Draft Report - Analysis of the U.S. Hydrofluorocarbon Reclamation Market: Stakeholders, Drivers, and Practices

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Stratospheric Protection Division
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List of Abbreviations and Acronyms

AHRI	Air-Conditioning, Heating, and Refrigeration Institute
AIM	American Innovation and Manufacturing
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CAA	Clean Air Act
CARB	California Air Resources Board
CFC	Chlorofluorocarbon
CO_2e	Carbon dioxide equivalent
EPA	Environmental Protection Agency
GC	Gas chromatograph
GHG	Greenhouse gas
GWP	Global warming potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HFO	Hydrofluoroolefin
HVACR	Heating, ventilation, air conditioning, and refrigeration
IPR	Industrial process refrigeration
$MMTCO_2e$	Million metric tons of carbon dioxide equivalent
MVAC	Motor vehicle air conditioning
ODP	Ozone depletion potential
ODS	Ozone depleting substances
R4 Program	Refrigerant Recovery, Reclaim, and Reuse Requirements (CARB Program)
RRA	Refrigerant Reclaim Australia
U.S.	United States
VRF	Variable refrigerant flow

Executive Summary

Background

The American Innovation and Manufacturing Act (AIM Act or AIM), enacted on December 27, 2020 (codified at 42 U.S.C. 7675), directs the United States (U.S.) Environmental Protection Agency (EPA) to phase down hydrofluorocarbon (HFC) production and consumption by 85 percent by 2036. HFCs, which are highly potent greenhouse gases (GHG), are commonly used in refrigeration and air conditioning equipment, as well as in foams, aerosols, fire suppression, and other applications. A global phasedown of HFCs is expected to avoid up to 0.5°C of global warming by 2100.

The AIM Act authorizes EPA to address HFCs in three main ways:

- phasing down HFC production and consumption through an allowance allocation program;
- facilitating sector-based transitions to next-generation technologies; and
- issuing certain regulations for purposes of maximizing reclamation and minimizing releases of HFCs and their substitutes from equipment and ensuring the safety of technicians and consumers.

With respect to the third point, subsection (h) of the AIM Act directs EPA to promulgate regulations to control, where appropriate, any practice, process, or activity regarding the servicing, repair, disposal, or installation of equipment that involves a regulated substance; a substitute for a regulated substance; the reclaiming of a regulated substance used as a refrigerant; or the reclaiming of a substitute for a regulated substance used as a refrigerant.

Report Contents and Organization

This report summarizes available information on the reclamation of refrigerants, including information on the processes and methods used, the stakeholders involved, and the key barriers to increasing refrigerant reclamation in the United States. The report is organized as follows:

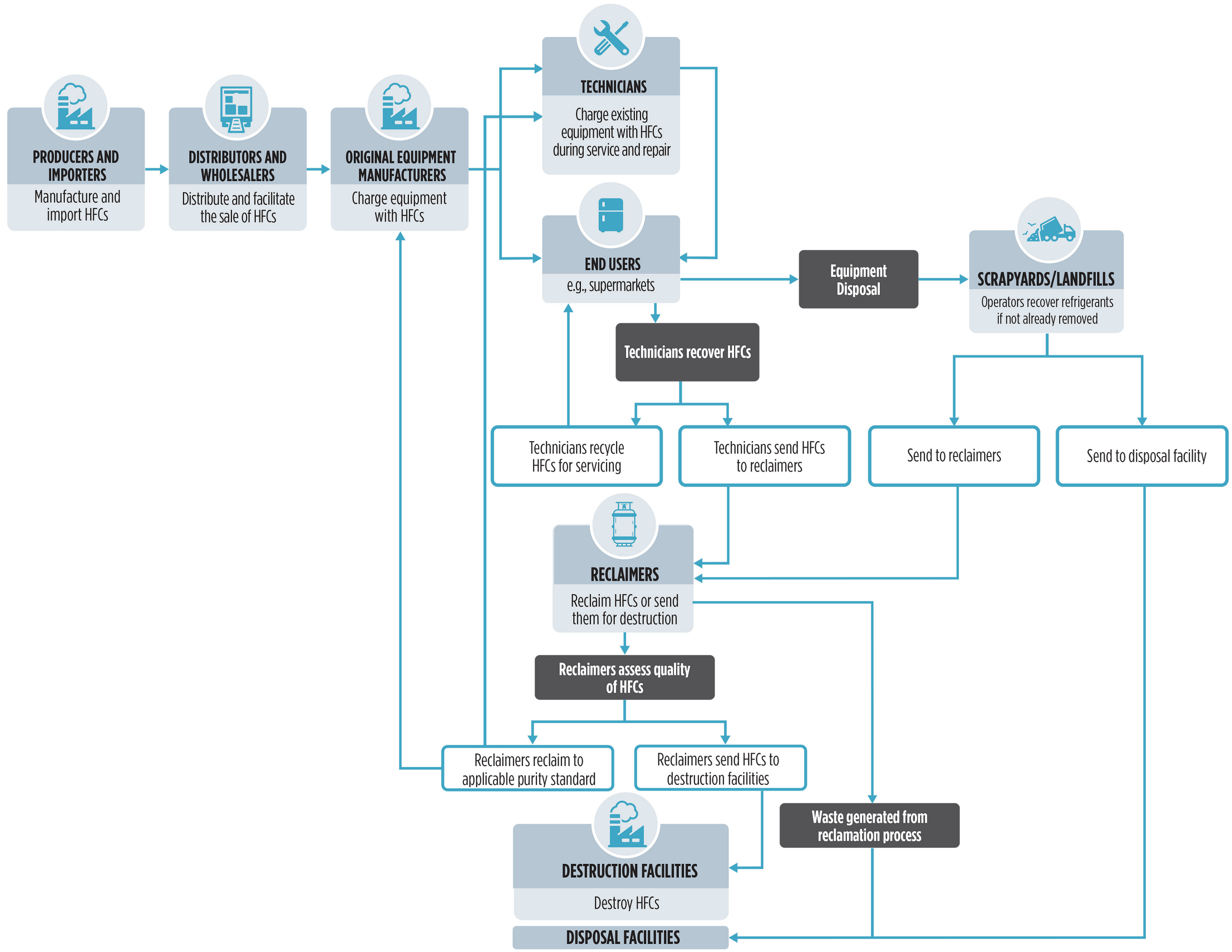
- Section 1 provides an introduction and context of the AIM Act and reclamation.
- Section 2 provides background information on reclamation and EPA’s regulatory authority over refrigerant reclamation as well as information on state actions pertaining to reclamation.
- Section 3 identifies key stakeholders in the reclamation industry and describes their roles and responsibilities.
- Section 4 identifies the sectors of the economy that use HFCs as refrigerants.
- Section 5 describes the U.S. reclamation market and includes a description of reclamation methods and processes, cost drivers, and incentives.
- Section 6 describes safety considerations for technicians and consumers.
- Section 7 discusses the barriers and key challenges to increasing refrigerant reclamation.

Key Findings

Reclamation Process and Stakeholders

A diverse group of industry stakeholders engage in the sale and reclamation of HFCs. Figure ES-1 illustrates the general flow of HFCs through each of the key stakeholders, including producers and importers, wholesalers (including distributors), technicians, end users, reclaimers, destruction facilities, and scrap recyclers and landfills. In general, technicians recover HFCs and either recycle them for use in existing equipment, send them for reclamation, or send them for destruction. Depending on the quality of the recovered refrigerant, reclaimers decide whether to reclaim the HFCs to the required purity standard (e.g., based on Air-Conditioning, Heating, and Refrigeration Institute Standard 700-2016) or send them to destruction facilities. Reclaimers may choose to send recovered refrigerants for destruction if they are too contaminated, making the reclamation process cost-prohibitive or infeasible from a technological standpoint.

Figure ES-1. General Flow Chart of HFCs through Industry including Recovery and Reclamation



Reclamation Market

Since 2017, EPA has required that certified reclaimers report data on HFC reclamation activity in accordance with regulations promulgated under section 608 of the Clean Air Act (CAA). These requirements are analogous to the longstanding requirements of ozone-depleting refrigerants. As shown in Table ES-1, the amount of reclaimed HFCs has remained relatively constant from 2017 to 2021, with annual totals ranging from 5.09 million pounds in 2017 to 6.06 million pounds in 2019. The HFC refrigerants with the highest reclamation totals are HFC-134a (9.97 million pounds total from 2017-2021) and R-410A (11.64 million pounds total from 2017-2021).

Table ES-1. HFC Refrigerant Reclamation from 2017 to 2021 (pounds)

Refrigerant	2017	2018	2019	2020	2021
HFC-134a	1,858,132	2,910,240	2,399,952	1,956,644	1,844,793
R-404A	486,719	506,639	485,338	478,556	416,352
R-407A	111,255	143,254	105,435	87,162	60,580
R-407C	167,445	167,248	213,668	315,424	366,521
R-410A	2,103,404	2,043,667	2,596,861	2,347,000	2,550,164
Other HFCs	363,311	479,261	258,486	206,029	173,022
Total	**5,090,266**	**5,250,309**	**6,059,740**	**5,390,816**	**5,411,433**

Table ES-2 presents data on reclaimed HFCs in terms of million metric tons of carbon dioxide equivalent ($MMTCO_2e$), a measure of the global warming potential (GWP) used to compare relative warming effects of GHGs in the atmosphere. For context, the consumption of HFCs was estimated at 309 $MMTCO_2e$ in 2020 (U.S. EPA 2021a). It is expected that the HFC reclamation market will increase in future years as more refrigeration and air conditioning equipment using HFC refrigerants reach their end-of-life and virgin HFC supplies are restricted consistent with the AIM Act. Over the next ten years, one estimate predicts that under the HFC phasedown, reclaimed HFCs will increase in sales by $0.8 billion and add almost 4,000 jobs (Inforum et al. 2019).

Table ES-2. HFC Refrigerant Reclamation Totals by Year ($MMTCO_2e$)

Refrigerant	2017	2018	2019	2020	2021
HFC-134a	1.21	1.24	1.56	1.27	1.20
R-404A	0.87	0.90	0.86	0.85	0.74
R-407A	0.11	0.14	0.10	0.08	0.06
R-407C	0.13	0.13	0.17	0.25	0.29
R-410A	1.99	1.94	2.46	2.22	2.41
Other HFCs[a]	0.59	0.77	0.37	0.31	0.28
Total	**4.89**	**5.11**	**5.52**	**4.99**	**4.99**

[a] Other HFCs were calculated in $MMTCO_2e$ using aggregated totals of each HFC reclaimed as reported during annual reporting per 40 CFR 82.164(d) and using their respective GWPs

Key Barriers to Increasing Reclamation

The report identifies some key barriers to increasing refrigerant recovery and reclamation:

- **Contamination, Blends, and Mixed Cylinders.** When cylinders contain refrigerant blends or different types of refrigerants, it is more difficult and time-consuming for reclaimers to process and reclaim the refrigerants.
- **Costs of Reclamation.** The cost of recovering and reclaiming refrigerant is increasing primarily due to new blends requiring new technologies. In addition, market fluctuations affect the relative price of reclaimed refrigerant to virgin refrigerant. Further, logistical costs, such as transporting recovered materials to the relatively few reclamation factilities nationwide and who bears that cost, also may factor in to the overall economics of reclaim.
- **Refrigerant Release Limits Recovery Potential.** When refrigerant is released from equipment, it results in less refrigerant available for recovery and reclamation. Accidental release and leakage rates vary depending on application and charge size, and may occur at different points throughout the lifetime of equipment, including during installation, servicing and maintenance, and at end-of-life. Intentional release, such as venting, may also occur.

1. Introduction

The American Innovation and Manufacturing Act (AIM Act or AIM), enacted on December 27, 2020 (codified at 42 U.S.C. 7675), directs the United States (U.S.) Environmental Protection Agency (EPA) to phase down hydrofluorocarbon (HFC) production and consumption by 85 percent by 2036. HFCs, which are highly potent greenhouse gases (GHG), are commonly used in refrigeration and air conditioning equipment, as well as in foams, aerosols, fire suppression and other applications. A global phasedown of HFCs is expected to avoid up to 0.5°C of global warming by 2100.

