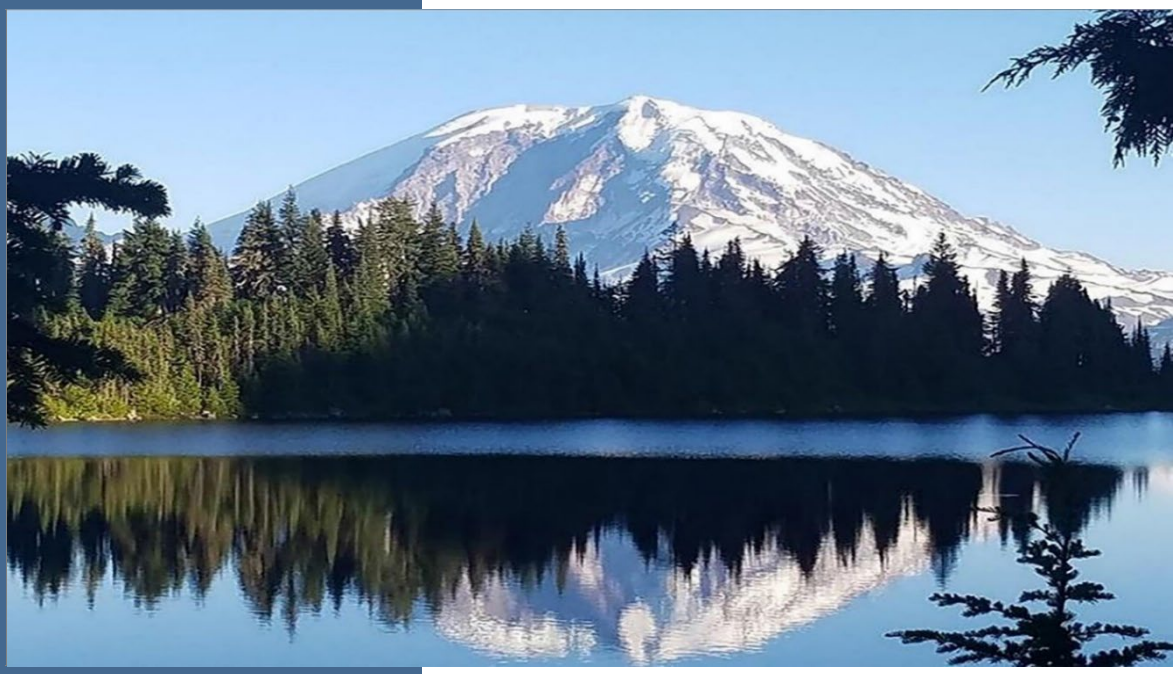

Report to the Legislature
The Hydrofluorocarbon Transition

Estimating Leakage of Refrigerants from Existing Systems in Washington

By

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For the

Air Quality Program

Washington State Department of Ecology

Olympia, Washington

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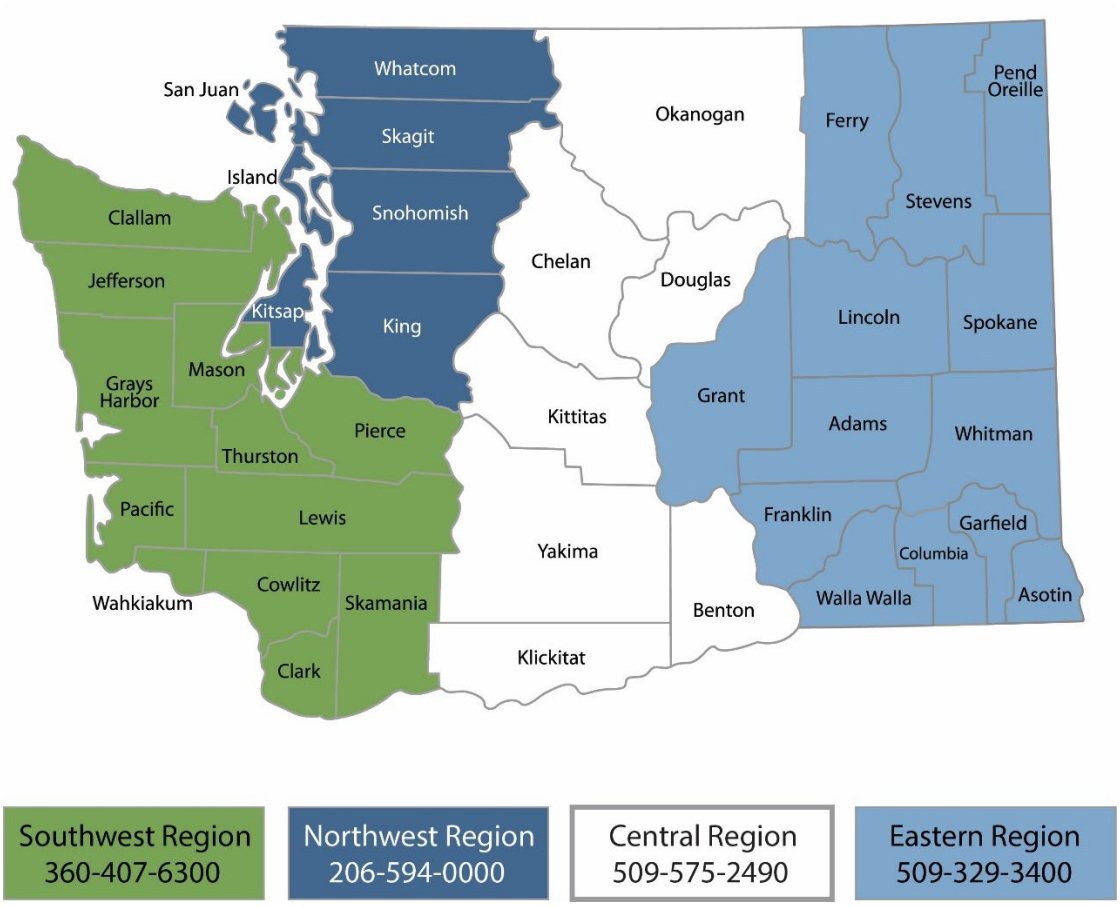

Region	Counties served	Mailing Address	Phone
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Northwest	Island, King, Kitsap, San Juan, Skagit, Snohomish, Whatcom	PO Box 330316 Shoreline, WA 98133	206-594-0000
Central	Benton, Chelan, Douglas, Kittitas, Klickitat, Okanogan, Yakima	1250 W Alder St Union Gap, WA 98903	509-575-2490
Eastern	Adams, Asotin, Columbia, Ferry, Franklin, Garfield, Grant, Lincoln, Pend Oreille, Spokane, Stevens, Walla Walla, Whitman	4601 N Monroe Spokane, WA 99205	509-329-3400
Headquarters	Across Washington	PO Box 46700 Olympia, WA 98504	360-407-6000

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ECOLOGY
State of Washington

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List of Acronyms

AIM – American Innovation and Manufacturing (Act)
CARB – California Air Resources Board
CFC – Chlorofluorocarbon
CO_2 – Carbon dioxide
CO_2e – Carbon dioxide equivalent
EPA – United States Environmental Protection Agency
F-gases – Fluorinated gases
GHG – Greenhouse gas
GWP – Global warming potential
HCFC – Hydrochlorofluorocarbon
HFC – Hydrofluorocarbon
HFO – Hydrofluoro-olefins
IPCC – Intergovernmental Panel on Climate Change
$MMTCO_2e$ – Million metric tonnes of carbon dioxide equivalent
NAICS – North American Industry Classification System
ODS – Ozone Depleting Substances
PFC - Perfluorocarbon
RCW – Revised Code of Washington
RMP – Refrigeration Management Program
SLCP – Short-lived climate pollutant
WAC – Washington Administrative Code

Executive Summary

In 2019 and 2021, the Washington State Legislature passed laws regulating the uses of hydrofluorocarbons (HFCs). RCW 70A.60.030(1) requires the Department of Ecology to establish a refrigerant management program designed to reduce emissions of refrigerants. The program must apply to refrigeration and air conditioning equipment that uses 50 pounds or more of regulated refrigerant. (Equipment using less than 50 pounds is exempt under the statute.) Ecology is currently in rulemaking to establish the refrigerant management program.

This report provides estimates of refrigerant leakage from existing systems in Washington State that will be used to support the development of the state's refrigerant management program. This report also fulfills the requirement in RCW 70A.60.030(1) that:

> "The department may require compliance with refrigerant management program requirements beginning no earlier than January 1, 2024, and no earlier than the adjournment of the regular legislative session following the submission of a report to the appropriate committees of the legislature by the department estimating leakage of refrigerants from existing systems in Washington, and estimating a statewide rate of leakage from the categories of systems that are subject to refrigerant management program rules adopted by the department under this section." [2]

Background

Hydrofluorocarbons (HFCs) are chemicals used in air conditioning and refrigeration, in producing insulating foams, and as propellants in aerosol products. They are potent greenhouse gases (GHGs), hundreds to thousands of times more powerful in warming the planet than carbon dioxide.

