0.012
Corn for grain	1.68	0.252
Corn for silage	0.17	0.026
Corn, sweet	0.08	0.012
Grapes	0.17	0.026
Hay, alfalfa	0.17	0.026
Hay, other	1.68	0.252
Haylage (silage)	0.17	0.026
Hops	5.80	0.870
Lentils	1.68	0.252
Nectarines	0.08	0.012
Oats	5.80	0.870
Onions	1.68	0.252
Onions, green	0.08	0.012
Peaches	0.08	0.012
Pears	0.08	0.012
Peas	0.17	0.026
Plums	0.08	0.012
Potatoes	1.68	0.252
Wheat	5.80	0.870

3.13.3 Emissions Estimates

Annual county emissions estimates of agricultural harvesting were calculated by multiplying the emission rates by the number of harvested acres by crop type.

$$\text{TPY} = (\text{acres}) \times (\text{lb pollutant/acre}) \times (1 \text{ T}/2000 \text{ lb})$$

3.14 Agricultural Tilling

Fugitive dust emissions from agricultural tilling include the airborne soil particulate emissions produced during the preparation of agricultural lands for planting. Fugitive dust emissions from agricultural tilling were estimated for PM₁₀ and PM_{2.5}. EPA calculated emissions after Ecology submitted the acres tilled by crop type and the number of passes per crop type by tilling practice type. Note that in contrast to EPA defaults, Ecology assumes that no tilling passes are made on land marked as no-till.

3.14.1 Activity Level

Acres tilled by crop type are the measure of activity. The total number of acres of farmland for crop types by county was obtained from the WSDA 2020 Agricultural Land Use GIS Data⁴⁷. Winter wheat and spring wheat were obtained from the USDA 2020 Census of Agriculture, provided by EPA and supplemented with the WSDA land use data for spring wheat in counties where USDA had no data. All farmland data was aggregated to the following crop types: barley, beans and peas, canola, corn, fallow, alfalfa hay, hay/grass/silage (non-alfalfa), oat, pasture, peas, potato, rye, sorghum, soybean, sunflower, beets, winter wheat, and spring wheat. All hay and seed categories were aggregated to their respective crop types where possible (e.g. alfalfa hay and alfalfa seed are treated as “alfalfa”). Only wheat fallow and tilled fallow were included for “fallow” crop type. Acres tilled by county for crop type groups are shown in Table 3-29.

3.14.2 Emissions Rates

The emission rates for agricultural tilling are based on the number of tilling passes made per year and the silt content of the soil. The number of tilling passes by crop type and farming practice (e.g. conservation or conventional land use) were taken from the Midwest Research Institute⁴⁸ and revised based on information from the WSU College of Agriculture⁴⁹. All pastureland is assumed to be no-till. The fraction of acres farmed that are conventional, no-till, or in conservation were obtained from the 2017 USDA Census of Agriculture.

The following equation was used to determine the emission rates from agricultural tilling^{50 51}.

$$\text{Emissions Rate (lbs/acre)} = c \times k \times s^{0.6} \times p$$

where:

- c = constant of 4.8 lbs/acre-pass
- k = dimensionless particle size multiplier (PM₁₀=0.21; PM_{2.5}=0.042)
- s = percent silt content of surface soil, defined as the mass fraction of particles smaller than 50 µm diameter found in surface soil
- p = number of tilling passes in a year

Silt content by county was based on the National Cooperative Soil Survey data⁵².

Table 3-29. Area of Farmland Tilled (Acres)

County	Beans & Peas	Grains	Hay	Potatoes	Fallow	Pasture	Other Crops
Adams	14,929	306,878	19,458	22,377	258,983	7,032	236
Asotin	373	26,754	5,585	0	23,523	14,020	0
Benton	11,500	136,423	9,360	29,449	99,774	15,328	1,857
Chelan	0	11	850	0	3,825	1,674	0
Clallam	0	605	4,564	0	351	4,466	0
Clark	0	891	13,280	0	1,340	14,279	0
Columbia	22,757	114,345	2,607	0	27,659	16,289	0
Cowlitz	0	626	2,458	1	286	2,208	0
Douglas	323	166,182	2,271	14	175,668	4,624	128
Ferry	0	422	6,122	0	2,034	8,116	0
Franklin	6,137	107,618	53,666	42,068	61,817	11,984	120
Garfield	793	93,707	2,369	0	56,467	33,583	0
Grant	46,169	224,104	119,20	43,691	109,374	22,871	400
Grays Harbor	47	3,201	10,365	3	377	8,805	0
Island	62	817	6,478	26	515	3,737	0
Jefferson	0	8	2,032	0	159	2,407	0
King	0	1,455	6,504	0	2,033	16,577	0
Kitsap	0	7	9,085	0	69	1,609	0
Kittitas	626	1,970	5,211	180	2,943	30,249	654
Klickitat	803	51,605	40,843	1,178	28,992	12,445	0
Lewis	0	2,204	33,395	0	2,653	26,369	0
Lincoln	6,872	393,897	22,433	3,254	250,644	34,090	492
Mason	0	40	1,910	0	65	2,404	0
Okanogan	0	11,787	23,603	4	19,090	37,148	0
Pacific	0	0	3,405	0	623	4,579	0
Pend Oreille	0	39	11,049	0	2,252	8,488	0
Pierce	89	189	5,350	0	1,292	14,841	0
San Juan	0	191	4,435	0	165	4,977	0
Skagit	2,028	16,441	18,309	9,674	2,207	11,523	0
Skamania	0	0	733	0	254	1,425	0
Snohomish	0	7,670	13,419	416	1,618	15,318	2
Spokane	16,008	173,681	57,528	331	27,339	11,884	1,001
Stevens	0	6,531	49,961	378	7,646	29,949	298
Thurston	36	162	9,896	1	691	17,337	1
Wahkiakum	0	0	2,552	0	410	4,099	0
Walla Walla	19,833	217,104	12,317	14,354	123,477	16,158	11
Whatcom	0	15,760	32,673	2,999	1,375	6,898	0
Whitman	71,409	607,042	20,923	0	161,580	45,974	78
Yakima	179	67,884	40,655	255	29,411	44,505	34
State Total	220,972	2,758,245	686,862	170,653	1,488,981	570,269	5,312