The AIM Act authorizes EPA to address HFCs in three main ways:

- phasing down HFC production and consumption through an allowance allocation program;
- facilitating sector-based transitions to next-generation technologies; and
- issuing certain regulations for purposes of maximizing reclamation and minimizing releases of HFCs and their substitutes from equipment.

With respect to the third point, subsection (h) of the AIM Act directs EPA to promulgate regulations to control, where appropriate, any practice, process, or activity regarding the servicing, repair, disposal, or installation of equipment that involves a regulated substance; a substitute for a regulated substance; the reclaiming of a regulated substance used as a refrigerant; or the reclaiming of a substitute for a regulated substance used as a refrigerant.

While this report focuses on the recovery and reclamation of regulated HFCs being used as refrigerants, subsection (h) of the AIM Act does not limit activities identified in subsection (h) only to refrigerants. [1] Although not a focus of this report, EPA understands that regulated HFCs and their substitutes recovered from other equipment, such as fire suppression systems, may be reprocessed and reused as well.

This report provides background information on the reclamation industry. This report is organized as follows:

- Section 2 provides background information on reclamation and EPA's regulatory authority over refrigerant reclamation as well as information on state actions pertaining to reclamation.
- Section 3 identifies key stakeholders in the reclamation industry and describes their roles and responsibilities.
- Section 4 identifies the sectors of the economy that use HFCs as refrigerants.
- Section 5 describes the U.S. reclamation market and includes a description of reclamation methods and processes, cost drivers, and incentives.
- Section 6 describes safety considerations for technicians and consumers.
- Section 7 discusses the barriers and key challenges to increasing refrigerant reclamation.
- Section 8 includes references cited in the text.
- Appendix A includes the statutory text of subsection (h) of the AIM Act.

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[1] Subsection (h)(4), however, states that: "No regulation promulgated pursuant to this subsection shall apply to a regulated substance or a substitute for a regulated substance that is contained in a foam."

2. Background

The multinational treaty known as *The Montreal Protocol on Substances that Deplete the Ozone Layer* (Montreal Protocol) is phasing out the production and consumption of ozone depleting substances (ODS). The Clean Air Act (CAA) amendments of 1990 included, among other things, provisions for protecting the stratospheric ozone layer. Specifically, title VI of the CAA included provisions to implement U.S. responsibilities under the Montreal Protocol, such as provisions directed at phasing out production and consumption of ODS. Title VI also includes complementary measures, such as identifying safer substitutes and regulating use and disposal of ODS.

In phasing out ODS, those with the highest ozone depletion potential (ODP) were phased out first. ODS regulated under title VI are divided into two classes: class I substances and class II substances. The CAA provides an initial list of class I and class II substances in sections 602(a) and 602(b), but also provides EPA authority to make additions to those lists if certain criteria are met. The current list of substances that are categorized as class I substances (e.g., chlorofluorocarbons (CFCs), methyl chloroform, carbon tetrachloride, methyl bromide, and halons) can be found at 40 CFR part 82, subpart A, appendix A, and as class II substances at 40 CFR part 82, subpart A, appendix B. The class II substances are all hydrochlorofluorocarbon (HCFCs). For most class I substances, the allocation of production and consumption allowances ended by 1996.[2] To implement the phaseout of class II substances, EPA developed a framework that placed restrictions on production and consumption allowances for class II substances starting in 2003.[3] The class II allowances reduce annually until complete phase-out is achieved in 2030.[4]

The Montreal Protocol has successfully reduced the production and consumption of ODS; however, it resulted in a shift toward greater use of HFCs, which are potent GHGs that have global warming potentials (GWPs) (a measure of the relative climate impact of a GHG) that can be hundreds to thousands of times greater than carbon dioxide (CO_2). In 2016, in Kigali, Rwanda, countries agreed to an amendment to the Montreal Protocol, known as the Kigali Amendment, which provides for a global phasedown of the production and consumption of HFCs.

In 2020, Congress enacted the AIM Act, which directs EPA to phase down HFC production and consumption by 85 percent by 2036 and also includes other provisions for EPA to regulate HFCs. The AIM Act lists 18 saturated HFCs, and by reference any of their isomers not so listed, that are covered by the statute's provisions, referred to as "regulated substances" under the Act.

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[2] The class I substances for which EPA had stopped allocating production and consumption allowances by 1996 include CFCs, methyl chloroform, carbon tetrachloride, and halons. EPA last allocated production and consumption allowances for methyl bromide for 2005.

[3] For class II substances, EPA established a phaseout schedule to eliminate HCFC–141b first, to greatly restrict HCFC–142b and HCFC–22 next, and to subsequently place restrictions on other HCFCs, ultimately ending the allocation of production and consumption allowances for all HCFCs by 2030. EPA stopped allocating production and consumption allowances for HCFC–141b as of 2003; for HCFC–225ca/cb as of 2015; and for HCFC–22 and HCFC–142b as of 2020. Since 2020, the two remaining class II substances, HCFC-123 and HCFC-124, have received only small allowances for servicing of refrigeration, air-conditioning, and fire suppression equipment existing on January 1, 2020.

[4] For additional detail on the phaseout of ODS, please refer to *https://www.epa.gov/ods-phaseout*.

Congress also assigned an "exchange value" to each regulated substance, which is numerically equivalent to the 100-year GWPs listed in the 2007 Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report.

The AIM Act authorizes EPA to address HFCs in three main ways: phasing down HFC production and consumption through an allowance allocation program; issuing certain regulations for purposes of maximizing reclamation and minimizing releases of HFCs and their substitutes from equipment; and facilitating sector-based transition to next-generation technologies. The phasedown provisions are consistent with the Kigali Amendment. This report focuses on the recovery and reclamation of regulated substances. Reclamation has played a key role in maintaining the supply of ODS during their phaseout, so that appliances and equipment can be used for their full useful lifetime and not retired prematurely. For example, reclaimed HCFC-22 may continue to be used for as long as it is available to service existing HCFC-22 systems (U.S. EPA 2020). Reclamation is also expected to help ease the impacts of the phasedown of production and consumption of HFCs in accordance with the AIM Act.

2.1 What is Reclamation?

In this context, reclamation refers to the reprocessing of a recovered substance to an established specification for purity as verified using a prescribed analytical methodology. Reclamation can play an important role as the United States phases down HFC production and consumption. The reclamation process involves reprocessing and upgrading recovered substances through such mechanisms as filtering, drying, distillation, and chemical treatment to restore the substance to industry specifications (Stratus Consulting 2010). The AIM Act defines both reclaim and reclamation as follows (42 U.S.C. 7675(b)(9)):

> *(A) the reprocessing of a recovered regulated substance to at least the purity described in standard 700–2016 of the Air-Conditioning, Heating, and Refrigeration Institute (or an appropriate successor standard adopted by the Administrator); and*
>
> *(B) the verification of the purity of that regulated substance using, at a minimum, the analytical methodology described in the standard referred to in subparagraph (A).*

The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Standard 700-2016 (AHRI Standard 700) establishes purity specifications and methods of testing to verify the composition of refrigerants regardless of source (new, reclaimed and/or repackaged) for use in new and existing refrigeration and air conditioning products (AHRI 2019).

By bolstering the current supply of HFCs with refrigerants from existing systems, reclamation supports a smooth transition to alternatives. In addition, reclamation can minimize disruption of the current capital stock of equipment by allowing its continued use with existing refrigerant supplies (U.S. EPA 2016a).

Reclamation can also help avoid supply shortages of virgin (newly produced) refrigerants and can insulate the industry against price spikes that could affect the servicing of existing systems using HFCs. Refrigerant reclamation creates value for used refrigerants recovered from equipment, for example, during routine servicing, and helps embed good practices in refrigerant management throughout the supply chain.

A key example of the benefits of reclamation or recycling is the use of reclaimed or recycled ODS whose production has been phased out. This sector has a long history of using recycled ODS for both servicing and new equipment. For example, HCFC-123 can be recovered from chillers and reprocessed for reuse in fire suppression application where there is continued need.

Recycled halons are also important for use in fire suppression systems. EPA phased out the production and importation of virgin halons in the United States in 1994. Since that time, there has been continued demand for halons in both newly manufactured fire suppression equipment and servicing of existing equipment. Recycled halons have been the only supply in the United States for specialty fire suppression applications. Sources of recycled halons include stockpiles and recovered agent from cylinders both in the United States and abroad.[5]

The management of halons in the United States over the last several decades demonstrates a model of collaboration between industry, government, and key users, effective regulations to reduce emissions, a smooth transition to safer alternatives through revisions to industry standards, voluntary industry codes of practice, maintenance of halon banking, and government halon reserves. Existing halon stocks are purchased by commercial recyclers from decommissioned equipment, reprocessed to industry specifications, and sold back into the market. Similar to the handling of refrigerants under section 608 of the CAA, EPA's regulations addressing halons, at 40 CFR part 82, subpart H, include certain prohibitions on intentional release (venting) of halons and requirements for technicians to be trained regarding halon emission reduction.

Ultimately, demand for halons have been satisfied with recycled halons, ensuring equipment can be serviced and investments are not stranded. Recycled halons have been used for over 25 years to charge new fire suppression equipment and more recently recycled HCFCs have similarly been used in a fire suppression blend (U.S. EPA 2020). Reclamation of HFCs is underway and can help to meet demands for uses of HFCs in a similar fashion to halons.

2.2 Federal Statutory and Regulatory Provisions

Two sections in title VI of the CAA that are particularly relevant to reclamation are sections 608 and 609. EPA's current regulations under these sections of the CAA require certain refrigerant management practices by reclaimers, those who buy or sell refrigerant, technicians, owners and operators of air conditioning and refrigeration systems, and others. The refrigerant management regulations are at 40 CFR part 82, subpart F (subpart F). These requirements generally apply to the management of ODS and substitutes for ODS, such as HFCs, used as refrigerants.[6] As ODS production and import have been phased out under title VI of the CAA, refrigerant reclamation has provided an important source of ODS refrigerants to service existing equipment. Refrigerant

[5] For additional information on the halons program, please visit *https://www.epa.gov/ozone-layer-protection/halons-program*.

[6] One exception to this general rule is 40 CFR 82.157, which relates to appliance maintenance and leak repair, and which only applies to appliances containing an ODS as of April 10, 2020.

recovery, recycling, and reclamation occur primarily in stationary and mobile air conditioning and refrigeration applications.

CAA Section 608: National Recycling and Emission Reduction Program

Section 608 of the CAA, titled "National Recycling and Emission Reduction Program," has three main components. First, section 608(a) requires the EPA to establish standards and requirements regarding the use and disposal of class I and class II substances. The second component, section 608(b), requires that the regulations issued pursuant to subsection (a) contain requirements for the safe disposal of class I and class II substances. The third component, section 608(c), prohibits the knowing venting, release, or disposal of ODS refrigerants and their substitutes in the course of maintaining, servicing, repairing, or disposing of appliances or industrial process refrigeration (IPR).