Emissions estimates methodology

Ecology developed a method to estimate HFC emissions in Washington including the following:

- The number of businesses in the state that have equipment that might leak HFCs.
- The types of equipment that might leak HFCs.
- How much HFC leakage is attributable to each type of equipment.
- The types of HFC refrigerants different equipment uses.

Ecology adapted methodologies described by the California Air Resources Board (CARB) in their GHG emissions inventory reports to develop Washington's methodology, emission factors, and calculations of HFC emissions. A detailed explanation of how estimates were calculated is provided below and in the report's appendices.

[2] https://app.leg.wa.gov/RCW/default.aspx?cite=70A.60.030

Results

Ecology estimates approximately six million pounds of refrigerant leaks annually throughout Washington from all equipment categories with charges of 50 pounds or more of refrigerant. This represents 5.8 million metric tonnes of CO_2 equivalent ($MMTCO_2e$) statewide. Of this, we estimate 3.4 million metric tonnes of CO_2e are HFCs.

Next steps

Ecology's next steps are to complete the required rulemaking to implement Washington's Refrigerant Management Program (RMP). We expect to complete the rulemaking process by summer 2023. This will allow Ecology to implement the RMP in early 2024 and collect state-specific information about equipment, refrigerants, and leaks, which we can then use to update emissions estimates. Ecology will use this information to carry out a statutorily mandated program evaluation of the program every five years, beginning in 2029, and make any necessary updates to the program.

Background

Legislative Directive

RCW 70A.60.030(1) requires Ecology to prepare this report, as follows:

> "The department may require compliance with refrigerant management program requirements beginning no earlier than January 1, 2024, and no earlier than the adjournment of the regular legislative session following the submission of a report to the appropriate committees of the legislature by the department estimating leakage of refrigerants from existing systems in Washington, and estimating a statewide rate of leakage from the categories of systems that are subject to refrigerant management program rules adopted by the department under this section.

Hydrofluorocarbons (HFCs)

In the 1970s, scientists discovered that certain chemical compounds used in refrigeration systems, including chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), deplete the ozone layer. These are commonly known as ozone depleting substances (ODS). The ozone layer of earth's atmosphere acts as a global sunscreen, shielding the surface of the planet from many of the sun's harmful rays. In an effort to curb the damage to this natural protective layer, hydrofluorocarbons (HFCs) were developed to replace ODS.

A class of synthetic gases containing hydrogen, fluorine, and carbon atoms, HFCs are used in multiple applications, including air conditioning, refrigeration, foam blowing, solvents, aerosols, and fire suppression. As designed, these compounds are less harmful to the ozone layer than CFCs, but they are powerful climate-warming greenhouse gases (GHGs) that remain in the atmosphere for a relatively short time. This puts them in a class of short-lived climate pollutants (SLCPs) that are impactful because, pound for pound, they can trap more heat in the atmosphere than carbon dioxide (CO_2). Some HFCs, for example, can have up to 20,000 times the warming impact of CO_2.

As the use of HFCs has increased globally to replace ODS, so have climate-warming HFC emissions.[3] Without action, projections indicate that HFC emissions will increase from about one percent of global GHG emissions in 2022 to between 7 and 19 percent of global GHG emissions by 2050.[4]

Global Warming Potential

Global Warming Potential (GWP) measures how much heat a substance traps in the atmosphere compared to CO_2. Emissions, including those from HFCs, are analyzed using GWP

[3] United Nations Environment Programme and International Energy Agency (2020). *Cooling Emissions and Policy Synthesis Report*. UNEP, Nairobi and IEA, Paris.
[4] Environmental Investigation Agency (2015). https://eia-global.org/campaigns/Climate/what-are-hydrofluorocarbons

values.[5] The GWP represents the relative climate warming of a kilogram of emissions averaged over a set time period (generally 20 or 100 years). The larger the GWP for a GHG, the more that particular gas warms the earth compared to CO_2. In this report, we use 100-year GWP values from the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). [6] This is consistent with Ecology's official GHG inventory[7] as well as most other GHG emission inventories worldwide.

Washington State policy

In 2019, the Washington Legislature adopted Engrossed Second Substitute House Bill (E2SHB) 1112 (Chapter 70A.60 RCW), addressing GHG emissions originating from HFCs and initiating the transition away from HFCs. The law took effect July 28, 2019 and requires manufacturers to limit or eliminate the use of HFCs in various new products and equipment sold in Washington, including residential and commercial refrigerators, certain commercial cooling technologies, multiple foam products, and several aerosol propellants.

The restrictions phase in over five years with a January 1, 2021 compliance deadline for the first set of products. The rulemaking process to implement the restrictions included extensive stakeholder engagement. In addition, Ecology worked to align this rule with industry practices and HFC regulations in other states. Ecology adopted the final rule[8] in December 2020.

To further address significant sources of HFC emissions in Washington that were not covered by the 2019 law, the Washington Legislature adopted additional changes to Chapter 70A.60 RCW that took effect July 25, 2021. The 2021 revisions expanded the list of products subject to HFC restrictions to include heat pumps and air conditioning not previously addressed and added an option for Ecology to set GWP limits on certain equipment.

Additionally, the law requires the establishment of a Refrigerant Management Program (RMP) that expands Ecology's authority to regulate existing stationary refrigeration and air conditioning systems containing 50 pounds or more of a regulated refrigerant (typically large commercial systems).

The goal of the RMP is to "reduce emissions of refrigerants, including regulated substances and their substitutes, from activities or equipment responsible for significant volumes of such emissions."[9] Owners of large equipment containing 50 pounds or more of refrigerant must register these systems with Ecology, conduct periodic leak inspections and repairs, maintain

[5] California Air Resources Board (2020). Public Hearing to Consider the Proposed Amendments to the Prohibitions on Use of Certain Hydrofluorocarbons in Stationary Refrigeration, Chillers, Aerosols-Propellants, and Foam End-Uses Regulation: Initial Statement of Reasons. CARB.
[6] Where IPCC Fourth Assessment GWP values are not listed for specific F-gases, Washington Department of Ecology uses the 100-year GWP values listed in IPCC Fifth Assessment Report (IPCC, 2013), and where neither are not available, Washington Department of Ecology uses the 100-year GWP values as listed in the IPCC Third Assessment Report of the IPCC (IPCC, 2001).
[7] Department of Ecology, AQP. (2021). Washington State Greenhouse Gas Emissions Inventory: 1990-2018. Publication 20-02-020. Washington State Greenhouse Gas Emissions Inventory: 1990-2018 (https://apps.ecology.wa.gov/publications/documents/2002020.pdf).
[8] Chapter 173-443 WAC (https://app.leg.wa.gov/WAC/default.aspx?cite=173-443).
[9] RCW 70A.60.040

records, and submit periodic reports. Ecology must conduct periodic facility inspections and has authorization to collect fees to support these activities. The RMP cannot begin until January 1, 2024, and only after Ecology submits this report to the Legislature.

Refrigeration and air conditioning

Of all HFC emissions in Washington (Figure 1), stationary air conditioning (AC) and refrigeration contribute the largest emissions. Within those categories, leaks from commercial and industrial refrigeration and air conditioning (RAC) equipment containing 50 pounds or more of refrigerant are likely to make up significant portions of HFC emissions. Some examples of end uses in this sector, with 50 or more pounds of refrigerant include:

- Stationary air conditioning (buildings approximately 7,000 ft^2 and greater).
- Cold storage warehouses (commercial space approximately 1,400 ft^2 and greater).
- Retail food refrigeration (commercial space approximately 2,000 ft^2 and greater).
- Food processing (e.g., canning, freeze-drying, ice cream, etc.).
- Industrial process cooling (cooling related to manufacturing processes).