Table 3-30. Farming Practices and Silt Content

County	No-Till	Conservation	Conventional	Silt Content
Adams	4%	53%	42%	62%
Asotin	75%	20%	5%	63%
Benton	40%	44%	16%	43%
Chelan	75%	14%	11%	36%
Clallam	30%	15%	56%	41%
Clark	16%	9%	75%	52%
Columbia	43%	53%	4%	74%
Cowlitz	3%	0%	97%	38%
Douglas	23%	29%	49%	48%
Ferry	17%	4%	79%	52%
Franklin	9%	49%	43%	40%
Garfield	63%	31%	6%	67%
Grant	7%	32%	61%	48%
Grays Harbor	3%	38%	59%	49%
Island	20%	12%	68%	32%
Jefferson	67%	6%	28%	22%
King	10%	33%	57%	36%
Kitsap	25%	52%	23%	29%
Kittitas	13%	29%	58%	41%
Klickitat	46%	28%	26%	41%
Lewis	14%	6%	80%	49%
Lincoln	27%	45%	28%	64%
Mason	57%	4%	40%	37%
Okanogan	60%	11%	29%	44%
Pacific	6%	5%	89%	34%
Pend Oreille	5%	41%	54%	45%
Pierce	8%	13%	79%	24%
San Juan	28%	38%	34%	40%
Skagit	3%	3%	94%	31%
Skamania	25%	29%	46%	33%
Snohomish	22%	8%	70%	36%
Spokane	44%	39%	17%	52%
Stevens	8%	17%	76%	47%
Thurston	11%	22%	67%	42%
Wahkiakum	0%	43%	57%	58%
Walla Walla	43%	41%	16%	69%
Whatcom	7%	8%	85%	51%
Whitman	20%	65%	15%	66%
Yakima	29%	26%	45%	33%

Table 3-31. Tilling Passes for Field Crops

Crop	Conservation Use	Conventional Use
Alfalfa	3	3
Barley	3	5
Beans & Peas	3	3
Canola	3	3
Corn	2	6
Cover	1	1
Fallow	1	4
Hay	1	1
Oats	3	5
Potatoes	3	3
Rye	3	5
Sorghum	1	6
Soybeans	1	6
Spring Wheat	1	2
Sugar beets	3	3
Sunflower	3	3
Winter Wheat	2	4

3.14.3 Emissions Estimates

Annual county emissions estimates of agricultural tilling were calculated using the equation below.

$$\text{TPY} = (\text{acres tilled}) \times (\text{number of passes}) \times (\text{lb pollutant/acre}) \times (1 \text{ T}/2000 \text{ lb})$$

3.15 Land clearing

Emissions from land clearing burning were estimated. Land clearing is the burning of land debris, like trees, stumps, shrubbery, or other natural vegetation from projects that clear the land surface.

3.15.1 Activity Level

Land clearing emissions are based on 2020 land clearing burn permits issued by the Department of Ecology in counties under Ecology jurisdiction (Adams, Asotin, Chelan, Columbia, Douglas, Ferry, Franklin, Garfield, Grant, Kittitas, Klickitat, Lincoln, Okanogan, Pend Oreille, San Juan, Stevens, Walla Walla, and Whitman). Each land clearing permit indicates the total amount of brush that is burned at a location, in tons. For each of these 18 counties, Ecology summed the total tons burned, then calculated tons per capita using unincorporated population totals. Using the average tons per capita, Ecology estimated the tons burned in counties outside Ecology jurisdiction based on their unincorporated populations. Land clearing is illegal in King, Kitsap, Pierce, Snohomish, and Spokane counties, so emissions were assumed to be zero there.

3.15.2 Emission Rates

Land clearing emissions were assumed to be due to the burning of trees and brush. Thus, Ecology used emission rates for the agricultural burning crop type “Limbs and Brush”, shown in Table 3-17, for all land clearing emissions.

3.15.3 Emissions Estimates

Annual county emissions estimates were calculated by multiplying emission rates by the number of tons burned, scaled by a combustion completeness factor of 85%.

$$\text{TPY} = (\# \text{ tons}) \times (85\% \text{ combustion completeness}) \times (\text{emission rate in lb/T}) \times (1 \text{ T}/2000 \text{ lb})$$

Table 3-32. Land clearing tons burned by county

County	Tons cleared
Adams	16.5
Asotin	100.0
Benton	262.7
Chelan	517.0
Clallam	329.4
Clark	1674.8
Columbia	0.0
Cowlitz	347.4
Douglas	301.5
Ferry	10.0
Franklin	98.2
Garfield	6.4
Grant	545.0
Grays Harbor	208.4
Island	425.0
Jefferson	164.1
King	0.0
Kitsap	0.0
Kittitas	127.5
Klickitat	47.5
Lewis	355.4
Lincoln	50.0
Mason	397.8
Okanogan	65.0
Pacific	113.3
Pend Oreille	213.5
Pierce	0.0
San Juan	109.1
Skagit	378.0
Skamania	65.7
Snohomish	0.0
Spokane	0.0
Stevens	8.5
Thurston	1041.0
Wahkiakum	27.8
Walla Walla	122.8
Whatcom	665.9
Whitman	42.6
Yakima	633.5
State Total	9,471.3

3.16 Structure & Vehicle Fires

Emissions from accidental structure and vehicle fires were estimated. Structure fires resulting from unintentional actions, arson, or natural events were included. Vehicle fires included any commercial or private vehicles authorized for use on public roads. Fire emissions were estimated using methods in the Emission Inventory Improvement Program (EIIP).^{53, 54}

3.16.1 Activity Level

National structure and vehicle fire records are maintained by the Department of Homeland Security US Fire Administration. Records are kept on the National Fire Incident Reporting System (NFIRS).⁵⁵ Structure and vehicle fire data was taken from the NFIRS database by county for 2020. All counties reported 2020 data.

3.16.2 Emission Rates

The EIIP provided loading and emission factors.^{53,54} The loading factor was 1.15 tons consumed per structure fire and 0.25 tons consumed per vehicle fire. Emission factors are shown below. PM₁₀ and PM_{2.5} were estimated from total PM factors using California size fractions for unplanned structure fires (profile 137).⁵⁶

Table 3-33. Structure and Vehicle Fire Emission Factors (pounds per Ton consumed)

Pollutant	Pollutant Code	Structure Fire EF	Vehicle Fire EF
CO	CO	60	125
NO _x	NO _x	1.4	4
PM ₁₀	PM ₁₀	10.6	98
PM _{2.5}	PM _{2.5}	9.9	91
VOC	VOC	11	32
Acrolein	107028	4.41	N/A
Formaldehyde	50000	1.02	N/A
Hydrochloric acid	7647010	15.11	N/A
Hydrogen cyanide	74908	35.49	N/A

3.16.3 Emissions Estimates

Annual county emissions estimates were calculated by multiplying the emission rates by the number of fires and loading per fire.

$$\text{TPY} = (\text{\#fires}) \times (\text{Loading Factor}) \times (\text{emission rate in lb/T}) \times (1 \text{ T}/2000 \text{ lb})$$

Table 3-34. Structure and Vehicle Fire Counts

County	Structure Fires	Vehicle Fires
Adams	5	6
Asotin	27	12
Benton	207	120
Chelan	101	48
Clallam	99	41
Clark	356	187
Columbia	4	3
Cowlitz	127	74
Douglas	31	32
Ferry	4	0
Franklin	79	59
Garfield	8	2
Grant	156	88
Grays Harbor	192	60
Island	101	30
Jefferson	46	25
King	1875	779
Kitsap	177	97
Kittitas	69	46
Klickitat	23	19
Lewis	154	66
Lincoln	4	4
Mason	109	48
Okanogan	70	44
Pacific	37	6
Pend Oreille	22	7
Pierce	845	434
San Juan	24	9
Skagit	156	70
Skamania	6	6
Snohomish	509	218
Spokane	520	236
Stevens	84	30
Thurston	318	117
Wahkiakum	6	1
Walla Walla	69	32
Whatcom	260	93
Whitman	46	8
Yakima	446	221
State Total	7,372	3,378

3.17 Natural/Biogenic

Emissions from natural/biogenic activity of trees, shrubs, and soil were estimated using the Model of Emissions of Gases and Aerosols from Nature (MEGAN) v2.1⁵⁷. Monthly MEGAN results were obtained from the AIRPACT-5 framework at Washington State University for 2020. It should be noted that MEGAN does not include detailed information about agricultural vegetation in Washington.