EPA regulations (40 CFR part 82, subpart F) under section 608 of the CAA address the handling and recycling of refrigerants used in stationary refrigeration and air conditioning systems. Several of these requirements are particularly relevant to reclamation, including:

- Venting Prohibition: consistent with the venting prohibition under section 608(c) of the CAA, EPA's subpart F regulations at 40 CFR 82.154(a) prohibit individuals from knowingly venting or otherwise releasing into the environment ODS refrigerants and their substitutes (such as HFCs), while maintaining, servicing, repairing, or disposing of air conditioning or refrigeration equipment, while also providing for certain limited exceptions from this prohibition.
- Recovery: With certain limited exceptions, under 40 CFR 82.156, before opening (e.g., for servicing) or disposing of an appliance, technicians must ensure refrigerant is evacuated from air conditioning or refrigeration equipment to established vacuum levels. Similar requirements apply to persons opening or disposing of a small appliance, motor vehicle air conditioner (MVAC), or MVAC-like appliances.[7]
- Reclamation: Under 40 CFR 82.154(d)(1), the sale of used refrigerant is prohibited, with certain limited exceptions. Under one of those exceptions, used refrigerant may be resold

[7] EPA's subpart F regulations at 40 CFR 82.152 define "MVAC-like appliance" to mean "a mechanical vapor compression, open-drive compressor appliance with a full charge of 20 pounds or less of refrigerant used to cool the driver's or passenger's compartment of off-road vehicles or equipment. This includes, but is not limited to, the air-conditioning equipment found on agricultural or construction vehicles. This definition is not intended to cover appliances using R-22 refrigerant." By contrast, EPA's subpart F regulations at 40 CFR 82.152 define "Motor vehicle air conditioner (MVAC)" as "any appliance that is a motor vehicle air conditioner as defined in 40 CFR part 82, subpart B." The subpart B regulations at 40 CFR 82.32 provide that: "Motor vehicle air conditioners means mechanical vapor compression refrigeration equipment used to cool the driver's or passenger's compartment of any motor vehicle. This definition is not intended to encompass the hermetically sealed refrigeration systems used on motor vehicles for refrigerated cargo and the air conditioning systems on passenger buses using HCFC-22 refrigerant." Further, the subpart B regulations at 40 CFR 82.32 provide that: "Motor vehicle as used in this subpart means any vehicle which is self-propelled and designed for transporting persons or property on a street or highway, including but not limited to passenger cars, light duty vehicles, and heavy duty vehicles. This definition does not include a vehicle where final assembly of the vehicle has not been completed by the original equipment manufacturer."

if it has been reclaimed by an EPA-certified reclaimer. Under 40 CFR 82.164, reclaimers must also follow certain practices[8] when reclaiming such refrigerants for sale to a new owner, such as:

- Not releasing more than 1.5 percent of the refrigerant during the reclamation process;
- Reclaiming refrigerant such that it meets all the required specifications (based on AHRI Standard 700-2016, Specifications for Refrigerants) that are applicable to that refrigerant; and
- Verifying that each batch of refrigerant reclaimed meets these specifications using the required analytical methodology.

CAA Section 609: Servicing of Motor Vehicle Air Conditioners

Section 609 of the CAA specifically addresses the servicing of MVACs and require EPA to promulgate regulations establishing standards and requirements regarding the servicing of MVACs. EPA's regulations under section 609 are at 40 CFR part 82, subpart B. Under those regulations, any person repairing or servicing an MVAC system for consideration (i.e., payment in any form) involving the use of refrigerant[9] must use approved refrigerant recycling equipment and be properly trained and certified. These regulations also require recovered refrigerant to be either recycled or reclaimed, consistent with certain regulatory requirements, before it can be charged or recharged into an MVAC system. This requirement applies even if the refrigerant is being returned to the system from which it was removed.

EPA's subpart F regulations define reclaim to mean to "reprocess recovered refrigerant to all of the specifications in appendix A of this subpart (based on AHRI Standard 700-2016, *Specifications for Refrigerants*) that are applicable to that refrigerant and to verify that the refrigerant meets these specifications using the analytical methodology prescribed in section 5 of appendix A of this subpart" (40 CFR 82.152 (definition of "reclaim")).

Under subpart F, recovery involves removing refrigerant in any condition from an appliance and storing it in an external container without necessarily testing or processing it in any way (40 CFR 82.152 (definition of "recover")).

Similarly, under subpart F, recycling a refrigerant involves extracting it from an appliance and cleaning the refrigerant for reuse in equipment of the same owner without meeting all of the requirements for reclamation. In general, recycled refrigerant is refrigerant that is cleaned using oil separation and single or multiple passes through devices, such as replaceable core filter-

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[8] A complete list of requirements is available at 40 CFR 82.164 and they are briefly described in an EPA fact sheet for reclaimers, available at *https://www.epa.gov/sites/default/files/2016-09/documents/608_fact_sheet_reclaimers_0.pdf.*

[9] The term "refrigerant" as used in CAA Section 609 has included class I or class II substances and substitutes since November 15, 1995.

driers, which reduce moisture, acidity, and particulate matter (40 CFR 82.152 (definition of "recycle")).

Under the AIM Act, the terms reclaim and reclamation are both defined to mean "(A) the reprocessing of a recovered regulated substance to at least the purity described in standard 700-2016 of the Air-Conditioning, Heating, and Refrigeration Institute (or an appropriate successor standard adopted by the Administrator); and (B) the verification of the purity of that regulated substance using, at a minimum, the analytical methodology described in the standard referred to in subparagraph (A)" (42 U.S.C. 7675(b)(9)). The term **recover** is defined in the AIM Act to mean "the process by which a regulated substance is (A) removed, in any condition, from equipment; and (B) stored in an external container, with or without testing or processing the regulated substance" (42 U.S.C. 7675(b)(10)). These are similar to EPA's existing definitions in the refrigerant management regulations.

Subsection (h) of the AIM Act includes provisions related to the management of regulated HFCs and their substitutes. Subsection (h)(1) provides that "[f]or purposes of maximizing reclaiming and minimizing the release of a regulated substance from equipment and ensuring the safety of technicians and consumers," EPA "shall promulgate regulations to control, where appropriate, any practice, process, or activity regarding the servicing, repair, disposal, or installation of equipment … that involves (A) a regulated substance; (B) a substitute for a regulated substance; (C) the reclaiming of a regulated substance used as a refrigerant; or (D) the reclaiming of a substitute for a regulated substance used as a refrigerant." Subsection (h) also provides that "[i]n carrying out this section, the Administrator shall consider the use of authority available to the Administrator under this section to increase opportunities for the reclaiming of regulated substances used as refrigerants" (subsection (h)(2)(A)) and authorizes EPA in promulgating regulations carrying out subsection (h) of the AIM Act to "coordinate those regulations with any other [EPA] regulations" involving "the same or a similar practice, process, or activity regarding the servicing, repair, disposal, or installation of equipment," or reclaiming (subsection (h)(3)). Such regulations could potentially include the refrigerant management program established under title VI of the Clean Air Act.

2.3 State Statutory and Regulatory Provisions

California

In December 2021, the California Air Resources Board (CARB) finalized amendments to its regulation on prohibitions on the use of certain HFCs in stationary refrigeration, stationary air conditioning, and other end-uses. Section 95376 of this regulation established the Refrigerant Recovery, Reclaim, and Reuse Requirements (R4 Program), which requires that manufacturers of two types of air conditioning end-uses, *other air conditioning (new) equipment, residential and non-residential*;[10] and *variable refrigerant flow (VRF) equipment*, must use a minimum

[10] "Other Air-conditioning" or "Other Air-conditioning Equipment" is defined in California's regulation as any residential or non-residential air-conditioning equipment or air-conditioning system not otherwise defined as "room air conditioner," "wall air conditioner," "window air conditioner," "packaged terminal air conditioner (PTAC)," "packaged terminal heat pump (PTHP)," "portable air conditioner," "residential dehumidifier," or "variable refrigerant flow (VRF) system." (17 CCR § 95373 2021)

amount of reclaimed refrigerant[11], starting in 2023. For other air conditioning equipment (new), residential and non-residential, the regulations require that manufacturers utilize a volume of reclaimed refrigerant in 2023 and 2024 that is approximately 10 percent of the total HFC entered into California in the equipment in the baseline years. For VRF equipment, the regulations require that manufacturers utilize a volume of reclaimed refrigerant in 2023 and 2024 that is approximately 15 percent of the total HFC entered into California in this equipment in the baseline years, and then increases to a 25 percent reclaim requirement in 2025. The reclaimed refrigerant requirement can be met using the reclaimed refrigerant for factory charge of new equipment, field charge of new equipment, or servicing existing equipment. The requirement may also be met by using a refrigerant with a GWP of less than 750 during these activities. The reclaimed refrigerant does not need to be sourced from inside the state. Furthermore, CARB defines "certified reclaimed refrigerant" for the purposes of this requirement as not containing more than 15 percent virgin refrigerant by weight (17 CCR § 95376 2021).

As the requirements under the R4 program do not become effective until 2023, information is not available about the effect this program may have on reclamation rates. Although similar reclamation programs have been discussed in proposed rulemakings for other states, California is the first state to implement such a reclaim program in the United States.

Washington

In 2021, the State of Washington finalized House Bill 1050, which expanded HFC restrictions. The new law set a maximum GWP for HFCs used in new stationary air conditioning equipment, new and existing stationary refrigeration equipment, and ice rinks. In addition, the legislation established a refrigerant management program to address refrigerant emissions from large air conditioning and refrigeration equipment (Washington Department of Ecology 2022). Lastly, House Bill 1050 mandated the Washington Department of Ecology to prepare a report summarizing approaches for state regulators to manage the end-of-life and disposal of refrigerants. They found an "incentive-based approach incorporating extended producer responsibility may maximize the recovery and disposal of refrigerants" and that a "fee-based program that provides incentives to consumers and businesses for proper refrigerant disposal, recovery, reclaim, and reuse would significantly reduce HFC emissions" (Drumheller et al. 2021).

Other States

Ten additional states (i.e., Colorado, Delaware, Massachusetts, Maryland, Maine, New Jersey, New York, Rhode Island, Virginia, and Vermont) have enacted legislation and/or adopted regulations that prohibit certain HFCs in specific end-uses. Four states (i.e., Connecticut, New Mexico, Oregon, and Pennsylvania) have legislation at various stages of development to reduce HFC emissions through prohibitions of certain HFCs in specific end-uses, but no bills have been signed into law by their governors (North American Sustainable Refrigeration Council n.d.).

[11] The minimum amount is calculated according to a baseline which uses the average number of pounds of refrigerant in equipment that entered California in 2018 and 2019. For manufacturers with no shipments into California in those years, the requirement for using certified reclaimed refrigerant will be based on the current year the refrigerant enters California.

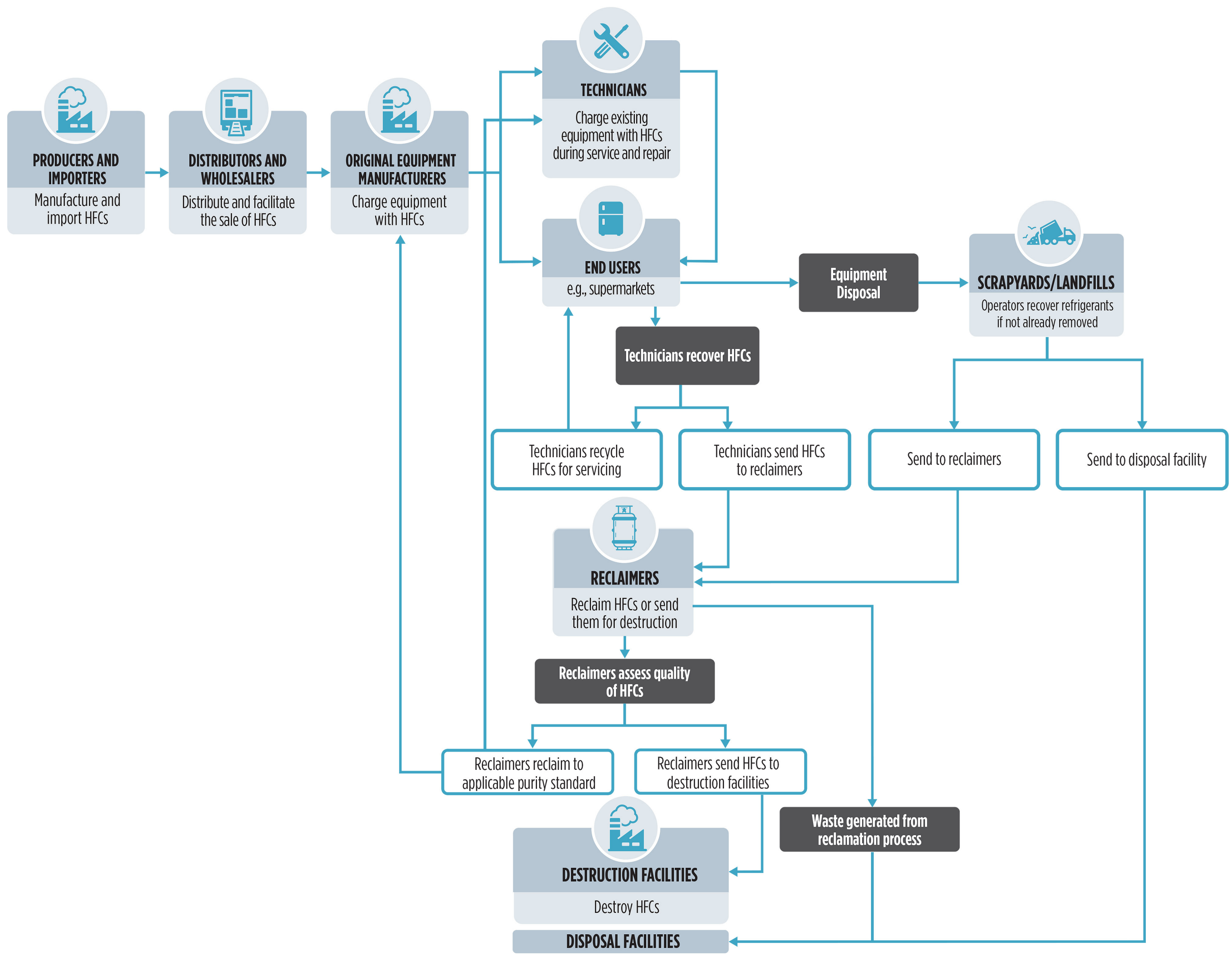
EPA is not aware of any states developing additional HFC regulations that would include refrigerant management requirements or reclamation.