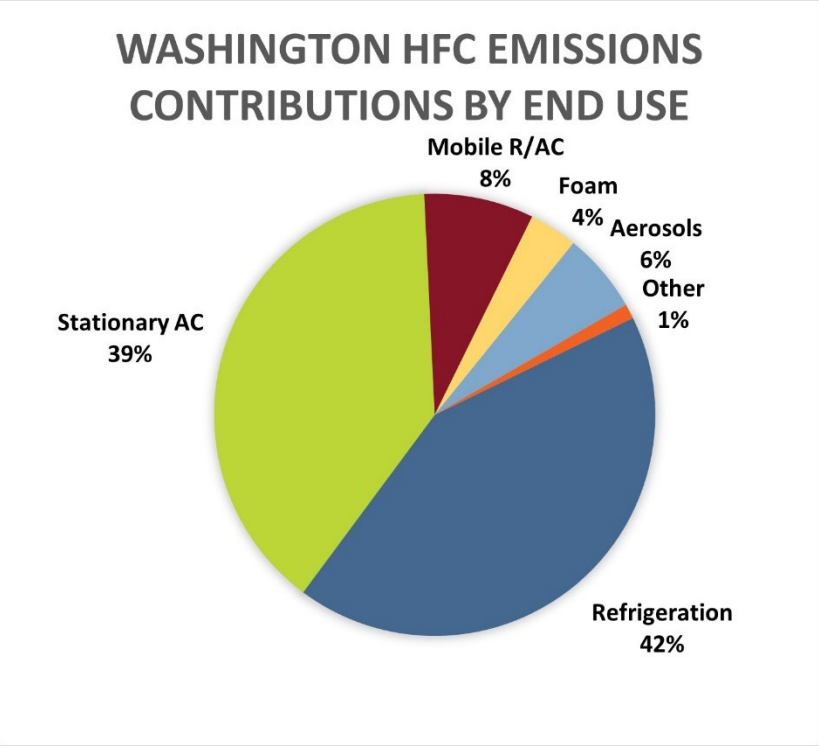

Figure 1. Washington HFC Emissions Contributions by End Use[10]

[10] Modified from Department of Ecology (2021). Report to the Legislature: The Hydrofluorocarbon Transition. Publication 21-02-004. Report to the Legislature: The Hydrofluorocarbon Transition (https://apps.ecology.wa.gov/publications/documents/2102004.pdf).

Refrigerant management program development and implementation

RCW 70A.60.030 directed the establishment of a RMP for facilities that have refrigeration and air conditioning systems that contain 50 or more pounds of high-GWP refrigerant, i.e., a refrigerant with a GWP of greater than 150. Owners and operators of this equipment will be required to register their equipment with Ecology, conduct periodic leak inspections, and follow maintenance guidelines to prevent equipment from leaking over a threshold set by Ecology. In addition, the RMP will require owners and operators to:

- Maintain records and submit annual reports to Ecology for certain systems.
- Submit reports documenting any leaks discovered that cause their leak rate to exceed annual thresholds.
- Furnish records upon request documenting that they are following required operating and maintenance procedures.

These requirements will not only help ensure refrigerant leaks are addressed and repaired in a timely manner but will also help provide Ecology with the information needed to make better estimates of refrigerant emissions in the future.

Methodology for Estimating HFC Emissions

Ecology developed a method to estimate HFC emissions in Washington including the following:

- The number of businesses in the state that have equipment that might leak HFCs.
- The types of equipment that might leak HFCs.
- How much HFC leakage is attributable to each type of equipment.
- The types of HFC refrigerants used in different equipment.

Ecology studied methodologies described by CARB in their GHG emissions inventory reports to develop Washington's methodology, emission factors, and calculations of HFC emissions. As the only other state that has detailed HFC emissions data, including businesses reporting refrigeration and air conditioning leakage, CARB's methodology provided a guide for Ecology in the development of our state-specific methodology. A detailed explanation of how estimates were calculated is provided below and in the report's appendices.

General methodology of emission estimation

Ecology adopted methodologies described by CARB in its GHG emissions inventory reports to estimate Washington's HFC emissions.

To estimate HFC emissions in California, CARB used (1) data from mandatory reporting under fluorinated gas and refrigerant management programs for California businesses and (2) refrigeration and air conditioning equipment market reports. This allowed them to develop emission profiles for categories of refrigerant-containing equipment that were subject to California's RMP requirements. Within each category and subcategory, they estimated:[11]

- Quantities of refrigeration and air conditioning equipment.
- Refrigerant type and capacity in pounds.
- Annual loss (leakage) rates.[12]

To estimate HFC emissions in Washington, Ecology started with the inventory of stationary refrigeration and air conditioning equipment developed by CARB, which listed specific NAICS codes identifying the businesses that utilized each type of equipment, as a guide to determine which Washington businesses would likely be covered under the RMP.[13] The CARB inventory does not include air conditioning because CARB does not regulate AC through their RMP. As air conditioning units with 50 pounds or more of refrigerant are regulated under Washington's RMP (RCW 70A.60.030), Ecology then incorporated NAICS codes for businesses that would be expected to have AC systems.

[11] CARB (2016). California's High Global Warming Potential Gases Emission Inventory – Emission Inventory Methodology and Technical Support Document. April 2016.
[12] CARB (2009a). Inventory of Direct and Indirect GHG Emissions from Stationary Air Conditioning and Refrigeration Sources, with Special Emphasis on Retail Food Refrigeration and Unitary Air Conditioning. ARMINES Center for Energy and Processes for CARB, March 2009.
[13] CARB (2016).

Estimating units in Washington

Based on the methodology explained above and using data gathered through Data Axle's "U.S. Businesses Database,"[14] Ecology estimated the number of units in Washington for each business sector. At the time of our search (Spring 2022), the Data Axle database contained more than 360,000 active businesses across the state. To differentiate the types of equipment assumed to be located at businesses, we placed businesses into emission subcategories (e.g., small commercial refrigeration) based on their North American Industry Classification System (NAICS) categories (Appendix A).

While CARB focused on subcategories related to process cooling and cold storage systems, Washington's RMP is broader and also must account for emissions from all systems with 50 or more pounds of refrigerant. This includes businesses, such as office buildings, that use air conditioning for comfort cooling only.

Ecology included all reasonably-considered businesses that potentially use refrigeration and air conditioning equipment containing 50 pounds or more of refrigerant.[15] Key areas of uncertainty in this estimate include:

- There may be locations with multiple smaller refrigeration or air conditioning units, each less than the 50-pound threshold, instead of a single large unit containing more than 50 pounds of refrigerant.
- There may be businesses with equipment larger than originally estimated, based on their process or site-specific needs.

Through implementation of the RMP, Ecology will obtain business-specific data and allow us to refine emission estimates.

Emission categories and sub-categories

The types of equipment containing 50 or more pounds of refrigerant fall into different end-use categories based in part on equipment characteristics. Ecology used the following sector categories:[16]

- Commercial Refrigeration, including supermarkets, grocery stores, and supply chain cold storage warehousing.
- Industrial Process Refrigeration, including cooling related directly to industrial processes, such as metallurgy/metal working, pharmaceuticals, and food processing.
- Air Conditioning, including units used for comfort cooling and data center cooling.

[14] Data Axle Reference Solutions (https://www.referenceusa.com).
[15] Appendix A includes a list of all NAICS codes included in the emissions calculations determination.
[16] CARB (2009b). Appendix B: California Facilities and GHG Emissions Inventory – High GWP Stationary Source Refrigerant Management Program. State of CA Air Resources Board Research Division. October, 2009.

HFC emissions categories are further broken down into sub-categories based on refrigerant charge size for equipment containing 50 pounds or more of refrigerant. See Table 1.

Table 1. Equipment category, equipment type, and refrigerant charge

Emission Category	Emission Sub-Category	Pounds of Refrigerant in system
Air Conditioning	Small	50 to 199
	Medium	200 to 1,499
	Large	1,500+
Commercial Refrigeration Centralized	Small	50 to 199
	Medium	200 to 1,499
	Large	1,500+
Commercial Refrigeration Cold Storage	Small	50 to 199
	Medium	200 to 1,499
	Large	1,500+
Industrial Process Refrigeration	Small	50 to 199
	Medium	200 to 1,499
	Large	1,500+

Description of emission categories

Air conditioning

Air conditioning equipment containing 50 or more pounds of refrigerant can include units such as chillers, centralized systems that provide plant-wide cooling, portable units, and air handling units used for comfort cooling. The type of unit utilized is dependent on the required end use and cooling loads, as well as the space available to install the units.

Commercial refrigeration (centralized and cold storage)

Commercial refrigeration equipment containing 50 or more pounds of refrigerant includes refrigerated equipment found in supermarkets, large grocery stores, and other retail/wholesale food establishments. This type of refrigeration equipment typically includes refrigerant condensing units that contain 50 to 200 pounds of refrigerant. It may also include larger centralized systems that can contain more than 200 pounds of refrigerant, with a central compressor rack and condensing unit system linked through extensive installations of piping.

Commercial refrigeration also includes cold storage warehouses. However, many of these systems use natural refrigerants, such as ammonia, with only 20 percent of those in the market using HFCs in 2018.[17]

[17] CARB (2009a).