3.17.1 Activity Level

MEGAN is a process-based model that uses landcover (e.g. plant functional type and leaf area index) and meteorology to estimate emissions from soil and vegetation. Meteorological information was obtained from the UW WRF 4-km forecasts. Plant activity is determined within the model by using a leaf age model, a canopy environment model, soil moisture algorithms, CO₂ algorithms, and light and temperature algorithms. The different plant functional types are shown in the table below.

Table 3-35. MEGAN Functional Plant Types

Class #	Plant Type
1	Needleleaf Evergreen Temperate Tree
2	Needleleaf Evergreen Boreal Tree
3	Needleleaf Deciduous Boreal Tree
4	Broadleaf Evergreen Tropical Tree
5	Broadleaf Evergreen Temperate Tree
6	Broadleaf Deciduous Tropical Tree
7	Broadleaf Deciduous Temperate Tree
8	Broadleaf Deciduous Boreal Tree
9	Broadleaf Evergreen Temperate Shrub
10	Broadleaf Deciduous Temperate Shrub
11	Broadleaf Deciduous Boreal Shrub
12	Arctic C3 Grass
13	Cool C3 Grass
14	Warm C4 Grass
15	Crop

3.17.2 Emission Rates

The MEGAN model estimates emissions of individual VOCs, NO, and CO. The VOCs reported include isoprene, methanol, ethanol, acetaldehyde, acetone, alpha-pinene, beta-pinene, t-beta-ocimene, limonene, ethene, and propene, terpenoids, monoterpenes and sesquiterpenes. The emission factors for each pollutant by plant class # are shown in the table below. AIRPACT groups many of these VOCs together and they were added together to get a total VOC estimate.

Table 3-36. MEGAN v2.1 Biogenic Emission Factors by Class Number ($\mu\text{g}/\text{m}^2/\text{hr}$)

Compound	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Isoprene	600	3000	1	7000	10000	7000	10000	11000	2000	4000	4000	1600	800	200	1
Myrcene	70	70	60	80	30	80	30	30	30	50	30	0.3	0.3	0.3	0.3
Sabinene	70	70	40	80	50	80	50	50	50	70	50	0.7	0.7	0.7	0.7
Limonene	100	100	130	80	80	80	80	80	60	100	60	0.7	0.7	0.7	0.7
3-Carene	160	160	80	40	30	40	30	30	30	100	30	0.3	0.3	0.3	0.3
t- β -Ocimene	70	70	60	150	120	150	120	120	90	150	90	2	2	2	2
β -Pinene	300	300	200	120	130	120	130	130	100	150	100	1.5	1.5	1.5	1.5
α -Pinene	500	500	510	600	400	600	400	400	200	300	200	2	2	2	2
Other Monoterpenes	180	180	170	150	150	150	150	150	110	200	110	5	5	5	5
α -Farnesene	40	40	40	60	40	60	40	40	40	40	40	3	3	3	4
β -Caryophyllene	80	80	80	60	40	60	40	40	50	50	50	1	1	1	4
Other Sesquiterpenes	120	120	120	120	100	120	100	100	100	100	100	2	2	2	2
232-MBO	700	60	0.01	0.01	0.01	0.01	0.01	2	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Methanol	900	900	900	500	900	500	900	900	900	900	900	500	500	500	900
Acetone	240	240	240	240	240	240	240	240	240	240	240	80	80	80	80
CO	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Bidirectional VOC	500	500	500	500	500	500	500	500	500	500	500	80	80	80	80
Stress VOC	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
Other VOC	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140

3.17.3 Emissions Estimates

Annual county emissions estimates were calculated by adding the monthly MEGAN emissions estimates for 2020. Emissions estimates of VOCs, NO, and CO came directly from the process described above.

3.18 Emissions Calculated by EPA

The Dept. of Ecology acquired CAP emission estimates from EPA for several source types, as calculated in the 2020 NEI using EPA defaults and methodology, listed in Table 3-37. The technical support document for the 2020 NEI provides more information about each source type calculated by EPA¹.

Table 3-37. Emissions Source Types Calculated by EPA using Defaults

ECY SCC Category	ECY SCC Group	Description
F_RES	F_RES	Residential non-Wood Fuel
AIR	AIR	Aircraft: military, commercial, general aviation
SHIP	SHIP	Commercial Marine Vessels
RR	RR	Locomotives [line-haul; not switch yards]
FOOD	FOOD	Food and Kindred Products
SOLV	SURFC	Surface coating
SOLV	DEGR	Degreasing
SOLV	DRY	Dry cleaning
SOLV	GRAPH	Graphic arts
SOLV	COCM-S	Consumer and commercial solvents
SOLV	ASPHLT	Asphalt
SOLV	AGR_PEST	Agricultural Pesticides
PETROL	PPS	Petroleum gas cans and bulk plants
PETROL	GASSTN	Gas stations [storage tank filling and breathing; not vehicle refueling]
PETROL	AV-GAS	Aviation gas storage and transport
PETROL	PPT	Petroleum truck transport
MISC	COMPOST	Composting
FERT	FERT	Fertilizer Application
LIVE	LIVE_SILAGE	Agricultural Silage Livestock Feed
LIVE	LIVE_B	Livestock Waste - Beef
LIVE	LIVE_O	Livestock Waste - Other
LIVE	LIVE_D	Livestock Waste - Dairy
LIVE	LIVE_DUST	Livestock Dust from Hooves
MISC	GRILL_RES	Residential outdoor charcoal grilling
MISC	OTH_COMBUST	Other Combustion

4 Emissions Summaries

Annual emissions summaries are presented below for criteria pollutants and ammonia. More detailed information (e.g. sub-categories or by SCC) can also be generated upon request. Abbreviations used are listed in Table 1-1.