3. Reclamation Stakeholders

3.1 Overview

A diverse mix of industry stakeholders engage in the sale and reclamation of HFCs. Figure 1 illustrates the general flow of HFCs through each of the key stakeholders, including producers and importers, wholesalers (including distributors), end users, reclaimers, destruction facilities, and scrap recyclers and landfills. In general, technicians may recover HFCs and either recycle them for use in existing equipment, send them for reclamation, or send them for destruction. Depending on factors including the quality of the recovered refrigerant, reclaimers decide whether to process the HFCs to the applicable purity standard (e.g., based on AHRI Standard 700-2016) or send them for destruction. For example, the market price of the refrigerant, among other factors, may influence whether a reclaimer will choose to reclaim lower quality recovered refrigerant or send it offsite for destruction. Reclaimers may choose to send recovered refrigerants for destruction if they are too contaminated and reclamation is deemed not technologically and/or economically feasible.

Figure 1. General Flow Chart of HFCs through Industry including Recovery and Reclamation



3.2 Reclaimers

EPA certifies refrigerant reclaimers and publishes a list of their names and contact information. As of October 2022, there are over 50 EPA-certified refrigerant reclaimers.[12] Reclaimers receive refrigerant recovered from existing refrigeration and air conditioning equipment and process the refrigerant through various means to achieve a targeted purity and blend composition. Reclaimers typically inspect the recovered refrigerant that they receive to determine whether the refrigerant is technologically and/or economically feasible to reclaim or should be destroyed. At least one reclaimer has capacity to destroy refrigerant themselves, while some may pay destruction companies with the capability to destroy the refrigerant (U.S. EPA 2018). Reclaimers will often pay wholesalers and technicians for the recovered refrigerant and charge back a fee for the recovered refrigerant that must be destroyed.

For quantities that can be reclaimed, reclaimers sell the refrigerant back into the supply chain through equipment or refrigerant-specific wholesalers or directly to heating, ventilation, air conditioning, and refrigeration (HVACR) technicians. In interviews with reclaimers in 2018 and 2019, [13] EPA learned about the various ways in which reclaimers sell refrigerant back into the supply chain. From those interviews, EPA understands that reclaimers may sell exclusively to wholesalers, directly to technicians and contractors, or through a third-party agent.

3.3 Wholesalers and Distributors

Wholesalers include distribution companies that provide a full range of HVACR equipment, components, and refrigerants, as well as those that focus exclusively on refrigerants. The wholesalers sell virgin or reclaimed refrigerant to HVACR technicians, who then use the refrigerant to charge customer equipment. Currently, refrigerant is not typically marketed or sold as “reclaimed refrigerant.”

Wholesalers may sell or otherwise provide empty recovery cylinders to technicians so they can recover refrigerant from existing HVACR systems and return the full cylinders with recovered refrigerant to the wholesalers. Wholesalers then provide the recovered refrigerant to reclaimers for processing and may facilitate any credits or fees for the refrigerant recovered by technicians.

3.4 Technicians

EPA certifies technicians per the regulations under sections 608 and 609 of the CAA (40 CFR 82.161, 40 CFR 82.40). Technicians include contractors that install and service HVACR systems for residential, commercial, and industrial customers, independent operators, in-house technicians employed by larger commercial and industrial facilities (e.g., food retailers), as well as those repairing or servicing motor vehicle air conditioners for consideration (i.e., payment of any form). Technicians may purchase virgin or reclaimed refrigerant from wholesalers, and sometimes directly from reclaimers. Similarly, some technicians may return recovered refrigerant to wholesalers or reclaimers in smaller quantities on a daily or weekly basis, whereas others may store refrigerant for less-frequent returns. Many technicians will handle refrigerant

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[12] For a list of EPA-certified reclaimers, please see *https://www.epa.gov/section608/epa-certified-refrigerant-reclaimers*.

[13] Between 2018 and 2019, EPA conducted interviews with eight reclaimers to obtain more information on the industry, including reclamation technologies and equipment and potential challenges and barriers.

recovery and processing themselves, although some use subcontractors who specialize in equipment disposal and refrigerant recovery so they can focus on installations and servicing.

4. Current Subsectors and Applications using Refrigerants

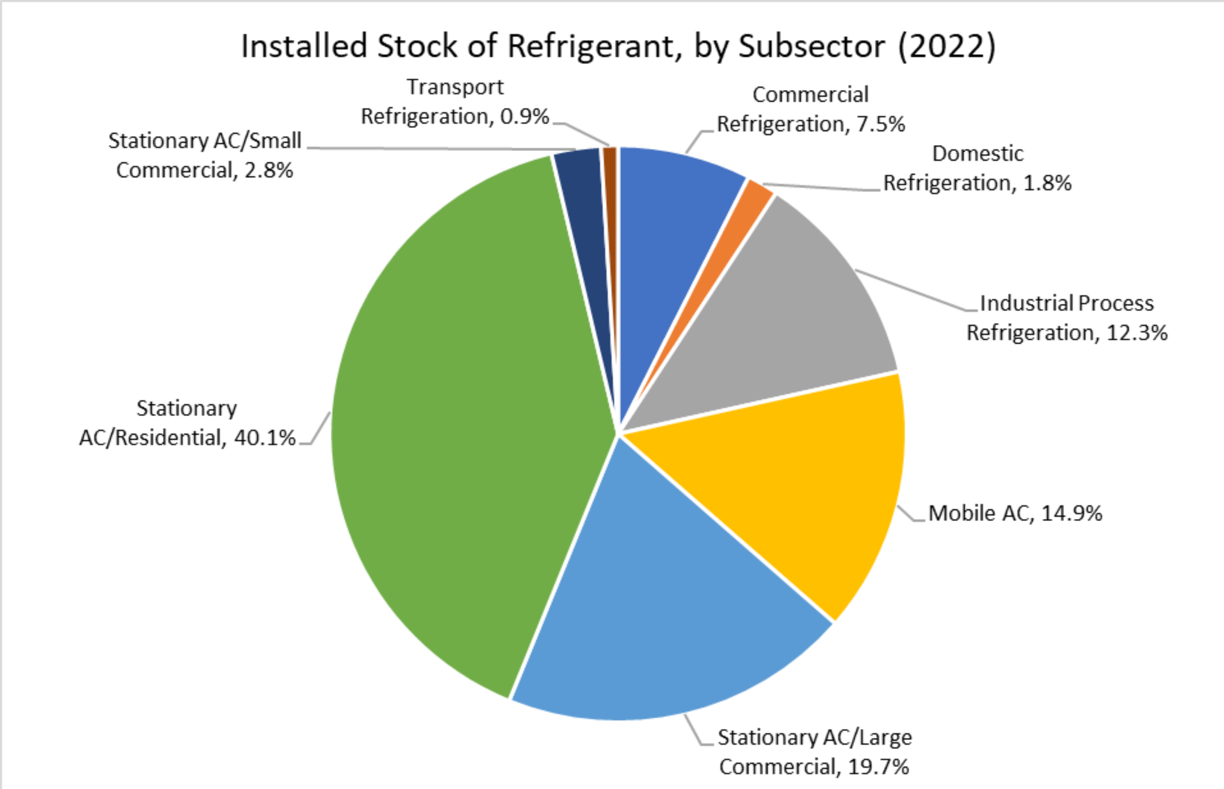
In general, refrigerant use is based on which sectors and subsectors they are used in and the particular applications in which they are used that within those sectors. For the purposes of this report, EPA considered which refrigerants are used and how – and while there are many ways to categorize sectors and subsectors, we used the categories as established in EPA's Vintaging Model (VM). Applications refer to certain classes of uses that would fall within a subsector. For example, the commercial refrigeration subsector may include retail food refrigeration as an application. Refrigerants that are currently in use may be available for recovery and possible reclamation when the equipment using the refrigerant reach their end-of-life or cease operation.

EPA's VM was developed to estimate the annual emissions from sectors that have used ODS. The VM tracks inventory of in-use stocks and emissions from annual vintages of new equipment containing ODS and substitutes that enter into service.[14] Figure 2 shows the estimated stock of refrigerants in 2022 in various refrigeration and air conditioning subsectors.[15] The total installed stock of refrigerants is 1.1 million metric tons. The air conditioning subsectors account for approximately 77.5 percent of the installed stock, with the greatest amount in stationary air conditioning/residential (40.1%). Refrigeration subsectors account for approximately 22.5 percent of the installed stock of refrigerants.

[14] EPA's Vintaging Model of ODS Substitutes - *https://www.epa.gov/ozone-layer-protection/epas-vintaging-model-ods-substitutes*.

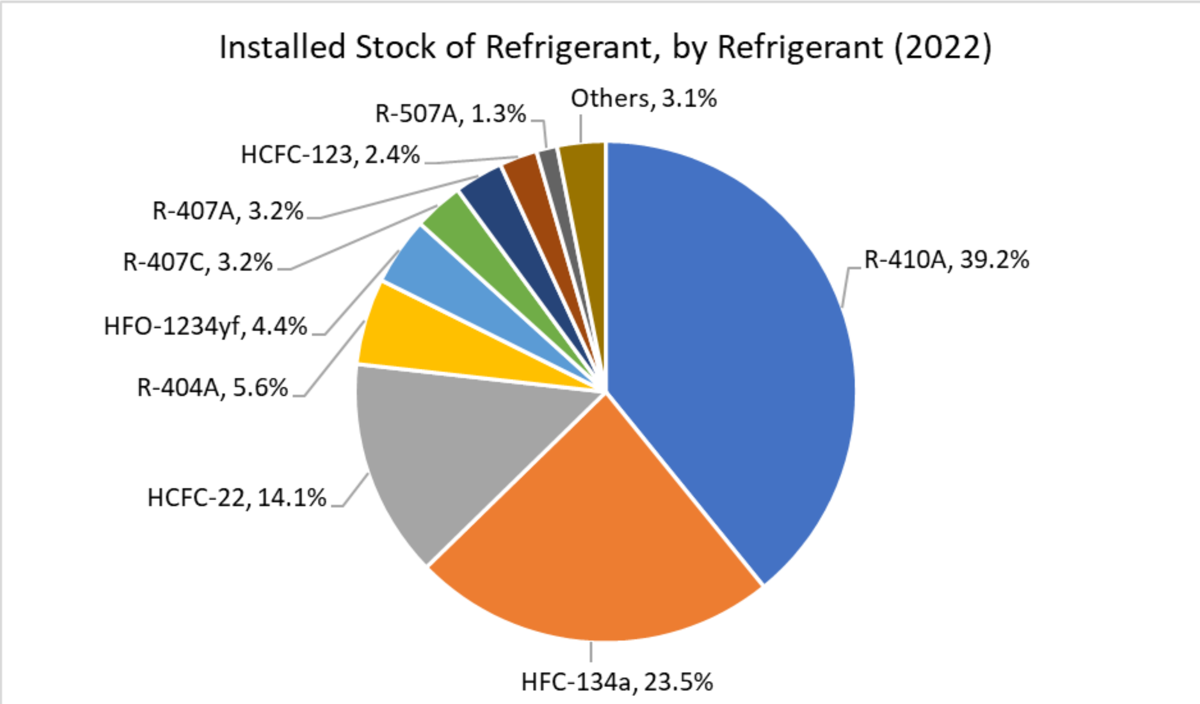
[15] Data pulled from VM IO file_v5.1_03.23.2022.