Industrial process refrigeration

Industrial process refrigeration includes custom-designed systems specified by the industrial application. They range in complexity and may have different systems for various processes. Industrial applications include, but are not limited to, chemical, petrochemical, pharmaceutical, oil and gas, and metallurgical industries. Industrial process refrigeration also includes food processing which can include dairy processing, breweries, flash freezing facilities, and other applications. These systems are generally larger, with an average charge of more than 200 pounds of refrigerant per unit, which places them within the "large" and "medium" size categories. Like cold storage warehouses, industrial process refrigeration systems utilize natural refrigerant in up to 80 percent of units currently in use.[18]

Calculation method and inputs

To calculate estimated statewide emissions of leaking refrigerant from equipment in Washington, Ecology used the IPCC's emission factor approach, following CARB's example.[19] Emissions were calculated by multiplying the estimated number of units, the average charge of refrigerant in each type of unit, and the leak rate, which is the rate of refrigerant loss over a year of operation. This is the same approach used by CARB for its greenhouse gas inventory and RMP.

In addition to using the IPCC approach, Ecology adopted some emission factors (e.g., refrigerant leaks) created by CARB based on recorded data from their established refrigerant management and GHG inventory programs. Details on how Ecology determined which factors to use in calculating emissions for different categories of emissions sources are described in the following section.

Average charge amount and leak rate determinations

Because Ecology does not have information specific to equipment located in Washington, Ecology used CARB's estimates of average charge amount per unit.[20]

There are two sources of leak rate estimates: one published by CARB[21] and one by the EPA[22]. Ecology used the leak rates established by the EPA for the purposes of this report based on the assumption that Washington businesses' current practices are in line with those set forth by the EPA.[23]

The data presented in this report are a snapshot based on currently available data. The baseline year is set to 2020, as that is the most recent year for which Ecology was able to obtain

[18] BSRIA (2019). Industrial Refrigeration 2019 – USA Report US1705/1 Edition 2, BSRIA.
[19] IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Institute for Global Environmental Strategies (IGES), Japan.
[20] CARB (2016).
[21] CARB (2016).
[22] Section 608, Title VI of the CAA, 40 CFR Part 82, Subpart F.
[23] Section 608, Title VI of the CAA, 40 CFR Part 82, Subpart F.

information (NAICS code records) for Washington businesses. Ecology assumed these businesses are actively following best practices and achieving leak rates no higher than those suggested by the EPA.

Results

Ecology estimates that more than 72,000 of the more than 360,000 businesses in Washington may have equipment large enough to fall into RMP-regulated categories. Approximately six million pounds of refrigerant leaks annually from all equipment categories with charges of 50 pounds or more of refrigerant in Washington. This is the equivalent of 5.8 million metric tonnes of CO_2 equivalent ($MMTCO_2e$) statewide. Of this leakage, we estimate 3.4 $MMTCO_2e$ are HFCs. Table 2 contains the estimated number of units, average refrigerant charge, and average annual leak rate used to determine estimates of leakage by equipment type, as well as the resulting annual loss of refrigerant. Table 3 contains emissions estimates by industry sector.

Table 2. Estimated units, charge, leak rate, and refrigerant loss by equipment type and size

Equipment	Size	# of Units in 2020	Average Refrigerant Charge (lb.)	Average Annual Leak (loss) Rate	Annual Loss (lb.)
Refrigeration Centralized	Small	1,270	125	20%	31,756
	Medium	983	704	20%	138,438
	Large	794	3,635	20%	577,456
Refrigeration Cold Storage	Small	327	122	20%	7,990
	Medium	153	494	20%	15,081
	Large	133	7,929	20%	210,832
Air Conditioning	Small	36,949	100	10%	369,490
	Medium	25,297	767	10%	2,008,542
	Large	5,582	3,978	10%	2,220,520
Industrial Process Refrigeration	Small	173	125	30%	6,476
	Medium	230	1,100	30%	75,979
	Large	173	5,242	30%	271,557

Ecology adopted a model used by CARB[24] to determine emissions by refrigerant, i.e., CFC, HCFC, or HFC, per subcategory. The model and calculations are presented in Appendix B. We then converted emissions to $MMTCO_2e$ (Table 3).

[24] CARB, (2009b).

Table 3. Estimated HFC emissions from units in Washington by industry sector

Category	Size	Refrigerant (lb.)	CFC Emissions ($MMTCO_2e$)	HCFC Emissions ($MMTCO_2e$)	HFC Emissions ($MMTCO_2e$)
Retail Food	Small	31,756	0.0102	0.0049	0.0293
	Medium	138,438	0.0006	0.0248	0.1528
	Large	577,456	0.011	0.1005	0.6783
Cold Storage	Small	7,990	0.0009	0.0018	0.0096
	Medium	15,081	0.0016	0.0034	0.0182
	Large	210,832	0.0263	0.0493	0.2477
Industrial Process Refrigeration/Cooling	Small	369,490	0.002	0.0008	0.004
	Medium	2,008,542	0.0192	0.0089	0.0489
	Large	2,220,520	0.0599	0.031	0.1792
Air Conditioning	Small	6,476	0	0.2111	0.1064
	Medium	75,979	0.7908	0.5104	0.7960
	Large	271,557	0.4573	0.0949	1.1043
Subtotal			1.3798	1.0418	3.3746
Combined Total					**5.7963**

Discussion

Ecology estimates that as much as 5.8 $MMTCO_2e$ emissions occur due to refrigerant leakage from equipment containing 50 pounds or more of refrigerants in Washington every year (Figure 2).

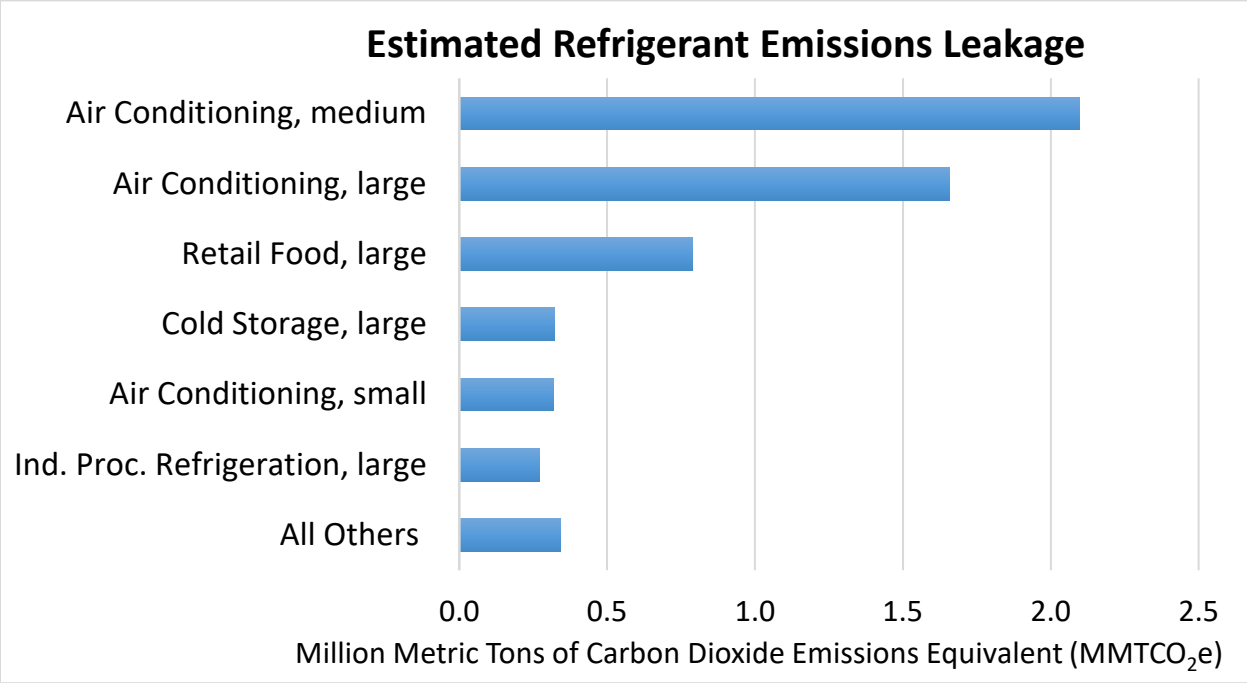

Figure 2. Washington Refrigerant Leakage Emissions ($MMTCO_2e$)

The largest portion of emissions comes from the air conditioning sector, despite this being the sector with the lowest estimated leak rate (10 percent). This is due to the large number of air conditioning systems in the state. Because of the large numbers of this type of equipment estimated to be installed in Washington, even a small reduction in leak rates would provide large benefits in reducing HFC emissions.