Table 4-1. Statewide Emissions in Tons per Year

Category	CO	NH3	NOX	PM10	PM2.5	SO2	VOC
AIR	9,699		1,691	233	200	202	1,232
BOAT	29,365	5	2,731	85	79	2	5,340
CONST				54,100	5,539		
F_ICI	7,028	109	8,119	2,334	1,938	441	473
F_RES	1,999	887	5,003	56	48	32	275
FERT		15,661					
FOOD	2,156			5,630	5,230		773
LIVE		31,227		11,754	2,408		9,820
MISC	2,229	195	55	456	376	5	1,512
NAT	44,219		2,680				214,163
NRM	224,050	37	16,615	1,881	1,785	18	16,395
OB_AG	22,335	6,007	1,080	3,225	3,135	151	2,710
OB_RES	12,658	197	292	2,237	2,187	44	1,557
OB_RX	12,113	1,995	638	2,470	2,152	16	3,028
ORM	330,309	1,817	60,029	3,911	1,769	175	27,675
PETROL							11,009
POINT	28,763	506	26,025	3,970	3,323	7,483	9,025
ROADS				54,899	7,181		
RR	2,862	9	13,629	352	342	10	575
RWC	124,009	870	1,911	17,446	17,438	378	21,060
SHIP	1,691	3	13,549	280	266	256	534
SOLV							69,076
TILL_HARV				76,422	14,895		
WF	512,337	8,426	7,866	52,901	44,832	4,118	121,121
Total	1,367,822	67,950	161,914	294,642	115,122	13,329	517,353

Table 4-2. Annual Statewide Emissions Source Percentages by Pollutant

Category	CO	NH3	NOX	PM10	PM2.5	SO2	VOC
AIR	0.71%		1.04%	0.08%	0.17%	1.51%	0.24%
BOAT	2.15%	0.01%	1.69%	0.03%	0.07%	0.02%	1.03%
CONST				18.36%	4.81%		
F_ICI	0.51%	0.16%	5.01%	0.79%	1.68%	3.31%	0.09%
F_RES	0.15%	1.31%	3.09%	0.02%	0.04%	0.24%	0.05%
FERT	0.00%	23.05%	0.00%	0.00%	0.00%	0.00%	0.00%
FOOD	0.16%			1.91%	4.54%		0.15%
LIVE		45.96%		3.99%	2.09%		1.90%
MISC	0.16%	0.29%	0.03%	0.15%	0.33%	0.04%	0.29%
NAT	3.23%		1.66%				41.40%
NRM	16.38%	0.05%	10.26 %	0.64%	1.55%	0.13%	3.17%
OB_AG	1.63%	8.84%	0.67%	1.09%	2.72%	1.13%	0.52%
OB_RES	0.93%	0.29%	0.18%	0.76%	1.90%	0.33%	0.30%
OB_RX	0.89%	2.94%	0.39%	0.84%	1.87%	0.12%	0.59%
ORM	24.15%	2.67%	37.07 %	1.33%	1.54%	1.31%	5.35%
PETROL							2.13%
POINT	2.10%	0.74%	16.07 %	1.35%	2.89%	56.14%	1.74%
ROADS				18.63%	6.24%		
RR	0.21%	0.01%	8.42%	0.12%	0.30%	0.08%	0.11%
RWC	9.07%	1.28%	1.18%	5.92%	15.15 %	2.83%	4.07%
SHIP	0.12%	0.00%	8.37%	0.10%	0.23%	1.92%	0.10%
SOLV							13.35%
TILL_HARV				25.94%	12.94 %		
WF	37.46%	12.40%	4.86%	17.95%	38.94 %	30.89%	23.41%
Total	100%	100%	100%	100%	100%	100%	100%

Table 4-3. County PM₁₀ Emissions Estimates in Tons per Year

County	OB_AG	AIR	FOOD	SHIP	TILL_HARV	CONST	ROADS	F_ICI	POINT	LIVE	RR	MISC	NRM	BOAT	ORM	F_RES	OB_RES	RWC	OB_RX	WF
Adams	111	3	11		12,522	87	1,373	5		469	28	1	40	0	26	0	7	29	3	19
Asotin	0	0	11	0	316	73	363	4		233	0	2	6	0	10	0	6	30	1	3
Benton	134	2	138	1	2,952	7,911	573	59	5	392	28	12	53	2	116	0	48	129	16	134
Chelan	24	1	64		25	987	660	28		7	7	5	19	2	47	0	32	395	22	1,785
Clallam	2	4	53	41	68	139	309	14	24	72	0	6	15	1	45	0	38	355	129	78
Clark		4	294	8	143	2,868	643	132	60	294	20	30	79	4	209	2	156	1,236	15	17
Columbia	456	0	1	0	1,668	24	761	1		71	0	0	33	0	4	0	2	19	2	92
Cowlitz		2	71	11	72	716	327	35	396	205	19	7	17	2	81	0	44	423	46	68
Douglas	44	3	21		6,009	502	3,599	7	23	115	1	3	25	1	23	0	14	126	17	2,928
Ferry		0	3		158	469	1,973	1		75	1	0	13	0	8	0	6	71	334	3,270
Franklin	176	6	40	1	4,428	2,199	1,293	23		623	22	5	40	1	41	0	21	106	1	953
Garfield	88		1	0	1,138	2	892	0		98	0	0	11	0	4	0	2	9		
Grant	301	13	49		10,110	1,014	2,311	22	23	2,405	6	6	69	2	63	0	36	174	5	149
Grays Harbor	5	1	47	7	147	38	575	14	244	66	1	6	15	1	50	0	37	330	185	4
Island	5	7	45	12	87	148	154	10	4	71	0	6	14	2	33	1	47	304	1	
Jefferson		4	23	14	12	82	467	6	47	22	0	3	13	1	23	0	23	225	87	22
King	11	66	2,199	60	117	12,588	5,640	935	87	280	22	120	471	18	1,037	25	461	2,652	6	113
Kitsap		6	166	36	100	254	585	43	15	13	0	17	47	4	121	3	86	825		3
Kittitas	25	4	38		193	770	487	10		287	3	4	18	1	66	0	20	197	18	657
Klickitat	34	2	9	1	1,241	77	1,133	4	226	227	37	2	18	0	16	0	12	83	236	73
Lewis	7	6	59		310	430	496	19	568	316	14	6	17	1	63	0	46	396	139	15
Lincoln	29	2	8		10,022	483	2,170	2		124	15	1	52	0	18	0	8	40	7	2,350
Mason		6	35	0	22	104	418	8	33	15	1	5	10	2	31	0	44	396	29	5
Okanogan	30	7	18		389	469	2,335	7		513	1	3	13	1	33	0	28	275	75	8,081
Pacific		0	16	5	78	29	428	5	16	56	0	2	6	0	13	0	17	172	51	1
Pend Oreille	4	0	6		148	120	2,276	2	4	41	1	1	10	0	9	0	12	145	110	77
Pierce		11	551	21	75	2,149	1,079	217	325	133	20	55	184	9	467	5	222	1,559	70	232
San Juan	3	11	14	16	61	121	99	4		22	0	2	7	1	4	0	18	143	2	0
Skagit		6	93	15	638	836	568	43	469	247	5	9	30	3	86	1	55	407	121	8
Skamania			3	0	27	17	220	2		8	16	1	10	0	9	0	9	102	29	20,732
Snohomish	3	23	589	9	259	2,405	1,388	293	15	241	13	45	150	9	388	5	214	2,555	54	4,821
Spokane	23	10	357		2,644	7,964	7,673	150	139	330	33	33	98	5	282	4	133	1,146	89	126
Stevens	6	1	17		889	294	4,279	7	171	236	2	3	16	1	26	0	29	311	321	82
Thurston	8	5	193	1	95	834	738	55	0	198	12	19	44	3	154	1	110	759	9	258
Wahkiakum			1	6	68	23	94	1		63	0	0	1	0	3	0	4	33	6	1
Walla Walla	682	2	40	0	4,482	1,023	398	19	122	328	8	4	41	1	32	0	17	113	5	7
Whatcom	10	5	178	13	754	2,104	705	73	883	642	6	14	46	3	107	2	87	655	100	58
Whitman	359	4	23	0	11,906	74	2,616	11	16	239	5	2	80	0	25	0	12	56	1	618
Yakima	646	4	148		2,048	3,672	2,802	63	55	1,977	5	17	54	2	137	1	75	465	131	5,062
State Total	3,225	233	5,630	280	76,422	54,100	54,899	2,334	3,970	11,754	352	456	1,881	85	3,911	56	2,237	17,446	2,470	52,901