Figure 2. Installed stock of ODS and substitute refrigerants by subsector, by mass



The VM also provides estimates on the types of ODS and substitutes that are in installed stock both within the refrigeration and air conditioning sector, and across the sector. Figure 3 shows the breakdown of installed stock of the most abundant refrigerants. The top three refrigerants in installed stock are R-410A (39%), HFC-134a (24%), and HCFC-22 (14%). The following sections provide additional information on each of the subsectors within the refrigeration and air conditioning sector, including typical refrigerants used in applications within these subsectors.

Figure 3. Installed stock of ODS and substitute refrigerants by refrigerant, by mass



4.1 Refrigeration Subsectors

There are four main refrigeration subsectors with estimates of installed refrigerant stock from the VM: IPR, domestic refrigeration, commercial refrigeration, and transport refrigeration.

4.1.1 Industrial Process Refrigeration

IPR accounts for the greatest amount of installed stock of ODS and substitute refrigerants among refrigeration subsectors. It accounts for 12.3 percent of the total installed stock across all refrigeration and air conditioning subsectors, and over half (54.7%) among refrigeration subsectors. IPR systems are used to cool process streams in industrial applications and may involve complex and customized systems for a given application. Typically, the equipment and systems used in IPR have a large refrigerant charge size to accommodate for the significant cooling demands at a facility. In addition to industrial refrigeration applications, the IPR subsector of the VM includes estimates of installed stocks of refrigerants in cold storage.

IPR applications may use different refrigerants depending on the application (e.g., the cooling demand needed). The most common ODS and substitutes used as refrigerants in IPR applications are HCFC-22, HFC-134a, and R-404A, making up about three quarters of the installed ODS and substitutes. Beyond HFCs and ODS, other refrigerants such as ammonia (R-717) is also used in IPR applications.[16]

[16] Air-Conditioning, Heating, & Refrigeration Institute (AHRI). 2019. AHRI Letter Responding to CARB's Request for Input and Clarifications Following the August 6, 2019, Public Meeting for Industrial Process Refrigeration and Transport Refrigeration Equipment.

4.1.2 Commercial Refrigeration

Commercial refrigeration accounts for 7.5 percent of the installed stock of ODS and substitute refrigerants among all refrigeration and air conditioning subsectors. Among only refrigeration subsectors, commercial refrigeration accounts for about one third of the installed stock of ODS and substitute refrigerants. Commercial refrigeration includes a wide range of applications that depends on the specific uses of the equipment. Such applications may include retail food refrigeration (e.g., supermarket systems, refrigerated display cases, refrigerated food processing and dispensing equipment) and vending machines. Within these applications, there may be a variety of different types of equipment used. For example, supermarket systems may be large and complex depending on the layout of the store and its geographic location. Refrigerated dispensing equipment may include products such as soft-serve ice cream machines.

Along with the variety of applications within commercial refrigeration, the amount of refrigerant charged in the equipment and the type of refrigerant used vary by application and use. The most common ODS and substitute refrigerants in installed stock in the commercial refrigeration subsector are R-407A, R-404A, and HCFC-22 (collectively accounting for 87 percent of the installed stock of refrigerants in this subsector). As the industry transitions to lower-GWP refrigerants, there are many suitable substitutes depending on the application within commercial refrigeration. For example, some supermarket systems are using CO_2 (R-744) as a refrigerant.[17]

4.1.3 Domestic Refrigeration

Domestic refrigeration accounts for less than 2 percent of the total installed stock of ODS and substitutes refrigerants. Of the refrigeration subsectors, domestic refrigeration accounts for nearly 8 percent. The domestic refrigeration subsector covers residential applications of refrigeration equipment, including household refrigerators, freezers, and combination refrigerator/freezers. These types of equipment are intended for residential use but may be used outside of the home. Products with both a refrigerator and freezer (i.e., combination refrigerator/freezer) are the most common. Other products included in this subsector may include chilled kitchen drawers and wine coolers.

Among ODS and substitutes, the most common refrigerant in installed stocks in domestic refrigeration in the United States is HFC-134a, accounting for about 89 percent of the subsector. Prior to the Montreal Protocol, CFC-12 was commonly used before most of the industry transitioned to HFC-134a for domestic refrigeration applications. According to the 2022 progress report from the Technology and Economic Assessment Panel (TEAP) to the Montreal Protocol, isobutane (R-600a) is now used in 75 percent of all new units globally, with the remainder being HFC-134a.[18]

[17] U.S. EPA, GreenChill Partner Spotlight: Hannaford, February 2022. Available at: *https://www.epa.gov/system/files/documents/2022-02/greenchill-partner-spotlight-hannaford-feb-2022.pdf*

[18] The Technology and Economic Assessment Panel is an advisory body to the parties to the Montreal Protocol and is recognized as a premier global technical body; reports available at: *https://ozone.unep.org/science/assessment/teap.*

4.1.4 Transport Refrigeration

Transport refrigeration accounts for just under one percent of the total installed stock of ODS and substitute refrigerants. This subsector accounts for the lowest percentage among refrigeration subsectors at 4.2 percent of the total installed stock of ODS and substitute refrigerants in the refrigeration subsectors. Transport refrigeration generally includes the movement of perishable goods (e.g., food) and pharmaceuticals at low temperatures (between -22 °F and 61 °F). Various modes of transportation take place within this subsector, including road, ships, and intermodal containers. Transport refrigeration via roads, which is the most common mode of transport refrigeration, includes refrigerated vans, trucks, and trailer-mounted systems. Transport refrigeration via ship, or marine, includes transport of perishable goods via refrigerated ship and marine branches (e.g., merchant, naval, fishing, cruise-shipping). Intermodal containers in transport refrigeration are refrigerated containers that allow uninterrupted storage during transport on different mobile platforms, including railways, trucks, and ships.

The most common ODS and substitute refrigerants in installed stock for transport refrigeration are R-404A (50 percent), HFC-134a (20 percent), R-507A (16 percent), and HCFC-22 (10 percent). Recently, manufacturers have been designing equipment to use other substitute refrigerants, including R-744, R-513A, and R-452A. The type of refrigerant selected may depend on the application or mode of transport refrigeration. For example, a particular refrigerant may be selected depending on its cooling capacity or other properties, such as non-flammability.

4.2 Air conditioning Subsectors

There are four main air conditioning subsectors with estimates of installed refrigerant stock from the VM: stationary air conditioning – residential; stationary air conditioning – large commercial; stationary air conditioning – small commercial; and mobile air conditioning.

4.2.1 Stationary Air conditioning – Residential

Stationary air conditioning – residential has the greatest estimated installed stock of ODS and substitute refrigerants among all air conditioning and refrigeration subsectors at about 40 percent of the total. Among air conditioning applications, stationary air conditioning – residential accounts for 51.7 percent. Equipment within this application include those for cooling individual rooms and single-family homes. The equipment may contain self-contained or split systems. Self-contained systems may include window air conditioning units, portable air conditioning units, and wall-mounted self-contained units. Split systems may include ducted and non-ducted mini-splits, variable refrigerant flow systems, and ducted unitary split systems.

R-410A accounts for the majority (85 percent) of the installed stock of ODS and substitute refrigerants in stationary air conditioning – residential. The remaining installed stock in this subsector is primarily HCFC-22 at 13 percent of the total. R-454B and HFC-32 have been emerging as possible substitutes for equipment using R-410A as industry is transitioning to lower-GWP refrigerants.[19]

[19] Turpin, J, R-454B Emerges as a Replacement for R-410A, ACHR News, August 2020. Available at: *https://www.achrnews.com/articles/143548-r-454b-emerges-as-a-replacement-for-r-410a*.

4.2.2 Stationary Air conditioning – Large Commercial

Stationary air conditioning – large commercial accounts for 19.7 percent of the total installed stock of ODS and substitute refrigerants in the refrigeration and air conditioning sector. Among air conditioning subsectors, stationary air conditioning – large commercial accounts for 25.5 percent of the installed stock of refrigerants. Large commercial applications for stationary air conditioning include comfort cooling for larger buildings, such as offices, hotels, arenas, and more. Comfort cooling in these applications is often achieved using a chiller (e.g., centrifugal or positive displacement). In commercial applications, centrifugal chillers may more often be used for higher cooling demands, while positive displacement chillers tend to be used for smaller capacity needs, like mid- and low-rise buildings.

The most common ODS and substitute refrigerants in installed stock in stationary air conditioning – large commercial are HFC-134a (38 percent), HCFC-22 (21 percent), R-407C (16 percent), HCFC-123 (9 percent), R-410A (8 percent). The VM also shows estimates of installed stock of some lower-GWP refrigerants, including R-450A (4 percent) and R-513A (4 percent).

4.2.3 Stationary Air conditioning – Small Commercial

Stationary air conditioning – small commercial makes up the lowest percentage of the total installed stock of ODS and substitute refrigerants at 2.8 percent in the refrigeration and air conditioning sector, or 3.6 percent among air conditioning subsectors. Like the residential applications for stationary air conditioning, small commercial applications may also be self-contained or split systems. Small commercial stationary air conditioning applications may include commercial unitary air conditioning systems and packaged terminal air conditioners.

Similar to residential applications for stationary air conditioning, R-410A (92%) is the dominant type of refrigerant among installed stock of ODS and substitutes in small commercial applications. The remainder is primarily HCFC-22. Again, R-454B and HFC-32 have been emerging as possible substitutes for equipment in this sector as they are typically suitable substitutes for applications where R-410A may be used.

4.2.4 Mobile Air Conditioning

Mobile air conditioning accounts for 14.9 percent of the installed stock of ODS and substitute refrigerants in the overall refrigeration and air conditioning sector. Among air conditioning subsectors, mobile air conditioning accounts for 25.5 percent of the installed stock of refrigerants. The mobile air conditioning subsector in this analysis includes systems that are used to cool the passenger compartment of light-duty vehicles, light-duty trucks, heavy-duty vehicles, school and tour buses, transit buses, and passenger rail vehicles.

There are two refrigerants that make up essentially all of the installed stock of ODS and substitutes in mobile air conditioning: HFC-134a (71 percent) and hydrofluoroolefin (HFO)-1234yf (29 percent). All of the estimated installed stock of HFO-1234yf are in the mobile air conditioning subsector. Much of the MVAC subsector is transitioning to using HFO-1234yf, particularly for light-duty vehicles. According to the 2021 EPA Automotive Trends Report, approximately 85 percent of model year 2020 light-duty vehicles sold used HFO-1234yf and some manufacturers have implemented HFO-1234yf across their entire vehicle brands.[20]

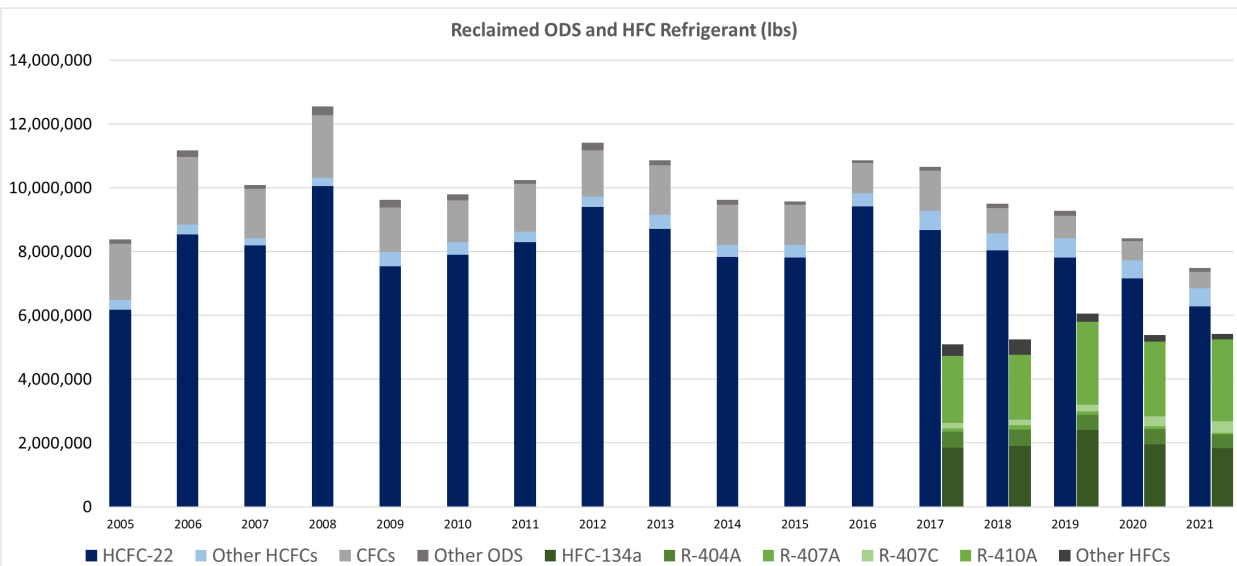
5. Reclamation Market for HFCs

This section provides information on the historical reclamation market in the United States, beginning with a section on the size of the HFC reclamation market in the recent past and present (Section 5.1). Section 5.2 describes the processes and methods of reclamation, including sources, equipment, and other aspects. Section 5.3 then presents cost drivers of reclaimed HFCs. Section 5.4 provides incentives to recover and reclaim refrigerants.