Retail food refrigeration systems, mainly those that are centralized, constitute the second largest source of refrigerant emissions in the state. Of these, the largest systems have the most leaks. Although there are fewer systems of this size in place, the average charge of refrigerant is larger overall. When combined with similar leakage rates to those of smaller equipment, this accounts for greater emissions. As with air conditioning systems, reducing leaks in large retail food refrigeration systems will provide significant reductions in HFC emissions from currently operating systems.

This assessment represents the best information on HFC leakage in Washington currently available. Washington's RMP is scheduled to take effect in 2024 and implementing this program will provide much more detailed information from Washington's emissions sources that will allow Ecology to update and refine the estimates presented in this report.

There are several sources of uncertainty in this report. For example, we assume that each business uses a single system, however, businesses' actual air conditioning and refrigeration needs may vary. A business may choose to use multiple, separate, smaller units rather than a single 50+ pound unit; or they may need more (or less) refrigeration than we assumed. These differences will shift them from one subcategory to another. The RMP will exempt systems with less than 50 pounds of refrigerant; therefore, some businesses that we currently estimate will be in the RMP may not be end up being required to register. The estimates presented in this report are conservative, and it is possible that the overall leakage emissions in the state are lower.

RCW 70A.60.030(10) requires Ecology to review the RMP every five years after the initial effective date. These reviews must include:

- An examination of whether leak rate targets and leak rate limits set for the Washington RMP are being met.
- Whether those targets need adjustment to reflect changes to equipment or refrigerants used in any of the sectors covered by the RMP.
- Whether the program remains necessary to carry out the goals of the statute.

Addressing HFCs through Ecology's RMP is a key component of the state's strategy to meet its statutory GHG emissions reduction limits. This program, alongside restrictions on new HFC-containing equipment and complementary policies such as the Climate Commitment Act, Clean Fuel Standard, and the Clean Vehicles Program, will help the state lower emissions and decarbonize our economy.

In addition to reducing GHG emissions to the atmosphere, reducing refrigerant leaks will provide significant cost savings to Washington businesses. For example, prior to the implementation of the American Innovation and Manufacturing (AIM) Act phasedown in HFC production, EPA estimated that reducing refrigerant leaks nationwide could save more than $100 million every year in refrigerant costs alone (not including costs for replacement machinery and technician time).[25] Businesses such as supermarkets and retail grocers may further benefit from leak reductions as preventative maintenance reduces the number of equipment failures resulting in the loss of grocery products.

[25] EPA (2022). The Green Chill Partnership: Refrigerant leak prevention through regular maintenance (https://www.epa.gov/greenchill/refrigerant-leak-prevention-through-regular-maintenance). Accessed July 12, 2022.

Conclusion

Ecology estimates that equipment covered by the Washington Refrigerant Management Program emits approximately 5.8 $MMTCO_2e$ of refrigerants annually.

Knowing how much refrigerant is being released to the atmosphere is the first step in reducing HFC emissions. Refrigerant emissions can be reduced through several methods, including the increased use of less harmful refrigerants in new and retrofitted equipment; conducting preventive maintenance on refrigerant-containing equipment; conducting regular leak testing of equipment currently in operation; and performing the proper reclamation or disposal of refrigerants in systems that reach their end of life.

Combined with other statewide carbon reduction programs, HFC emission reductions will help Washington achieve its statutory GHG emission reduction limit of 95 percent below 1990 levels by 2050. Ecology will continue to monitor estimated refrigerant leaks to the atmosphere and marketplace changes affecting Washington businesses. This information will be important in future decision making and legislative actions.

Ecology's next steps are to complete the required rulemaking to implement Washington's RMP. We expect to complete the rulemaking process by summer 2023. In addition to reducing HFC emissions, implementing the RMP program will allow Ecology to collect Washington-specific information about equipment, refrigerants, and leaks, which we can then use to update emission estimates. This information will be used to inform a statutorily mandated evaluation of the program in 2029.

Appendix A. NAICS Codes

Businesses in Washington Ecology assumes operate air conditioning, commercial refrigeration, or industrial process refrigeration equipment using 50 pounds or more of an HFC, or another regulated, refrigerant.

Table 4. NAICS industries and codes used for emissions estimates

NAICS Sector or Subsector	NAICS Industry	Code
Agriculture, Forestry, Fishing, and Hunting (11)		
Crop Production (111)		
	Mushroom Farming	111411
	Postharvest Crop Activities (except cotton ginning)	115114
Utilities (22)		
Utilities (221)		
	Hydroelectric Power Generation	221111
	Fossil Fuel Electric Power Generation	221112
	Nuclear Electric Power Generation	221113
	Solar Electric Power Generation	221114
	Wind Electric Power Generation	221115
	Geothermal Electric Power Generation	221116
	Biomass Electric Power Generation	221117
Manufacturing (31-33)		
Food Manufacturing (311)		
	Dog and Cat Food Manufacturing	311111
	Other Animal Food Manufacturing	311119
	Non-chocolate Confectionery Manufacturing	311340
	Chocolate and Confectionery Manufacturing from Cacao Beans	311351
	Confectionery Manufacturing from Purchased Chocolate	311352
	Frozen Fruit, Juice, and Vegetable Manufacturing	311411
	Frozen Specialty Food Manufacturing	311412
	Fruit and Vegetable Canning	311421
	Specialty Canning	311422
	Dried and Dehydrated Food Manufacturing	311423
	Fluid Milk Manufacturing	311511
	Creamery Butter Manufacturing	311512
	Cheese Manufacturing	311513
	Dry, Condensed, and Evaporated Dairy Product Manufacturing	311514
	Ice Cream and Frozen Dessert Manufacturing	311520
	Animal (except Poultry) Slaughtering	311611
	Meat Processed from Carcasses	311612
	Rendering and Meat Byproduct Processing	311613
	Poultry Processing	311615
	Seafood Product Preparation and Packaging	311710
	Retail Bakeries	311811
	Commercial Bakeries	311812

NAICS Sector or Subsector	NAICS Industry	Code
	Frozen Cakes, Pies, and Other Pastries Manufacturing	311813
	Cookie and Cracker Manufacturing	311821
	Dry Pasta, Dough, and Flour Mixes Manufacturing from Purchased Flour	311824
	Tortilla Manufacturing	311830
	Roasted Nuts and Peanut Butter Manufacturing	311911
	Other Snack Food Manufacturing	311919
	Mayonnaise, Dressing, and Other Prepared Sauce Manufacturing	311941
	Perishable Prepared Food Manufacturing	311991
	All Other Miscellaneous Food Manufacturing	311999
Beverage and Tobacco Product Manufacturing (312)		
	Soft Drink Manufacturing	312111
	Bottled Water Manufacturing	312112
	Ice Manufacturing	312113
	Breweries	312120
	Wineries	312130
	Distilleries	312140
Textile Mills (313)		
	Fabric Coating Mills	313320
Paper Manufacturing (322)		
	Pulp Mills	322110
	Paper Mills	322120
	Paperboard Mills	322130
	Corrugated and Solid Fiber Box Manufacturing	322211
	Folding Paperboard Box Manufacturing	322212
	Other Paperboard Container Manufacturing	322219
	Paper Bag and Coated and Treated Paper Manufacturing	322220
	Stationery Product Manufacturing	322230
	Sanitary Paper Product Manufacturing	322291
	All Other Converted Paper Product Manufacturing	322299
Printing and Related Support Activities (323)		
	Commercial Printing (except Screen and Books)	323111
	Commercial Screen Printing	323113
	Books Printing	323117
Petroleum and Coal Products Manufacturing (324)		
	Petroleum Lubricating Oil and Grease Manufacturing	324191
	All Other Petroleum and Coal Products Manufacturing	324199
Chemical Manufacturing (325)		
	Industrial Gas Manufacturing	325120
	Synthetic Dye and Pigment Manufacturing	325130
	Other Basic Inorganic Chemical Manufacturing	325180
	All Other Basic Organic Chemical Manufacturing	325199
	Plastics Material and Resin Manufacturing	325211
	Artificial and Synthetic Fibers and Filaments Manufacturing	325220
	Nitrogenous Fertilizer Manufacturing	325311
	Phosphatic Fertilizer Manufacturing	325312