Table 4-4. County PM_{2.5} Emissions Estimates in Tons per Year

County	OB_AG	AIR	FOOD	SHIP	TILL_HARV	CONST	ROADS	F_ICI	POINT	LIVE	RR	MISC	NRM	BOAT	ORM	F_RES	OB_RES	RWC	OB_RX	WF
Adams	106	2	10		2,464	9	145	4		95	27	1	39	0	16	0	6	29	3	16
Asotin	0	0	10	0	59	7	40	3		48	0	1	6	0	5	0	6	30	1	3
Benton	128	2	128	1	570	791	80	49	2	81	28	10	51	2	54	0	47	129	14	114
Chelan	22	1	59		5	99	101	23		2	7	4	18	1	23	0	31	395	19	1,512
Clallam	1	4	49	38	13	16	70	12	14	15	0	5	14	1	22	0	37	355	112	66
Clark		4	273	7	28	290	151	109	58	60	19	24	75	4	96	2	152	1,236	13	15
Columbia	452	0	1	0	323	3	80	1		14	0	0	31	0	2	0	2	19	2	78
Cowlitz		1	66	10	14	83	79	29	355	42	19	6	16	1	44	0	43	423	40	58
Douglas	42	3	20		1,178	50	372	5	7	24	1	2	24	1	10	0	14	126	15	2,481
Ferry		0	2		31	58	213	1		15	1	0	12	0	4	0	6	71	291	2,771
Franklin	169	5	37	1	873	224	139	19		127	21	4	38	1	19	0	20	106	1	808
Garfield	87		1	0	213	0	92	0		20	0	0	10	0	2	0	2	9		
Grant	289	12	46		1,995	104	253	18	22	497	6	5	66	1	34	0	34	174	4	126
Grays Harbor	5	0	44	6	29	4	106	11	212	14	1	5	14	1	24	0	36	330	161	4
Island	4	7	41	11	17	16	37	9	3	15	0	5	13	2	16	1	45	304	1	
Jefferson		3	21	13	2	10	76	5	5	4	0	2	12	1	12	0	22	225	76	18
King	11	59	2,042	57	23	1,274	858	782	72	58	22	99	444	17	413	22	458	2,645	5	96
Kitsap		5	155	35	20	26	115	36	2	3	0	14	44	4	53	3	84	825		2
Kittitas	24	3	35		37	80	77	8		60	3	3	17	1	41	0	19	197	16	557
Klickitat	32	2	9	1	239	8	131	4	83	47	36	1	17	0	9	0	11	83	206	62
Lewis	6	5	55		60	47	100	16	496	57	13	5	16	1	35	0	44	396	121	13
Lincoln	28	1	7		1,951	48	227	1		25	14	1	50	0	11	0	8	40	6	1,992
Mason		5	32	0	4	13	75	7	20	3	1	4	9	1	16	0	42	396	25	5
Okanogan	28	6	16		76	50	275	6		107	1	3	12	1	19	0	27	275	65	6,848
Pacific		0	15	5	15	3	67	4	9	12	0	1	5	0	7	0	17	172	44	1
Pend Oreille	4	0	5		29	14	244	1	3	9	1	1	9	0	6	0	11	145	96	66
Pierce		9	512	19	14	231	240	181	270	25	19	45	174	8	193	4	220	1,558	61	196
San Juan	3	10	13	16	11	13	13	4		4	0	1	7	1	2	0	18	143	1	0
Skagit		5	86	14	125	89	113	36	444	51	5	7	28	3	43	1	53	407	105	6
Skamania			3	0	5	2	38	2		1	16	1	9	0	5	0	9	102	25	17,570
Snohomish	2	19	548	9	51	250	329	239		48	12	37	141	9	172	4	211	2,555	47	4,085
Spokane	22	8	331		504	799	844	125	111	68	32	27	93	5	126	4	131	1,146	78	106
Stevens	6	1	16		176	34	470	6	127	49	2	3	15	1	16	0	28	311	280	69
Thurston	7	4	179	1	18	88	136	46	0	37	11	15	42	3	70	1	107	759	8	219
Wahkiakum			1	6	14	3	15	0		13	0	0	1	0	2	0	4	33	5	1
Walla Walla	672	2	37	0	867	103	48	16	115	68	8	3	39	0	16	0	16	113	4	6
Whatcom	10	4	166	13	150	220	133	60	870	133	6	12	43	3	51	1	84	655	87	49
Whitman	357	4	21	0	2,291	7	278	9	7	49	5	2	77	0	13	0	12	56	1	524
Yakima	616	4	137		401	373	320	52	12	408	4	14	52	2	65	1	72	465	114	4,290
State Total	3,135	200	5,230	266	14,895	5,539	7,181	1,938	3,323	2,408	342	376	1,785	79	1,769	48	2,187	17,438	2,152	44,832