5.1 Size of the HFC Reclamation Market

Figure 4 provides the total quantities of reclaimed substances since 2000, as reported annually to EPA by reclaimers per 40 CFR 82.164(d).[21] The figure shows data for certain ODS (e.g., HCFCs, CFCs) and HFCs. ODS are shown in the stacked grey and blue columns and HFCs are shown in the stacked green columns. Reclaimers were not required to include HFC refrigerant in reports to EPA until 2017 (U.S. EPA 2016b).

Figure 4. Reclaimed ODS and HFC Refrigerants from 2000 to 2021



After a relatively consistent upward trend between 2001 and 2008, reaching a peak of 12.55 million lbs, ODS reclamation was reasonably stable between 2009 and 2017 ranging between 8.39-11.32 million lbs per year. Since 2016, ODS reclamation quantities have begun to decrease steadily by an average of 6.4% each year. HFC reclamation has remained relatively constant,

[20] EPA, 2021. The 2021 EPA Automotive Trends Report. Available at: *https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1013L1O.pdf.*

[21] Information on refrigerant reclamation trends available at *https://www.epa.gov/section608/summary-refrigerant-reclamation-trends*.

between 5.09 and 6.06 million pounds from 2017 to 2021. In 2021, the most common HFCs and blends using HFCs as refrigerants reclaimed were R-410A (2.55 million pounds) and HFC-134a (1.84 million pounds) (Table 1). R-404A (416,000 pounds) and R-407C (367,000 pounds) are also relatively commonly reclaimed as every other HFC is reclaimed in quantities that are less than 100,000 pounds each year.

Table 1. HFC Refrigerant Reclamation Totals by Year (pounds)

Refrigerant	2017	2018	2019	2020	2021
HFC-134a	1,858,132	1,910,240	2,399,952	1,956,644	1,844,793
R-404A	486,719	506,639	485,338	478,556	416,352
R-407A	111,255	143,254	105,435	87,162	60,580
R-407C	167,445	167,248	213,668	315,424	366,521
R-410A	2,103,404	2,043,667	2,596,861	2,347,000	2,550,164
Other HFCs	363,311	479,261	258,486	206,029	173,022
Total	**5,090,266**	**5,250,309**	**6,059,740**	**5,390,816**	**5,411,433**

As noted in section 2 of this report, the AIM Act assigns each regulated HFC with an exchange value. HFCs are potent greenhouse gases that have a capacity to trap hundreds to thousands times the amount of heat in the atmosphere relative to CO_2, as presented by each individual chemical's GWP.[22] GWPs can be used to compare relative warming effects of GHGs in the atmosphere using a common unit, carbon dioxide equivalent (CO_2e), and often is presented in million metric tons CO_2e ($MMTCO_2e$).

To present the data in Table 1 in $MMTCO_2e$, the totals for each refrigerant were converted from pounds using GWPs that range from 1,430 (HFC-134a) to 14,800 (HFC-23). Subsection (c) of the AIM Act currently provides the full list of exchange values for regulated HFCs. Multiplying the respective GWP by the number of pounds of each HFC yields the exchange value in pounds. To obtain $MMTCO_2e$, the total exchange value in pounds was first divided by 2,204.6 (the number of pounds in a metric ton) and then divided by one million. Table 2 presents the total estimated reclaimed HFC refrigerants in $MMTCO_2e$. EPA data indicate that the consumption of HFC refrigerants was estimated at 309 $MMTCO_2e$ for 2020 (U.S. EPA 2021a), so the reclamation market below 2 percent of the total.

[22] See 42 U.S.C. 7675(c); see also Appendix A to Part 84 - Regulated Substances. As explained in the Allocation Framework Rule (86 FR 55116), EPA has determined these are the same as the 100-year GWPs listed in the 2007 Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report.

Table 2. HFC Refrigerant Reclamation (in $MMTCO_2e$)

Refrigerant	2017	2018	2019	2020	2021
HFC-134a	1.21	1.24	1.56	1.27	1.20
R-404A	0.87	0.90	0.86	0.85	0.74
R-407A	0.11	0.14	0.10	0.08	0.06
R-407C	0.13	0.13	0.17	0.25	0.29
R-410A	1.99	1.94	2.46	2.22	2.41
Other HFCs[a]	0.59	0.77	0.37	0.32	0.28
Total	**4.89**	**5.11**	**5.52**	**4.99**	**4.99**
Percentage of 2019 reported consumption	1.6%	1.7%	1.8%	1.6%	1.6%

[a] Other HFCs were calculated in $MMTCO_2e$ using aggregated totals of each HFC reclaimed as reported during annual reporting per 40 CFR 82.164(d) and using their respective GWPs

Sources: U.S. EPA (2021b, 2022)

It is expected that the HFC reclamation market will increase in future years as more refrigeration and air conditioning equipment using HFC refrigerants reach their end-of-life, and more HFCs are potentially available for recovery and reclamation. In addition, virgin HFC supplies are restricted consistent with the AIM Act, and industry may look to reclaimed materials for servicing existing equipment. One estimate predicts that under the HFC phasedown, reclaimed HFCs will increase in sales by $0.8 billion and add almost 4,000 jobs (Inforum et al. 2019).

5.2 Reclamation Methods and Processes

In 2010, EPA commissioned an analysis of the state of the reclamation industry (Stratus Consulting 2010). For the study, several reclaimers, one industry organization, one laboratory, and four air conditioning and refrigeration equipment manufacturers were interviewed. At that time, the vast majority (approximately 80 percent) of reclaimed refrigerant was HCFC-22. Additionally, EPA interviewed reclaimers between 2018 and 2019 on the reclamation industry as a whole, their role in the reclamation industry, and the reclamation methods and processes they performed. EPA hosted a public reclamation workshop in 2021 to provide general information on the AIM Act and reclamation, as well as open discussion on preliminary questions.

The 2010 study found that the reclaimers mix-and-match quantities of refrigerant from different cylinders to produce bulk batches that meet or exceed a given overall purity level. The objective is to maximize the amount of recovered refrigerant while minimizing the energy required to return each batch to the required purity level (e.g., 99.5 percent). The study also found that reclaimers' business operations determined their reclamation methods. A small reclaimer that only processes small batches of almost pure HCFC-22 might use different processes than a large reclaimer that processes large batches of refrigerant with a higher proportion of mixed gas. For example, smaller reclaimers may rely more on "off-the-shelf" systems that have limited technical capacity and throughput. A larger reclaimer may have the ability to process a greater capacity of recovered materials and may use a more complex and/or customized system to reclaim (e.g., via distillation).

The sections below discuss the sources of recovered refrigerant (Section 5.2.1), equipment used in reclamation (Section 5.2.2), the use of virgin gas by reclaimers (Section 5.2.3), how much refrigerant they stockpile at any given time (Section 5.2.4), and the reclamation of HCFC-22 specifically (Section 5.2.5).

5.2.1 Sources of Recovered Refrigerant

Reclaimers obtain recovered HFCs for reclamation through a number of means:

- Refrigerant wholesalers or distributors that collect recovered refrigerant as a service to contractors
- Contractors/technicians who recover refrigerants and send materials to reclaimers
- Scrap metal recycling yards that recover refrigerant from small appliances and motor vehicle air conditioners before shredding
- Owner/operators of large appliances such as chillers and supermarkets. (U.S. EPA 2021c)

The 2010 study found that recovered refrigerant comes from numerous sources. Most often, reclaimers received recovered refrigerant indirectly from wholesalers who accepted cylinders as a service to technicians. Less frequently, the refrigerant came directly from technicians who dropped it off at reclaimers' facilities (Stratus Consulting 2010).

Similarly, from past interviews in 2018 and 2019, EPA understands that reclaimers may receive recovered refrigerant from a variety of locations. Based on these interviews, EPA understands that some reclaimers receive recovered refrigerant primarily from HVACR contractors and technicians (both small and large), while others primarily work with wholesalers. EPA learned that one reclaimer receives recovered HFCs from supermarkets, chillers, and ice rinks; and that another reclaimer provides reclamation/recycling as a side service for their customers.

Additionally, EPA understands that reclaimers that primarily work with wholesalers may be less aware of the original application of the recovered refrigerant. Those that recover their own materials or work closely with contractors and technicians may have more information on the original application in which the recovered refrigerant was used. For example, based on the interviews in 2018 and 2019, EPA understands that a common source of recovered HFC-134a for some reclaimers is from residential refrigerators. EPA also learned that one reclaimer that does on-site recovery maintains a database for the source of all of their recovered refrigerant.

5.2.2 Equipment Used in Reclamation

Based on the 2010 study, reclaimers first weighed the cylinder (to determine the volume of refrigerant inside) and determined the contents of each cylinder, generally using a hand-held gas analyzer (e.g., a Neutronics refrigerant analyzer). If the contents appeared to be mixed, the reclaimer sometimes used a gas chromatograph (GC) to determine the container's contents in more detail. The study found distillation to be the most common primary separation method for reclamation systems. Other methods may include adsorption/desorption, cryogenic subcooling, and other processes used to address the different specifications established in appendix A to 40 CFR part 82, subpart F (Stratus Consulting 2010).

According to the 2010 study, the typical reclamation process uses one of three pieces of equipment/technologies: a compressor for distillation, adsorbent beds for adsorption/desorption separation, or cryogenic filters to cool the refrigerant (Stratus Consulting 2010). Among these separations, distillation is the most common primary separation method for reclamation systems, and larger reclaimers are more likely to have this capability.

- ➢ In a compressor-based distillation system, a compressor is used to increase the pressure of the refrigerant to use ambient air to condense the refrigerant.

- In an adsorption/desorption system, the contaminated refrigerant enters an initial adsorption chamber where the refrigerant is adsorbed to an adsorbent bed; impurities are not adsorbed in this chamber and continue to a second chamber, from which they are discharged. After the impurities have been isolated, the refrigerant can be desorbed from the adsorption bed and collected from the system.
- In a cryogenic subcooling system, dirty refrigerant is cooled in three stages. The refrigerant is then sent through cryogenic filtration with coalescent filters to remove most small particles. In the last step, a microprocessor-controlled purge device releases the non-condensable substances.[23]

The type of equipment used in the industry can vary considerably and may depend on factors such as the size of the reclaiming operation and the amount of refrigerant that the reclaimers are handling. Smaller operations typically use "off-the-shelf" equipment, while larger operations purchase or manufacture custom equipment. Off-the-shelf equipment are pre-designed systems that are sold to be used for the reclamation of recovered refrigerants. Some systems may also recover the refrigerant and reclaim in a single pass. At the time of the 2010 study, a few off-the-shelf small-sized reclamation equipment models could be purchased for reclamation. These off-the-shelf models were limited in terms of capacity and speed (2 to 5 pounds per minute).