NAICS Sector or Subsector	NAICS Industry	Code
	Medicinal and Botanical Manufacturing	325411
	Pharmaceutical Preparation Manufacturing	325412
	In-Vitro Diagnostic Substance Manufacturing	325413
	Biological Product (except Diagnostic) Manufacturing	325414
	Paint and Coating Manufacturing	325510
	Adhesive Manufacturing	325520
	Soap and Other Detergent Manufacturing	325611
	Polish and Other Sanitation Good Manufacturing	325612
	Surface Active Agent Manufacturing	325613
	Toilet Preparation Manufacturing	325620
	Printing Ink Manufacturing	325910
	Explosives Manufacturing	325920
	Custom Compounding of Purchased Resins	325991
	All Other Miscellaneous Chemical Product and Preparation Manufacturing	325998
Plastics and Rubber Manufacturing (326)		
	Plastics Bag and Pouch Manufacturing	326111
	Unlaminated Plastics Film and Sheet (except Packaging) Manufacturing	326113
	Unlaminated Plastics Profile Shape Manufacturing	326121
	Plastics Pipe and Pipe Fitting Manufacturing	326122
	Laminated Plastics Plate, Sheet (except Packaging), and Shape Manufacturing	326130
	Urethane and Other Foam Product (except Polystyrene) Manufacturing	326150
	Plastics Bottle Manufacturing	326160
	Plastics Plumbing Fixture Manufacturing	326191
	All Other Plastics Product Manufacturing	326199
	Tire Manufacturing (except Retreading)	326211
	Rubber and Plastics Hoses and Belting Manufacturing	326220
	Rubber Product Manufacturing for Mechanical Use	326291
	All Other Rubber Product Manufacturing	326299
	Nonmetallic Mineral Product Manufacturing (327)	
	Flat Glass Manufacturing	327211
	Other Pressed and Blown Glass and Glassware Manufacturing	327212
	Glass Container Manufacturing	327213
	Glass Product Manufacturing Made of Purchased Glass	327215
Fabricated Metal Product Manufacturing (332)		
	Machine Shops	332710
Computer and Electronic Product Manufacturing (334)		
	Electronic Computer Manufacturing	334111
	Computer Storage Device Manufacturing	334112
	Computer Terminal and Other Computer Peripheral Equipment Manufacturing	334118
	Telephone Apparatus Manufacturing	334210

NAICS Sector or Subsector	NAICS Industry	Code
	Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing	334220
	Other Communications Equipment Manufacturing	334290
	Audio and Video Equipment Manufacturing	334310
	Bare Printed Circuit Board Manufacturing	334412
	Semiconductor and Related Device Manufacturing	334413
	Capacitor, Resistor, Coil, Transformer, and Other Inductor Manufacturing	334416
	Electronic Connector Manufacturing	334417
	Other Electronic Component Manufacturing	334419
	Electromedical and Electrotherapeutic Apparatus Manufacturing	334510
	Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing	334511
	Automatic Environmental Control Manufacturing for Residential, Commercial, and Appliance Use	334512
	Instruments and Related Products Manufacturing for Measuring, Displaying, and Controlling Industrial Process Variables	334513
	Totalizing Fluid Meter and Counting Device Manufacturing	334514
	Instrument Manufacturing for Measuring and Testing Electricity and Electrical Signals	334515
	Analytical Laboratory Instrument Manufacturing	334516
	Irradiation Apparatus Manufacturing	334517
	Other Measuring and Controlling Device Manufacturing	334519
	Manufacturing and Reproducing Magnetic and Optical Media	334610
Electrical Equipment, Appliance, and Component Manufacturing (335)		
	Small Electrical Appliance Manufacturing	335210
	Major Household Appliance Manufacturing	335220
	Power, Distribution, and Specialty Transformer Manufacturing	335311
	Motor and Generator Manufacturing	335312
	Switchgear and Switchboard Apparatus Manufacturing	335313
	Relay and Industrial Control Manufacturing	335314
	Fiber Optic Cable Manufacturing	335921
	Other Communication and Energy Wire Manufacturing	335929
	Current-Carrying Wiring Device Manufacturing	335931
	Noncurrent-Carrying Wiring Device Manufacturing	335932
	Carbon and Graphite Product Manufacturing	335991
	All Other Miscellaneous Electrical Equipment and Component Manufacturing	335999
Transportation Equipment Manufacturing (336)		
	Motor Vehicle Electrical and Electronic Equipment Manufacturing	336320
	Aircraft Manufacturing	336411
	Aircraft Engine and Engine Parts Manufacturing	336412
	Other Aircraft Parts and Auxiliary Equipment Manufacturing	336413
	Guided Missile and Space Vehicle Manufacturing	336414

NAICS Sector or Subsector	NAICS Industry	Code
	Guided Missile and Space Vehicle Propulsion Unit and Propulsion Unit Parts Manufacturing	336415
	Other Guided Missile and Space Vehicle Parts and Auxiliary Equipment Manufacturing	336419
Miscellaneous Manufacturing (339)		
	Surgical and Medical Instrument Manufacturing	339112
	Surgical Appliance and Supplies Manufacturing	339113
	Dental Equipment and Supplies Manufacturing	339114
	Ophthalmic Goods Manufacturing	339115
	Dental Laboratories	339116
Wholesale Trade (42)		
Merchant Wholesalers, Durable Goods (423)		
	Automobile and Other Motor Vehicle Merchant Wholesalers	423110
	Motor Vehicle Supplies and New Parts Merchant Wholesalers	423120
	Tire and Tube Merchant Wholesalers	423130
	Motor Vehicle Parts (Used) Merchant Wholesalers	423140
	Furniture Merchant Wholesalers	423210
	Home Furnishing Merchant Wholesalers	423220
	Lumber, Plywood, Millwork, and Wood Panel Merchant Wholesalers	423310
	Brick, Stone, and Related Construction Material Merchant Wholesalers	423320
	Roofing, Siding, and Insulation Material Merchant Wholesalers	423330
	Other Construction Material Merchant Wholesalers	423390
	Photographic Equipment and Supplies Merchant Wholesalers	423410
	Office Equipment Merchant Wholesalers	423420
	Computer and Computer Peripheral Equipment and Software Merchant Wholesalers	423430
	Other Commercial Equipment Merchant Wholesalers	423440
	Medical, Dental, and Hospital Equipment and Supplies Merchant Wholesalers	423450
	Ophthalmic Goods Merchant Wholesalers	423460
	Other Professional Equipment and Supplies Merchant Wholesalers	423490
	Electrical Apparatus and Equipment, Wiring Supplies, and Related Equipment Merchant Wholesalers	423610
	Household Appliances, Electric Housewares, and Consumer Electronics Merchant Wholesalers	423620
	Other Electronic Parts and Equipment Merchant Wholesalers	423690
	Hardware Merchant Wholesalers	423710
	Plumbing and Heating Equipment and Supplies (Hydronics) Merchant Wholesalers	423720
	Warm Air Heating and Air-Conditioning Equipment and Supplies Merchant Wholesalers	423730
	Refrigeration Equipment and Supplies Merchant Wholesalers	423740
	Construction and Mining (except Oil Well) Machinery and Equipment Merchant Wholesalers	423810
	Farm and Garden Machinery and Equipment Merchant Wholesalers	423820

NAICS Sector or Subsector	NAICS Industry	Code
	Industrial Machinery and Equipment Merchant Wholesalers	423830
	Industrial Supplies Merchant Wholesalers	423840
	Service Establishment Equipment and Supplies Merchant Wholesalers	423850
	Transportation Equipment and Supplies (except Motor Vehicle) Merchant Wholesalers	423860
	Sporting and Recreational Goods and Supplies Merchant Wholesalers	423910
	Toy and Hobby Goods and Supplies Merchant Wholesalers	423920
	Recyclable Material Merchant Wholesalers	423930
	Jewelry, Watch, Precious Stone, and Precious Metal Merchant Wholesalers	423940
	Other Miscellaneous Durable Goods Merchant Wholesalers	423990
Merchant Wholesalers, Nondurable Goods (424)		
	Printing and Writing Paper Merchant Wholesalers	424110
	Stationery and Office Supplies Merchant Wholesalers	424120
	Industrial and Personal Service Paper Merchant Wholesalers	424130
	Drugs and Druggists' Sundries Merchant Wholesalers	424210
	Piece Goods, Notions, and Other Dry Goods Merchant Wholesalers	424310
	Footwear Merchant Wholesalers	424340
	General Line Grocery Merchant Wholesalers	424410
	Packaged Frozen Food Merchant Wholesalers	424420
	Dairy Product (except Dried or Canned) Merchant Wholesalers	424430
	Poultry and Poultry Product Merchant Wholesalers	424440
	Confectionery Merchant Wholesalers	424450
	Fish and Seafood Merchant Wholesalers	424460
	Meat and Meat Product Merchant Wholesalers	424470
	Fresh Fruit and Vegetable Merchant Wholesalers	424480
	Other Grocery and Related Products Merchant Wholesalers	424490
	Grain and Field Bean Merchant Wholesalers	424510
	Livestock Merchant Wholesalers	424520
	Other Farm Product Raw Material Merchant Wholesalers	424590
	Plastics Materials and Basic Forms and Shapes Merchant Wholesalers	424610
	Other Chemical and Allied Products Merchant Wholesalers	424690
	Farm Supplies Merchant Wholesalers	424910
	Book, Periodical, and Newspaper Merchant Wholesalers	424920
	Flower, Nursery Stock, and Florists' Supplies Merchant Wholesalers	424930
	Tobacco Product and Electronic Cigarette Merchant Wholesalers	424940
	Paint, Varnish, and Supplies Merchant Wholesalers	424950
	Other Miscellaneous Nondurable Goods Merchant Wholesalers	424990
Wholesale Trade Agents and Brokers (425)		
	Wholesale Trade Agents and Brokers	425120
Retail Trade (44-45)		
Motor Vehicle and Parts Dealers (441)		
	New Car Dealers	441110
Building Material and Garden Equipment and Supplies Dealer (444)		
	Home Centers	444110