Table 4-5. County SO₂ Emissions Estimates in Tons per Year

County	OB_AG	AIR	SHIP	F_ICI	POINT	RR	MISC	NRM	BOAT	ORM	F_RES	OB_RES	RWC	OB_RX	WF
Adams	3	0		1		1	0	0	0	2	0	0	1	0	2
Asotin	0	0	0	1		0	0	0	0	0	0	0	1	0	0
Benton	3	0	0	11	1	1	0	0	0	5	0	1	3	0	14
Chelan	0	0		6		0	0	0	0	2	0	1	10	0	117
Clallam	0	1	57	3	6	0	0	0	0	2	0	1	9	1	5
Clark		1	10	27	7	1	0	1	0	9	2	3	25	0	2
Columbia	38	0	0	0		0	0	0	0	0	0	0	0	0	7
Cowlitz		1	16	8	724	1	0	0	0	4	0	1	11	0	4
Douglas	1	1		1	3	0	0	0	0	1	0	0	3	0	298
Ferry		0		0		0	0	0	0	0	0	0	2	2	254
Franklin	5	6	0	5		1	0	0	0	2	0	0	3	0	97
Garfield	10		0	0		0	0	0	0	0	0	0	0		
Grant	7	9		5	7	0	0	1	0	3	0	1	4	0	14
Grays Harbor	0	0	4	3	72	0	0	0	0	2	0	1	8	1	0
Island	0	10	14	2		0	0	0	0	1	0	1	7	0	
Jefferson		1	16	1	81	0	0	0	0	1	0	0	6	1	1
King	0	124	43	154	129	1	1	5	1	46	12	8	50	0	7
Kitsap		1	26	7		0	0	0	0	5	1	2	17		0
Kittitas	1	1		2		0	0	0	0	4	0	0	5	0	64
Klickitat	1	1	0	1	21	1	0	0	0	1	0	0	2	2	6
Lewis	0	2		4	1,701	0	0	0	0	3	0	1	10	1	1
Lincoln	1	0		0		0	0	0	0	1	0	0	1	0	238
Mason		5	0	2	0	0	0	0	0	2	0	1	10	0	0
Okanogan	0	4		1		0	0	0	0	2	0	1	7	0	735
Pacific		0	0	1	3	0	0	0	0	1	0	0	4	0	0
Pend Oreille	0	0		0	13	0	0	0	0	0	0	0	4	1	5
Pierce		2	35	40	258	1	1	2	0	20	3	4	30	0	17
San Juan	0	6	5	1		0	0	0	0	0	0	0	4	0	0
Skagit		1	11	10	433	0	0	0	0	4	1	1	10	1	1
Skamania			0	0		0	0	0	0	0	0	0	3	0	1,350
Snohomish	0	6	3	71	11	0	0	2	0	17	4	4	51	0	314
Spokane	1	12		26	33	1	0	1	0	12	3	3	23	1	10
Stevens	0	0		2	9	0	0	0	0	1	0	1	9	2	6
Thurston	0	1	1	9	0	0	0	0	0	7	1	2	15	0	17
Wahkiakum			6	0		0	0	0	0	0	0	0	1	0	0
Walla Walla	42	1	0	4	1,099	0	0	0	0	1	0	0	3	0	1
Whatcom	0	2	8	16	2,869	0	0	0	0	5	1	2	13	1	4
Whitman	29	1	0	3	2	0	0	1	0	1	0	0	1	0	60
Yakima	9	2		13	2	0	0	1	0	6	1	2	9	1	466
State Total	151	202	256	441	7,483	10	5	18	2	175	32	44	378	16	4,118

Table 4-6. County NOx Emissions Estimates in Tons per Year

County	OB_AG	AIR	SHIP	F_ICI	POINT	RR	MISC	NAT	NRM	BOAT	ORM	F_RES	OB_RES	RWC	OB_RX	WF
Adams	26	2		19		1,091	0	92	534	3	694	7	1	3	1	4
Asotin	0	0	2	14		0	0	40	68	6	146	22	1	3	0	1
Benton	27	2	42	204	144	1,115	1	104	554	61	1,827	58	6	15	4	32
Chelan	19	1		98		256	1	90	155	40	821	4	5	37	6	184
Clallam	0	6	2,566	48	68	0	1	35	95	47	767	13	5	34	33	8
Clark		4	342	467	142	769	4	37	653	108	3,149	265	21	139	4	3
Columbia	195	0	5	3		6	0	39	226	1	87	1	0	2	1	14
Cowlitz		4	507	129	3,447	759	1	42	142	41	1,658	14	6	41	12	7
Douglas	32	8		23	8	54	0	71	314	18	472	2	2	12	4	692
Ferry		0		5		31	0	110	56	4	170	2	1	6	86	484
Franklin	50	54	21	83		849	1	78	486	21	817	35	3	10	0	224
Garfield	50		6	1		0	0	37	138	1	78	1	0	1		
Grant	91	88		79	55	243	1	151	862	35	1,329	5	6	16	1	33
Grays Harbor	1	0	273	49	321	34	1	57	103	23	857	26	5	32	48	0
Island	1	102	738	36	11	0	1	5	100	77	531	81	7	30	0	
Jefferson		3	859	22	555	0	0	34	91	49	462	24	3	21	22	2
King	3	1,040	2,645	3,168	1,822	861	14	60	3,492	672	12,979	1,810	53	344	2	12
Kitsap		9	1,759	146		12	2	12	331	165	1,781	177	11	91		0
Kittitas	6	4		33		113	0	80	156	15	1,635	37	3	18	5	146
Klickitat	21	7	51	16	91	1,458	0	104	167	6	335	11	2	8	61	12
Lewis	2	11		69	6,295	530	1	81	141	25	1,301	19	7	38	36	2
Lincoln	8	1		6		562	0	102	680	11	425	8	1	3	2	552
Mason		55	9	28	57	25	1	33	69	48	602	20	7	38	8	1
Okanogan	18	33		25		50	0	191	130	13	732	6	4	26	19	1,590
Pacific		5	200	17	62	0	0	24	34	13	277	6	2	16	13	0
Pend Oreille	0	0		6	14	36	0	62	53	8	207	2	2	13	28	10
Pierce		10	952	751	1,293	763	7	53	1,381	277	6,188	534	26	185	18	29
San Juan	1	55	637	16		0	0	4	44	61	85	13	3	14	0	0
Skagit		5	610	156	4,158	187	1	40	255	115	1,590	131	8	39	31	1
Skamania			17	7		632	0	48	39	4	185	5	1	9	8	2,113
Snohomish	1	39	381	1,075	141	494	5	51	1,104	308	5,619	599	26	281	14	492
Spokane	6	94		513	912	1,297	4	106	962	121	4,057	464	17	128	23	19
Stevens	1	1		27	467	62	0	155	144	29	597	24	4	28	83	12
Thurston	2	11	34	186	6	455	2	33	352	105	2,383	187	15	84	2	28
Wahkiakum			353	2		0	0	8	7	5	56	1	1	3	2	0
Walla Walla	244	3	17	67	1,056	314	0	73	489	13	569	41	2	11	1	2
Whatcom	3	13	507	261	4,848	234	2	42	389	134	1,726	217	12	74	26	6
Whitman	148	4	18	40	22	162	0	98	1,054	8	438	28	2	5	0	135
Yakima	126	15		224	32	174	2	197	566	41	2,400	103	11	51	34	1,016
State Total	1,080	1,691	13,549	8,119	26,025	13,629	55	2,680	16,615	2,731	60,029	5,003	292	1,911	638	7,866