Based on interviews with reclaimers in 2018 and 2019, EPA understands that the technology used for reclamation has remained relatively consistent over the last ten years. There have not been major changes in reclamation technology since its inception other than new electronics and speed drives to control the reclamation systems. While the technology itself has been consistent, the increase in mixed refrigerants returned for reclamation and the use of refrigerant blends have led to more complex reclamation systems. EPA learned in those interviews that there may be additional analytics to first test the refrigerant that has been recovered in addition to testing for purity specification after processing. Mixed refrigerants and multi-component blends may require complex fractional distillation, where the recovery of single-component refrigerants (more common with ODS) could be a simpler separation process.

EPA further learned from interviews in 2018 and 2019 that refrigerants may require multiple cycles through off-the-shelf equipment to get a clean result with an acceptable refrigerant purity and may have difficulties when processing recovered refrigerants that were mixed. Large-scale operations typically do not use off-the-shelf equipment because they are not capable of handling larger volumes of refrigerants. Larger reclaimers use customized equipment that can handle more refrigerants and provide a higher degree of accuracy when processing refrigerant blends. Among the reclaimers interviewed by EPA in 2018 and 2019, many used custom-built equipment and a GC. At least two reclaimers who were interviewed have separation towers and at least two used fractional distillation to separate mixed gas.

There is some new and ongoing research into techniques for separating HFC refrigerant mixtures into their constituent refrigerants. Some of these new techniques include (Shiflett Research Group n.d.):

[23] Refer to Stratus Consulting 2010 report for more detail on these processes.

- Ionic liquids: the unique properties of ionic liquids (no measurable vapor pressure, dissolution of many organic and inorganic compounds, variable solubility of gases and liquids, and high thermal, chemical, and electrochemical stability) can be used in many separation and purification processes, such as HFC separations.
- Membranes: membranes are a barrier that selectively allows the passage of some species while preventing the passage of others. It is possible to design membranes capable of separating difficult HFC blends while potentially requiring less energy and capital.
- Porous media: porous media include nano- to micro-sized materials that can be exploited for their molecular sieve capabilities and chemical properties to conduct difficult separations of HFC mixtures.

5.2.3 Use of Virgin Gas

As noted in section 5.2.2 above, companies may use separation processes (e.g., fractional distillation) to separate out impurities and other components (e.g., oils, contaminants) from the recovered refrigerant to ensure that the refrigerant meets purity specifications, such as AHRI Standard 700-2016. Based on conversations with reclaimers, fractional distillation and other technologies allow companies to separate refrigerant blends without the use of virgin gas. However, some reclaimers note that these technologies are less economical and more energy intensive than blending (Hudson Technologies Company 2021). In fact, separation through distillation required as much as 300 times more energy than blending to process (Mandracchia 2009, Stratus Consulting 2010). Although companies can meet the purity standards through distillation by separating out other components from the desired final material, EPA's reclamation requirements under CAA section 608 do not require companies to have any particular purification technology. As the HFC phasedown progresses, access to virgin material to facilitate reclamation through blending will likely decrease. This increases the importance of separation and distillation technologies, as well as better practices during maintenance and recovery to avoid refrigerants being mixed.

Several refrigerant reclaimers submitted comments[24] to EPA during the public comment period for the proposed AIM Act Allocation Framework Rule (86 FR 27150), indicating that virgin stock was necessary to meet AHRI Standard 700-2016, particularly if blending processes were used (e.g., A-Gas, Inc. 2021, Hudson Technologies Company 2021). In their public comments, reclaimers noted that the reclamation of HFC blends may also require balancing, which necessitates the addition of one or more virgin refrigerants to the process (e.g., Golden Refrigerant 2021, Hudson Technologies Company 2021). The 2010 study highlighted that on-site distillation is not widespread across the industry and that blending may be used to meet purity specifications (Stratus Consulting 2010). EPA responded to these public comments in finalizing the Allocation Framework Rule in 2021 (86 FR 55116).

For reclaimers who do not have distillation capacity, or for which distillation is not cost-effective, the throughput of refrigerant reclamation may be proportional to the amount of virgin materials they can access and the purity of the recovered refrigerants they receive. Under the Allocation Framework Rule, reclaimers that historically imported HFCs received allowances from the general pool. EPA also established a process under which eligible entities, including but

[24] Docket ID No. EPA-HQ-OAR-2021-0044

not limited to reclaimers, could receive allowances, even if they did not historically import HFCs (i.e., new market entrants). Some reclaimers received HFC consumption allowances in 2022 and for 2023 as a result of either being previous importers of HFCs or through the new market entrant process.

From interviews with reclaimers in 2018 and 2019, EPA understands that some of the larger refrigerant reclaimers may also operate a refrigerant “banking” system, where they establish a price market for reclaimed refrigerant sold under their own brand name. In these cases, it is possible that an HFC producer or importer would be in direct competition with a reclaimer, although it is unclear the prevalence of this scenario or whether there are significant price disparities between virgin and reclaimed products for different refrigerants. For smaller refrigerant reclaimers, who function as a pass-through cost and may not directly sell their reclaimed refrigerant back to the market, there may be less likelihood of direct competition with HFC importers or producers.

5.2.4 Refrigerant Stockpile

Information on the amount and type of refrigerants stockpiled by reclaimers is limited. In the 2010 study, reclaimers noted that they did not believe stockpiling refrigerants was common. Again, reclaimers contacted for that study were running smaller operations and may not have been able to afford to keep a large inventory of refrigerants. In 2010, some reclaimers thought that there may have been stockpiling of HCFC-22 in the industry while waiting for the price to increase. Additionally, reclaimers are not required to state whether the reclaimed refrigerant came from a stockpile or from a recent field recovery (Stratus Consulting 2010). In interviews EPA had with reclaimers between 2018 and 2019, one reclaimer stated that they store some R-410A until prices are at the level at which it can profitably be reclaimed.

As described in section 2 of this report, with the exception of a small allocation of allowances for HCFC-123 and HCFC-124, whose use is limited to servicing certain equipment, production and consumption of virgin ODS, including ODS refrigerants, have been phased out in the United States. Reclamation of HCFC refrigerant does not offset the production of HCFCs but provides another way for HCFC refrigerant to enter the market. EPA's intent has always been to facilitate a smooth transition to alternatives, which includes avoiding stranding equipment that has not yet reached the end of its useful life. For example, although certain restrictions apply to the use of class II substances under section 605(a) of the CAA, used HCFC-22 that is recovered and reclaimed, or virgin material produced before the 2020 phaseout, may continue to be used for as long as it is available to service refrigeration and air-conditioning equipment existing as of January 1, 2020. In this example, the availability of reclaimed HCFC-22 refrigerant may lower the market price of HCFC-22 refrigerant because reclaimed refrigerant helps supplement a limited supply of virgin refrigerant that can no longer be produced. This would reduce the perceived notion of a shortage and reduce the incentive for largescale stockpiling. EPA learned in interviews in 2018 and 2019 that some reclaimers use a “refrigerant bank” model that allows users to return recovered refrigerant and be guaranteed a similar quantity of refrigerant for a set price. This provides security to consumers on the availability of ODS refrigerant, which can reduce the need to stockpile it.

In the public comments to the Allocation Framework Rule, one reclaimer stated that there are limited data on virgin HFC stockpiling, including the size of such stockpiles (A-Gas, Inc. 2021).

Additionally, other stakeholders asserted that although there are surplus HFC stockpiles in the marketplace, they saw no evidence of this in the market data. They said that if there were actual HFC stockpiles, they would expect companies to sell them at an incentivized price to make a large profit, which is not happening (FluroFusion Specialty Chemicals, Inc. 2021, Kivlan and Company, Inc. 2021).

5.2.5 Reclamation of HCFC-22

As a result of a variety of restrictions on HCFC-22 under title VI of the CAA, including restrictions on HCFC production, consumption, and use, stockpiles of virgin HCFC-22 refrigerant have been shrinking over the past few years. HCFC-22 that is recovered and reclaimed, along with HCFC-22 produced prior to 2020, will help meet the needs of owners of existing HCFC-22 systems. To return recovered HCFC-22 refrigerant to purity specifications, reclaimers often blend reclaimed HCFC-22 with virgin HCFC-22. In some cases, HCFC-22 that cannot be reclaimed onsite may be sent to other reclaimers that have the necessary technology to improve the purity (e.g., distillation). In interviews with reclaimers in 2018 and 2019, one reclaimer noted the last few years the price has become too expensive to use virgin HCFC-22 to return the recovered HCFC-22 to specifications through blending. According to reclaimers, some refrigerant in the market that is being reclaimed is not pure enough to process without separation. With no additional production or import, remaining stocks of virgin HCFC-22 are not available in sufficiently large quantities to blend with recovered gas, so HCFC-22 outflows are now exclusively from reclaimed refrigerant. HCFC-22 is still being reclaimed and is still expected to be reclaimed for the foreseeable future as long as there is eligible HCFC-22 equipment in the field needing refrigerant for servicing.

5.3 Reclamation Cost Drivers

Proper refrigerant reclamation incurs a variety of costs borne by various parties throughout the refrigerant value chain. During interviews with reclaimers in 2018 and 2019, EPA learned that the overall reclamation cost may include cleaning the refrigerant, mixed gas separation, laboratory testing, and repackaging, in addition to sales and overhead expenses. The following sections qualitatively describe costs borne throughout each stage of the reclamation process.

5.3.1 Recovery at End-of-Equipment Life

The reclamation process begins with contractors dispatched to site locations who recover refrigerant from decommissioned equipment. Contractors incur upfront costs for refrigerant recovery equipment, including recovery machines, refrigerant cylinders, and field tests for moisture and contamination. As refrigerant recovery takes time, there can be an opportunity cost for contractors to properly recover all refrigerants (per EPA's regulations under CAA section 608) as opposed to illegally venting refrigerant. It is unclear whether any such opportunity costs are significant compared to the overall cost of a typical installation, and whether contractors typically pass along those costs to consumers in the form of hourly rates. Contractors also often bear any costs associated with transporting refrigerants to a distributor or reclaimer site. These costs may be more pronounced in rural areas or areas with low concentrations of refrigerant-containing equipment, as more travel is required per volume of refrigerant.

In other cases, small appliances and MVAC may be disposed of by an end-user and may ultimately end up for final processing at a scrap recycler or landfill. Per regulations in 40 CFR

82.155, the final processor must properly recover any remaining refrigerant from appliances, or the final processor must receive a signed verification that the refrigerant in the appliance has been properly recovered prior to delivery. In the case where the refrigerant is not recovered prior to delivery, operators at landfills or scrap yards may encounter challenges in recovering the refrigerant due to limited training. Further, these entities may not have direct relationships with other steps of the reclamation supply chain. While the collective amount of refrigerant able to be recovered from small appliances and motor vehicle air conditioners is significant, each individual scrap recycler or landfill operator likely recovers small quantities of refrigerant, limiting the economic benefit to the individual business of recovering the refrigerants.

5.3.2 Handling before Reclamation

Typically, contractors who recover used refrigerant will return the refrigerant to a distributor or wholesaler, who in turn will aggregate the refrigerant and interact with reclaimers. In these cases, the costs for storage and management may fall on the distributor or wholesaler. Larger contractors with the capability to store and catalogue volumes of refrigerants may work directly with a refrigerant reclaimer to return recovered refrigerants and to buy back reclaimed refrigerants. In these circumstances, the contractor bears the costs associated with storage and management. As the variety of different refrigerants being reclaimed increases, it is expected that storage and management costs will also increase. These anticipated cost increases account for additional refrigerant cylinders, more complex labeling and tracking, and any special equipment or handling required for processing flammable refrigerants.

5.3.3 Reclamation Costs

Refrigerant reclaimers must make significant capital expenditures to purchase the equipment required for testing refrigerant composition, removing impurities and waste products to meet the necessary purity standards, and altering blend compositions to be within required specifications. Section 5.2.2 describes the equipment used for refrigerant reclamation in greater detail. These capital expenditures are typically amortized across the lifetime of the equipment. For higher-complexity refrigerant blends, it is likely that equipment costs are higher as there are more steps required for component separation, mixing, and testing.