NAICS Sector or Subsector	NAICS Industry	Code
	Paint and Wallpaper Retailers	444120
Food and Beverage Retailers (445)		
	Supermarkets and Other Grocery Retailers	445110
	Fruit and Vegetable Retailers	445230
	Baked Goods Retailers	445291
	Confectionery and Nut Retailers	445292
	All Other Specialty Food Retailers	445298
Transportation and Warehousing (48-49)		
Support Activities for Transportation (488)		
	Air Traffic Control	488111
	Other Airport Operations	488119
Warehousing and Storage (493)		
	General Warehousing and Storage	493110
	Refrigerated Warehousing and Storage	493120
	Farm Product Warehousing and Storage	493130
	Other Warehousing and Storage	493190
Information (51)		
Motion Picture and Sound Recording Industries (512)		
	Motion Picture and Video Production	512110
	Motion Picture and Video Distribution	512120
	Motion Picture Theaters (except Drive-Ins)	512131
	Teleproduction and Other Postproduction Services	512191
	Other Motion Picture and Video Industries	512199
Computing Infrastructure Providers, Data Processing, Web Hosting, and Related Services (518)		
	Computing Infrastructure Providers, Data Processing, Web Hosting, and Related Services	518210
Finance and Insurance (52)		
Credit Intermediation and Related Activities (522)		
	Commercial Banking	522110
	Credit Unions	522130
	Other Activities Related to Credit Intermediation	522390
Insurance Carriers and Related Activities (524)		
	All Other Insurance Related Activities	524298
Real Estate and Rental and Leasing (53)		
Real Estate (531)		
	Lessors of Residential Buildings and Dwellings	531110
	Lessors of Nonresidential Buildings (except Mini-warehouses)	531120
	Lessors of Mini-warehouses and Self-Storage Units	531130
	Lessors of Other Real Estate Property	531190
	Residential Property Managers	531311
	Nonresidential Property Managers	531312
Consumer Good Rental (532)		
	Consumer Electronics and Appliances Rental	532210
	General Rental Centers	532310

NAICS Sector or Subsector	NAICS Industry	Code
Professional, Scientific, and Technical Services (54)		
Professional, Scientific, and Technical Services (541)		
	Offices of Lawyers	541110
	Offices of Notaries	541120
	Title Abstract and Settlement Offices	541191
	All Other Legal Services	541199
	Offices of Certified Public Accountants	541211
	Tax Preparation Services	541213
	Payroll Services	541214
	Other Accounting Services	541219
	Architectural Services	541310
	Landscape Architectural Services	541320
	Engineering Services	541330
	Drafting Services	541340
	Building Inspection Services	541350
	Geophysical Surveying and Mapping Services	541360
	Surveying and Mapping (except Geophysical) Services	541370
	Testing Laboratories and Services	541380
	Interior Design Services	541410
	Industrial Design Services	541420
	Graphic Design Services	541430
	Other Specialized Design Services	541490
	Custom Computer Programming Services	541511
	Computer Systems Design Services	541512
	Computer Facilities Management Services	541513
	Other Computer Related Services	541519
	Administrative Management and General Management Consulting Services	541611
	Human Resources Consulting Services	541612
	Marketing Consulting Services	541613
	Process, Physical Distribution, and Logistics Consulting Services	541614
	Other Management Consulting Services	541618
	Environmental Consulting Services	541620
	Other Scientific and Technical Consulting Services	541690
	Research and Development in Biotechnology (except Nano biotechnology)	541714
	Research and Development in the Physical, Engineering, and Life Sciences (except Nanotechnology and Biotechnology)	541715
	Research and Development in the Social Sciences and Humanities	541720
	Advertising Agencies	541810
	Public Relations Agencies	541820
	Media Buying Agencies	541830
	Media Representatives	541840
	Indoor and Outdoor Display Advertising	541850
	Direct Mail Advertising	541860

NAICS Sector or Subsector	NAICS Industry	Code
	Advertising Material Distribution Services	541870
	Other Services Related to Advertising	541890
	Marketing Research and Public Opinion Polling	541910
	Photography Studios, Portrait	541921
	Commercial Photography	541922
	Translation and Interpretation Services	541930
	Veterinary Services	541940
	All Other Professional, Scientific, and Technical Services	541990
Management of Companies and Enterprises (55)		
Management of Companies and Enterprises (551)		
	Offices of Bank Holding Companies	551111
	Offices of Other Holding Companies	551112
	Corporate, Subsidiary, and Regional Managing Offices	551114
Administrative and Support and Waste Management and Remediation Services (56)		
Administrative and Support Services (561)		
	Office Administrative Services	561110
	Facilities Support Services	561210
	Employment Placement Agencies	561311
	Executive Search Services	561312
	Temporary Help Services	561320
	Professional Employer Organizations	561330
	Document Preparation Services	561410
	Telephone Answering Services	561421
	Telemarketing Bureaus and Other Contact Centers	561422
	Private Mail Centers	561431
	Other Business Service Centers (including Copy Shops)	561439
	Collection Agencies	561440
	Credit Bureaus	561450
	Repossession Services	561491
	Court Reporting and Stenotype Services	561492
	All Other Business Support Services	561499
	Travel Agencies	561510
	Tour Operators	561520
	Convention and Visitors Bureaus	561591
	All Other Travel Arrangement and Reservation Services	561599
	Investigation Services	561611
	Security Guards and Patrol Services	561612
	Janitorial Services	561720
Educational Services (61)		
Educational Services (611)		
	Elementary and Secondary Schools	611110
	Junior Colleges	611210
	Colleges, Universities, and Professional Schools	611310
	Business and Secretarial Schools	611410
	Cosmetology and Barber Schools	611511

NAICS Sector or Subsector	NAICS Industry	Code
	Flight Training	611512
	Other Technical and Trade Schools	611519
	Fine Arts Schools	611610
	Sports and Recreation Instruction	611620
	Language Schools	611630
Health Care and Social Assistance (62)		
Ambulatory Health Care Services (621)		
	Offices of Physicians (Except Mental Health Specialists)	621111
	Offices of Physicians (Mental Health Specialists)	621112
	Offices of Dentists	621210
	Offices of Chiropractors	621310
	Offices of Optometrists	621320
	Offices of Mental Health Practitioners (Except Physicians)	621330
	Offices of Physical, Occupational, and Speech Therapists	621340
	Offices of Podiatrists	621391
	Offices of All Other Miscellaneous Health Practitioners	621399
	Family Planning Centers	621410
	Outpatient Mental Health and Substance Abuse Centers	621420
	HMO Medical Centers	621491
	Kidney Dialysis Centers	621492
	Freestanding Ambulatory Surgical and Emergency Centers	621493
	All Other Outpatient Care Centers	621498
	Medical Laboratories	621511
	Diagnostic Imaging Centers	621512
Hospitals (622)		
	General Medical and Surgical Hospitals	622110
	Psychiatric and Substance Abuse Hospitals	622210
	Specialty (except Psychiatric and Substance Abuse) Hospitals	622310
	Nursing and Residential Care Facilities (623)	
	Nursing Care Facilities (Skilled Nursing Facilities)	623110
	Residential Mental Health and Substance Abuse Facilities	623220
	Continuing Care Retirement Communities	623311
	Assisted Living Facilities for the Elderly	623312
	Other Residential Care Facilities	623990
Arts, Entertainment, and Recreation (71)		
Performing Arts, Spectator Sports, and Related Industries (711)		
	Theater Companies and Dinner Theaters	711110
	Sports Teams and Clubs	711211
	Other Spectator Sports	711219
Museums, Historical Sites, and Similar Institutions (712)		
	Museums	712110
	Zoos and Botanical Gardens	712130
Amusement, Gambling, and Recreation Industries (713)		
	Amusement Arcades	713120
	Casinos (except Casino Hotels)	713210