Table 4-7. County VOC Emissions Estimates in Tons per Year

County	OB_AG	AIR	FOOD	SHIP	F_ICI	POINT	LIVE	RR	MISC	NAT	PETROL	SOLV	NRM	BOAT	ORM	F_RES	OB_RES	RWC	OB_RX	WF
Adams	89	5	1		1		336	44	1	2,092	107	1,019	79	11	139	0	4	33	4	40
Asotin	0	0	1	0	1		47	0	1	1,194	11	187	43	21	97	1	5	34	1	7
Benton	103	4	19	1	12	9	271	45	69	2,835	370	2,693	292	177	832	3	34	156	19	282
Chelan	20	2	9		6		4	11	62	9,139	109	1,062	260	104	412	0	22	456	27	4,251
Clallam	1	8	7	115	3	61	25	0	3	5,681	114	579	208	82	411	1	25	416	158	185
Clark		7	41	13	27	69	148	33	15	3,584	187	3,822	677	296	1,637	15	115	1,531	18	39
Columbia	410	0	0	0	0		24	0	0	2,380	8	65	709	4	31	0	1	23	3	210
Cowlitz		4	10	20	8	650	40	31	4	5,642	114	981	212	113	603	1	29	492	56	162
Douglas	35	10	3		1	3	37	2	1	2,157	52	483	85	52	219	0	10	150	21	6,181
Ferry		0	0		0		26	1	0	11,523	14	66	391	9	66	0	3	81	410	7,490
Franklin	133	38	5	1	5		692	38	63	2,009	761	1,876	119	64	386	2	14	122	1	2,014
Garfield	71		0	0	0		31	0	0	1,306	6	44	34	2	22	0	1	10		
Grant	237	50	7		5	24	1,356	10	3	4,365	392	3,057	254	112	525	0	22	202	6	318
Grays Harbor	5	1	6	10	3	161	66	2	4	8,948	68	592	236	60	391	1	23	383	227	10
Island	4	51	6	30	2	36	24	0	2	560	47	611	136	128	352	4	30	359	1	
Jefferson		6	3	34	1	80	9	0	1	5,859	93	252	172	59	207	1	14	260	106	52
King	10	720	297	103	184	614	246	39	917	7,845	2,534	18,218	4,523	1,073	5,651	102	354	3,202	7	269
Kitsap		12	23	64	8	93	7	1	67	1,734	359	1,946	435	239	1,031	9	58	1,030		6
Kittitas	21	7	5		2		104	5	2	6,271	163	466	222	40	353	2	13	223	22	1,407
Klickitat	30	5	1	2	1	237	99	59	60	7,793	69	222	225	16	146	1	6	98	289	166
Lewis	6	12	8		4	442	283	22	3	10,921	155	674	190	62	490	1	27	457	170	36
Lincoln	22	3	1		0		56	23	0	2,979	78	254	128	27	108	0	4	44	9	4,969
Mason		29	5	0	2	144	5	1	2	4,729	98	466	134	106	342	1	27	457	36	13
Okanogan	24	22	2		1		131	2	2	16,743	307	633	113	39	297	0	15	319	92	17,710
Pacific		2	2	6	1	63	52	0	1	4,144	22	169	111	23	128	0	11	200	62	2
Pend Oreille	3	0	1		0	66	14	2	0	8,220	15	109	264	26	99	0	7	164	135	181
Pierce		19	77	44	44	773	68	33	28	6,429	1,589	6,863	1,531	553	2,985	30	165	1,908	86	542
San Juan	3	32	2	21	1		10	0	1	438	80	122	93	58	91	1	11	167	2	1
Skagit		10	13	22	9	1,862	398	8	5	5,301	158	1,333	329	167	679	7	37	466	148	18
Skamania			0	1	0		3	26	0	7,279	13	108	296	11	79	0	5	112	36	49,443
Snohomish	2	44	81	14	63	370	367	21	25	7,177	673	6,306	1,437	568	2,688	33	153	3,170	66	11,494
Spokane	19	72	50		30	195	125	55	78	5,769	780	4,225	759	371	2,082	26	91	1,424	109	288
Stevens	4	1	2		2	257	96	3	2	13,000	45	365	183	83	318	1	15	353	394	188
Thurston	7	10	27	1	11	229	204	19	9	3,790	246	2,265	358	206	1,123	10	78	934	11	612
Wahkiakum			0	14	0		18	0	0	1,371	4	39	6	10	26	0	2	38	8	2
Walla Walla	616	7	6	1	4	243	119	13	2	2,668	59	1,377	188	38	284	2	11	135	6	15
Whatcom	9	14	25	18	15	1,705	1,174	10	8	5,282	383	1,842	429	183	914	11	59	807	123	139
Whitman	330	11	3	1	2	30	63	8	1	2,313	286	536	141	24	172	2	7	64	1	1,327
Yakima	496	15	21		13	608	3,042	8	68	12,693	441	3,151	395	122	1,258	6	48	578	160	11,053
State Total	2,710	1,232	773	534	473	9,025	9,820	575	1,512	214,163	11,009	69,076	16,395	5,340	27,675	275	1,557	21,060	3,028	121,121

Table 4-8. County CO Emissions Estimates in Tons per Year

County	OB_AG	AIR	FOOD	SHIP	F_ICI	POINT	RR	MISC	NAT	NRM	BOAT	ORM	F_RES	OB_RES	RWC	OB_RX	WF
Adams	595	135	4		15		239	4	1,183	846	53	3,202	3	31	198	15	167
Asotin	2	0	4	0	12		0	8	411	494	98	894	9	38	209	4	30
Benton	648	116	53	6	177	20	243	58	1,155	4,105	858	9,755	24	277	930	76	1,177
Chelan	175	56	24		83		53	25	1,499	2,388	522	4,730	2	181	2,719	107	18,091
Clallam	10	160	20	285	42	30	0	28	873	2,246	471	4,415	4	207	2,476	633	788
Clark		207	113	41	394	188	162	146	596	10,451	1,460	17,676	110	922	9,010	72	162
Columbia	4,058	1	0	1	3		1	2	603	1,857	17	414	0	10	135	12	888
Cowlitz		68	27	60	103	2,422	164	35	997	2,312	556	7,874	6	240	2,938	223	689
Douglas	316	125	8		20	3	12	12	841	944	251	2,669	1	81	888	84	25,796
Ferry		14	1		4		4	2	1,932	984	47	872	0	27	483	1,639	31,686
Franklin	934	215	15	3	68		173	23	975	1,624	307	4,698	15	115	734	4	8,409
Garfield	819		0	1	1		0	1	463	247	12	337	0	8	62		
Grant	1,690	410	19		65	97	49	26	1,875	2,644	529	6,914	2	185	1,202	23	1,332
Grays Harbor	41	25	18	38	41	547	4	29	1,308	2,163	300	4,820	9	195	2,291	909	42
Island	29	161	17	80	31	5	0	32	97	2,163	751	3,297	26	249	2,131	5	
Jefferson		164	9	93	18	673	0	13	963	1,223	395	2,481	7	120	1,555	426	221
King	82	3,148	833	352	2,855	1,612	176	593	1,328	80,935	6,382	71,299	737	2,815	18,443	29	1,147
Kitsap		286	64	223	133		2	85	290	6,862	1,480	11,034	66	477	6,033		26
Kittitas	135	194	15		29		25	17	1,163	1,564	197	6,205	13	105	1,341	88	5,886
Klickitat	248	62	4	8	13	159	321	8	1,424	1,071	80	1,688	4	55	583	1,157	702
Lewis	51	227	23		58	3,560	113	27	1,942	1,998	314	6,298	7	228	2,733	679	154
Lincoln	157	79	3		5		120	4	1,360	1,183	136	1,812	3	36	266	34	20,741
Mason		169	14	1	24	53	3	22	810	1,496	559	3,660	7	225	2,730	143	54
Okanogan	192	240	7		22		6	16	2,766	1,108	187	3,800	2	129	1,899	367	74,384
Pacific		7	6	31	13	22	0	8	597	877	131	1,526	2	91	1,189	250	9
Pend Oreille	11	8	2		5	2	5	5	1,372	850	121	1,121	1	61	986	539	769
Pierce		507	213	105	657	1,819	156	269	1,088	24,673	3,020	35,496	217	1,323	11,147	342	2,299
San Juan	20	313	5	97	13		0	8	76	1,169	442	696	4	93	994	8	4
Skagit		272	36	83	128	1,729	41	44	932	3,642	1,035	8,499	51	301	2,814	593	77
Skamania			1	2	5		139	4	1,380	886	54	929	2	43	677	143	210,463
Snohomish	20	1,044	226	55	853	112	104	226	1,196	23,957	3,192	30,892	241	1,236	18,638	264	48,926
Spokane	119	444	139		454	212	273	161	1,432	12,607	1,775	23,634	192	743	8,363	437	1,217
Stevens	23	32	7		22	640	9	16	2,514	1,189	403	3,376	9	132	2,118	1,576	794
Thurston	49	191	75	5	168	3	96	92	621	5,723	1,134	13,317	74	633	5,522	43	2,600
Wahkiakum			0	42	2		0	2	204	98	55	284	0	18	226	31	7
Walla Walla	5,628	105	15	3	56	661	62	20	958	1,827	182	3,231	17	94	802	23	64
Whatcom	72	161	69	72	216	14,128	51	71	888	6,465	1,162	9,879	83	479	4,763	491	590
Whitman	3,278	173	9	3	33	55	23	11	1,500	1,631	113	2,288	11	61	387	4	5,552
Yakima	2,933	180	57		188	15	32	78	2,609	5,548	585	14,298	41	396	3,392	640	46,394
State Total	22,335	9,699	2,156	1,691	7,028	28,763	2,862	2,229	44,219	224,050	29,365	330,309	1,999	12,658	124,009	12,113	512,337

Table 4-9. County NH₃ Emissions Estimates in Tons per Year

County	OB_AG	SHIP	FERT	F_ICI	POINT	LIVE	RR	MISC	NRM	BOAT	ORM	F_RES	OB_RES	RWC	OB_RX	WF
Adams	118		1,007	0		1,281	1	0	1	0	20	1	0	1	3	3
Asotin	0	0	164	0		219	0	0	0	0	4	4	1	2	1	0
Benton	106	0	804	3	38	898	1	9	1	0	52	11	4	7	13	20
Chelan	47		264	1		19	0	9	0	0	24	1	5	18	18	296
Clallam	1	0	136	1	1	99	0	0	0	0	21	1	4	17	104	13
Clark		0	217	7	6	578	1	1	2	0	93	52	19	64	12	3
Columbia	1,392	0	284	0		105	0	0	1	0	2	0	0	1	2	15
Cowlitz		0	212	2	134	189	1	0	0	0	45	2	5	20	37	11
Douglas	80		584	0	8	151	0	0	0	0	14	0	2	6	14	430
Ferry			138	0		104	0	0	0	0	5	0	0	3	270	521
Franklin	195	0	733	1		2,297	1	9	1	0	25	7	2	5	1	140
Garfield	377	0	284	0		122	0	0	0	0	2	0	0	0		
Grant	332		1,342	1	5	4,546	0	0	1	0	37	1	5	8	4	22
Grays Harbor	7	0	263	1	26	196	0	0	0	0	26	3	3	16	150	1
Island	4	0	14	0	0	96	0	0	0	0	14	5	5	15	1	
Jefferson		0	105	0	25	36	0	0	0	0	13	0	2	11	70	4
King	13	1	305	39	6	758	1	125	10	1	439	344	34	132	5	19
Kitsap		0	100	2		50	0	9	1	0	55	25	6	42		0
Kittitas	16		564	0		371	0	0	0	0	41	4	2	9	15	98
Klickitat	57	0	385	0	6	353	1	8	0	0	9	2	1	4	191	12
Lewis	9		357	1	36	1,182	0	0	0	0	36	2	4	19	112	3
Lincoln	44		849	0		209	0	0	1	0	11	1	1	2	6	346
Mason		0	123	0		25	0	0	0	0	17	2	5	19	23	1
Okanogan	43		526	0		476	0	0	0	0	20	0	2	13	60	1,232
Pacific		0	127	0		152	0	0	0	0	8	0	2	8	41	0
Pend Oreille	1		98	0	1	52	0	0	0	0	5	0	2	7	89	13
Pierce		0	244	10	106	475	0	2	4	0	197	100	16	80	56	38
San Juan	2	0	34	0		56	0	0	0	0	2	0	2	7	1	0
Skagit		0	271	2	16	1,059	0	0	1	0	47	20	5	20	98	1
Skamania		0	148	0		28	0	0	0	0	5	1	1	5	24	3,439
Snohomish	4	0	305	17	2	1,135	0	2	3	0	171	107	15	131	44	800
Spokane	22		730	7	11	481	1	10	2	0	118	92	9	59	72	20
Stevens	3		327	0		350	0	0	0	0	15	3	2	14	260	13
Thurston	6	0	203	2		960	0	0	1	0	74	32	12	40	7	43
Wahkiakum		0	56	0		72	0	0	0	0	2	0	0	2	5	0
Walla Walla	1,627	0	719	1	39	451	0	0	1	0	16	8	2	6	4	1
Whatcom	11	0	355	4	39	2,708	0	1	1	0	49	32	9	34	81	10
Whitman	1,082	0	1,367	1		291	0	0	2	0	13	5	1	3	1	92
Yakima	407		917	3		8,597	0	9	1	0	68	18	8	24	105	769
State Total	6,007	3	15,661	109	506	31,227	9	195	37	5	1,817	887	197	870	1,995	8,426

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