NAICS Sector or Subsector	NAICS Industry	Code
	Bowling Centers	713950
	All Other Amusement and Recreation Industries	713990
Accommodation and Food Services (72)		
Accommodation (721)		
	Hotels (except Casino Hotels) and Motels	721110
Food Services and Drinking Places (722)		
	Drinking Places (Alcoholic Beverages)	722410
	Full-Service Restaurants	722511
	Limited-Service Restaurants	722513
	Snack and Nonalcoholic Beverage Bars	722515
Other Services (except Public Administration) (81)		
Repair and Maintenance (811)		
	All Other Automotive Repair and Maintenance	811198
	Other Personal and Household Goods Repair and Maintenance	811490
Personal and Laundry Services (812)		
	Funeral Homes and Funeral Services	812210
	Cemeteries and Crematories	812220
Religious, Grant making, Civic, Professional, and Similar Organizations (813)		
	Religious Organizations	813110
	Business Associations	813910
	Labor Unions and Similar Labor Organizations	813930
	Other Similar Organizations (except Business, Professional, Labor, and Political Organizations)	813990
Public Administration (92)		
Executive, Legislative, and Other General Government Support (921)		
	Executive Offices	921110
	Legislative Bodies	921120
	Other General Government Support	921190
	Courts	922110
	Correctional Institutions	922140

Appendix B. Category Specific Calculations

Types of refrigeration systems included

Commercial refrigeration, retail food systems

Commercial refrigeration equipment stores and displays chilled or frozen goods for commercial sale or use. This includes stand-alone units, refrigerated food processing and dispensing equipment, remote condensing units, supermarket systems, and vending machines.[26]

Ecology's calculation uses a sizing factor to estimate the amount of refrigerant in retail settings: 0.0225 pounds of refrigerant per square foot of commercial space.[27] This sizing factor allowed us to categorize businesses into the sub-categories described in this report and estimate facility square footage (Table 5) utilizing standard engineering factors.[28]

Table 5. Commercial refrigeration sizing, centralized systems

Refrigeration Size	Pounds of Refrigerant per System	Building Square Footage
Small	50 – 199	2,200 – <8,900
Medium	200 – 1,499	8,900 – <89,000
Large	1,500+	≥89,000

Commercial refrigeration, cold and frozen storage

We used standard cooling loads per square foot of floor space to estimate the amount of refrigerant in commercial cold storage: 140 BTU per square foot for cold storage (35 degrees Fahrenheit) and 210 BTU per square foot for frozen storage (-10 degrees Fahrenheit). We used standard engineering factors for sizing equipment to determine the square footage corresponding to the size categories presented in Table 6.

Table 6. Commercial refrigeration sizing, cold/frozen storage

Sub-Category	Cold Storage (ft^2)	Frozen Storage (ft^2)
Small	1,400 – 5,700	950 – 3,800
Medium	5,700 – 57,000	3,800 – 38,000
Large	≥57,000	≥38,000

Industrial Process Refrigeration

Often designed in place, industrial process refrigeration units carry out specific cooling needed for a particular industrial process. These systems are not closely related to building size or square footage. The amount of cooling required is not dependent upon a space needing cooling

[26] WAC 173-443-030:
[27] CARB (2009b).
[28] Calculating Cooling Loads (engineeringtoolbox.com), BTU Calculator: Refrigeration Sizing | U.S. Cooler Walk-ins (uscooler.com)

and systems can be comprised of several smaller units or a single large chiller. As such, Ecology made several assumptions.

We determined how many cooling units are in each category based on the number of businesses assumed to have these types of equipment. Unit sizes (small, medium, and large) are sorted into these categories by assuming percentages of units distributed throughout the businesses in Washington. We estimate industrial process refrigeration will consist of 30 percent small, 40 percent medium, and 30 percent large units that contain HFCs or ODS-regulated refrigerants (Table 7). Small units containing 50 to 199 pounds of refrigerant are usually located near the process with less need for long lengths of pipe required to transport refrigerant to the process. We assume a proportion of successively larger units, with the largest number of units falling in the medium size (200 to 1,499 pounds) category, in place depending on the industry and size of the operations. The size categories are broken out the same way in regard to pounds of refrigerant per category as all other categories.

Table 7. Industrial process refrigeration sizing

Size	Percentage of units
Small	30%
Medium	40%
Large	30%

Market data indicates that up to 80 percent of this equipment uses natural refrigerants[29], and therefore would not be subject to the requirements of the RMP. For the purpose of the estimations made in this report, and because we do not have Washington-specific information, Ecology has assumed that 80 percent of industrial process equipment in Washington State uses natural refrigerants.

Air Conditioning

We used a standard engineering factor of 25 BTU of cooling load per square foot of building space (Table 8) to estimate total cooling load for air conditioning systems.

Table 8. Air conditioning sizing

Size	Building Square Footage
Small	6,900 – 28,000 ft^2
Medium	28,000 – 280,000 ft^2
Large	≥280,000 ft^2

We used general industry standards to determine the sizes of units required to meet building cooling demands.

[29] BSRIA (2019). Industrial Refrigeration 2019 – USA Report US1705/1 Edition 2, BSRIA.

Types of refrigerants and global warming potentials

Refrigeration and air conditioning

Ecology used CARB data[30] to estimate refrigerant distribution by refrigerant type; including CFCs, HCFCs, and HFCs; and further by refrigeration and AC equipment type in 2020. CARB estimated the number of units in place, average lifetimes of equipment, ODS and alternatives (HFCs) phase-out over time, and the most likely non-ODS replacements currently in use.

The model that CARB used to calculate their emissions[31] estimates that the proportion of refrigeration and AC equipment using ODS refrigerants declined from 2010 to 2020, and the use of HFC refrigerants correspondingly grew over this same period as these refrigerants replaced ODS. The model uses several data assumptions to approximate transitions of refrigerants in existing equipment over time (Table 9[32]). Because the data assembled by CARB is not specific to California, but instead is based a distribution of refrigerant on the market by type, we followed these refrigerant distribution estimations.

When CARB completed their initial estimations, 75 percent of total greenhouse gas emissions from this equipment were from ODS, with the remaining 25 percent of GHG emissions from HFCs.[33] By 2020, estimates indicated that the total GHG emissions increased only slightly. However, the HFC portion of the emissions increased significantly from 25 percent to 75 percent of the total equipment emissions.

[30] CARB (2009b).
[31] CARB, (2009b).
[32] CARB (2009b).
[33] CARB (2009b).

Table 9. Refrigerant distribution by equipment type, 2010 and 2020

Equipment Type	Refrigerant	GWP	% Equipment 2010	% Equipment 2020	HFC or ODS
Centralized Systems					
	HCFC-22	1500	42.20%	3.00%	ODS
	R-404A	3260	39.70%	65.20%	HFC
	R-507	3300	18.10%	31.80%	HFC
Cold Storage					
	CFC-12	8100	2.00%	0.00%	ODS
	HCFC-22	1500	56.60%	28.10%	ODS
	R-404A	3260	26.20%	54.20%	HFC
	R-502	4500	6.60%	0.00%	ODS
	R-507	3300	8.60%	17.70%	HFC
Industrial Process Refrigeration					
	CFC-11	3800	1.00%	0.00%	ODS
	CFC-12	8100	15.60%	0.00%	ODS
	HCFC-22	1500	22.00%	11.00%	ODS
	HCFC-123	90	23.30%	29.40%	ODS
	HFC-134a	1300	33.30%	44.50%	HFC
	R-401A	970	0.40%	0.30%	HFC
	R-404A	3260	2.70%	8.80%	HFC
	R-410A	1725	0.90%	3.40%	HFC
	R-507	3300	0.80%	2.60%	HFC
Refrigerant Condensing Units					
	CFC-12	8100	2.20%	0.00%	ODS
	HCFC-22	1500	30.40%	7.30%	ODS
	HFC-134a	1300	40.40%	44.50%	HFC
	R-404A	3260	19.00%	33.30%	HFC
	R-507	3300	8.00%	14.90%	HFC
Chillers					
	CFC-11	3800	2.60%	0.00%	ODS
	CFC-12	8100	0.90%	0.00%	ODS
	HCFC-22	1500	73.80%	32.30%	ODS
	HCFC-123	90	6.80%	8.20%	ODS
	CFC-114	9300	0.10%	0.00%	ODS
	HFC-134a	1300	14.10%	32.30%	HFC
	HFC-236fa	6300	0.40%	0.10%	HFC
	R-407C	1526	1.00%	18.20%	HFC
	R-410A	1725	0.10%	8.90%	HFC
	R-500	6010	0.20%	0.00%	ODS
Unitary Air Conditioning					
	HCFC-22	1500	78.40%	15.00%	ODS
	HFC-134a	1300	0.10%	0.70%	HFC
	R-407C	1526	0.30%	1.50%	HFC
	R-410A	1725	21.20%	82.80%	HFC