There are also various operational costs for refrigerant reclamation, including electricity to the reclamation equipment as well as labor costs to run the reclamation equipment and perform quality assurance checks. Some portion of the recovered refrigerant may be lost during the reclamation process; refrigerant reclaimers may purchase quantities of virgin refrigerants to mix with reclaimed gas to achieve proper compositions. The cost of these purchases will vary depending on the quantity required and the price of the virgin refrigerant. Some refrigerant reclaimers also directly re-sell reclaimed refrigerant, in which case they assume marketing and administrative costs. In many cases, reclaimers will simply collect a pass-through toll from wholesalers to reclaim their refrigerants. In this scenario, the wholesaler will bear the costs associated with resale of the reclaimed refrigerant to equipment manufacturers and/or contractors.

Other logistical costs may also be considered as factors to reclamation, such as transporting recovered materials. It may not always be the case that when technicians recover refrigerants that they are located near a reclamation facility. The costs and time required to transport materials may be significant and possibly prohibitive depending on who in the supply chain bears the costs. Some reclaimers offer services to recover refrigerant on-site and may even offer buy-back incentives for certain types of refrigerants (e.g., Hudson Technologies Company n.d., Rapid Recovery n.d.). Even still, ready access to these services may be geographically dependent.

5.4 Reclamation Incentives

At the time of the 2010 report, many reclaimers established incentive programs to encourage technicians and wholesalers to turn in recovered HCFC-22. One reclaimer commented that EPA should be working with wholesalers to create economic incentives that would encourage technicians to return refrigerant. Reclaimers also noted that, if EPA's goal is to maximize the amount of refrigerant reentering the market, engaging technicians directly would help increase recovered quantities. They further noted that EPA could maximize the amount of refrigerant entering the market by requiring technicians to report additional information on the amount of refrigerant that the technicians recover and where the recovered refrigerant goes after it leaves the technicians (Stratus Consulting 2010).

During interviews EPA conducted with reclaimers between 2018 and 2019, the Agency learned about different incentives for HCFC-22 reclamation. EPA understands from these interviews that some reclaimers offer financial incentives and at least one does not. EPA also learned that one reclaimer offers financial incentives to wholesalers and strongly encourages them to share the incentive with their contractors. Another reclaimer has incentives that may shift over time based on prices. Further, EPA learned that reclaimers use various business models for the reclamation process. Some reclaimers operate as a "tolling" system (i.e., the entity bringing in the recovered refrigerant pays a pass-through fee to account for reclamation and disposal, and then receives a matching volume of reclaimed refrigerant available for reuse on the market). Other reclaimers operate as a "banking" system, where contractors and wholesalers deposit recovered refrigerant and retain the title to a matching volume of reclaimed refrigerant that can be withdrawn later. Reclaimers who typically sell the banked refrigerant on the open market will use their own branding, excluding patented blends.

5.4.1 Differences in Reclamation Incentive/Credit Programs

Several countries have set up refrigerant recovery and reclamation programs that establish prices and policies for incentives and credits. For example, in Australia, the industry-funded organization Reclaim Refrigerant Australia (RRA) recovers, reclaims, and destroys ODS and synthetic GHG refrigerants by placing a shared responsibility for end-of-life product management on producers or other entities in the supply chain. RRA establishes a levy system on imports for which the levies are then used to pay for rebates to refrigerant wholesalers, technicians, and contractors for recovering, handling, and returning refrigerants (RRA 2019).

The United States currently does not have a national incentive or credit-based recovery and reclamation program, such as a national refrigerant bank or specific crediting scheme for reclamation. Individual wholesalers and reclaimers that wish to offer such incentives would need to develop their own credit programs to incentivize the return of recovered refrigerant, as they may see fit. As the HVACR industry transitions to lower-GWP substitute refrigerants, it may become more difficult for individual wholesalers and reclaimers to accurately forecast prices for various refrigerants, which may reduce the feasibility of establishing incentive/credit programs for refrigerant recovery.

6. Safety of Technicians and Consumers

HVACR technicians are typically trained and, at minimum, required to have the appropriate certification under 40 CFR 82.161 for the equipment that they maintain, service, repair, or dispose of. While the process for recovering lower-GWP refrigerants will be similar to those in wide use today, technicians must be mindful of substitute refrigerants that carry flammability risks. As described in this section, the HVACR industry is currently preparing technicians to be knowledgeable of safe procedures to handle flammable refrigerants, which presents a change in historical refrigerant recovery and handling practices. Consumers are generally not involved in the refrigerant recovery process and should not experience any safety issues if technicians follow industry guidance and EPA requirements per 40 CFR Part 82 on proper recovery procedures.

Under EPA's regulations implementing CAA section 608, all persons who could reasonably be anticipated to violate the integrity of the refrigerant circuit during maintenance, service, repair, or disposal of appliances that contain ODS, as well as those containing non-exempt substitute refrigerants, such as HFCs, are required to meet certification requirements (40 CFR 82.161). Under regulations per CAA section 609, no person who repairs or services a MVAC or MVAC-like appliance may perform any service involving the refrigerant for the MVAC or MVAC-like appliance unless they properly use approved equipment and are trained and certified by an EPA-approved organization (40 CFR 82 subpart B).

Certain substitutes to HFC refrigerants, including higher flammability (e.g., A3; R-600a), lower flammability (e.g., A2L; R-454A), and higher toxicity (e.g., B2L; R-717) refrigerants, are likely to enter the market as the transition to lower-GWP refrigerants progresses. See Table 3 for the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) classification of refrigerant flammability and toxicity (ASHRAE 2019). Widespread use of A2L, A3, and B2L refrigerants may require additional training for service technicians to ensure safe handling when equipment using those refrigerants need servicing or require end-of-life recovery.

There may be other safety considerations when dealing with flammable refrigerants. EPA heard in our public workshop in 2021, that there should be considerations for the safe transport of flammable refrigerants like A2L refrigerants and treatment of these refrigerants under other regulation. For example, refrigerants that exhibit the hazardous waste characteristic of ignitibility per 40 CFR 261.21 may need to be managed as hazardous waste under the Resource Conservation and Recovery Act (RCRA).

Table 3. ASHRAE Refrigerant Designations

Higher Flammability	A3	B3
Lower Flammability	A2	B2
	A2L	B2L
No Flame Propagation	A1	B1
	Lower Toxicity	**Higher Toxicity**

Source: ASHRAE (2019)

7. Barriers and Key Challenges to Greater Refrigerant Recovery and Reclamation

There are barriers and key challenges that technicians, wholesalers, reclaimers, and other market actors have raised for consideration in order to increase the amount of refrigerant that is recovered and reclaimed for refrigeration and air conditioning systems. Barriers and challenges such as rising costs of reclaiming, market fluctuations, increased blends and mixed gases, and increased technological demands have led to a lack of incentivization to reclaim refrigerants. However, more recent price dynamics for HFCs may be changing historic trends.

7.1 Contamination and Accommodating Blends and Mixed Cylinders

From interviews with reclaimers in 2018 and 2019, EPA understands that one of the biggest challenges in the reclamation industry is dealing with mixed refrigerants or a recovery cylinder containing multiple types of refrigerants, an issue that may become more common with the increase in the variety of refrigerants being used. For example, technicians recovering refrigerant may inadvertently recover R-410A in a cylinder containing HCFC-22 or may knowingly do so if there is no other recovery cylinder available. Reclaiming mixed-refrigerant cylinders incurs increased time and difficulty to determine the precise composition of gases in the cylinder, separate the various component gases, and then return each component to the specified composition. From EPA's public workshop in 2021, the Agency understands that blends and mixed refrigerants are problematic, and that reclaimers who are unable to perform the required processing may decide to destroy the returned refrigerant rather than incurring additional costs. To ensure the maximum value for recovered refrigerants, technicians would likely have to increase the number of cylinders they carry to prevent mixing refrigerants.

Based on interviews in 2018 and 2019, EPA understands that with the HVACR industry's transition to lower-GWP substitutes, there will be a greater variety of refrigerants to the market. HVACR technicians servicing residential and light-commercial air conditioning equipment may need to carry multiple cylinders for the refrigerant used to service equipment (e.g., new) or any refrigerant that is recovered, including HCFC-22, R-410A, HFC-134a, HFC-32, and R-454B. Additionally, many lower-GWP refrigerants consist of multi-component HFC/HFO blends, which require additional steps to reach purity specifications and proper refrigerant compositions and are more difficult to separate than blends with only two components. Other lower-GWP refrigerants also carry flammability risks, which may increase costs and safety processes.

During interviews in 2018 and 2019, EPA learned of potential issues with mixed gases from the residential air conditioning sector, specifically the lack of proper maintenance or the reuse of gas from one job to the next, which leads to contamination. Further, EPA understands from these interviews that "topping-off" systems occurs when original refrigerants have not first been evacuated, which contributes to contaminated refrigerants that would be available for recovery.

Some reclaimers will blend virgin refrigerant, which can be combined with mixed recovered refrigerant, to increase the purity as a cost-effective option over the process of using a fractional distillation column. Additionally, blending uses less energy overall than other processes of separation or destruction. There have been concerns in the past that blended refrigerants could result in lower-quality refrigerants. Reclaimers have historically noted that blended refrigerants are also run through the reclamation system to remove contaminants, with the blended refrigerants' end product looking no different than other reclaimed refrigerants.

7.2 Price of Refrigerant

The costs associated with reclamation have historically been considered a barrier, with the price of refrigerants being a major factor. From interviews in 2018 and 2019, EPA learned that customers might not buy refrigerant marketed as reclaimed gas when there is virgin gas available for the same cost. However, EPA also heard that the cost of refrigerant recovery is increasing due to the advent of new blends requiring more sophisticated technologies such as fractional distillation or a GC to determine the precise compositions of recovered refrigerant blends.

Based on interviews in 2018 and 2019, EPA understands that other factors may affect the price of refrigerants as well. For example, EPA heard the view that the price of R-410A may be low because of supply from overseas. EPA also heard that market fluctuations in the price makes it difficult for reclaimers to operate profitably, and such fluctuations may be a result of various effects, including the import of refrigerants manufactured overseas into the U.S. market, court rulings, and allocation changes. As the HFC phasedown progresses, this price dynamic is expected to change, especially for high-GWP HFCs, which will likely become scarcer and/or more expensive over time. During EPA's public workshop in 2021, EPA learned that the price of HFC-134a has increased by as much as 77%.

7.3 Market Demand for Reclaimed Refrigerant

In general, EPA understands that reclaimers process recovered refrigerant that they can profitably sell back into the market. Except in situations where the production and import of virgin refrigerant are prohibited (e.g., HCFC-22), though certain exceptions may apply, there is little differentiation between virgin and reclaimed refrigerants for sale in the market. Technicians and other consumers have historically purchased refrigerant based on the lowest cost and/or availability and have not sought out reclaimed refrigerant specifically. From interviews in 2018 and 2019, EPA understands that wholesalers or technicians might not buy reclaimed refrigerant when they can buy virgin material for the same price.

7.4 Release Events over Useful Life and Disposal of Equipment

Although there are statutory and regulatory requirements under title VI of the CAA designed to restricting certain releases of refrigerants, refrigerant release continues to pose a challenge to greater refrigerant recovery as it results in less refrigerant that can be recovered from equipment. Refrigerant release for refrigeration and air conditioning equipment can occur at several points throughout the useful life of the equipment, including installation, servicing, operation, and end-of-life disposal. The types of release may vary by equipment type, operating environments, and site-specific situations. Leak rates in refrigeration systems may vary depending on a variety of factors, including the application of the equipment and the charge size of refrigerant in the equipment. For example in commercial refrigeration equipment, leak rates may vary between 15.6-24.2% (CARB 2020).

7.4.1 Installation and Servicing Leakage

For some new equipment, the manufacturer may charge (i.e., fill) the equipment with refrigerant at the factory, while other new equipment requires field charging with refrigerant during installation. Technicians sometimes add refrigerant to an existing system during periodic maintenance to replace the refrigerant lost due to leakage (e.g., "topping off"). Although a very small amount of refrigerant may leak in each of these situations, technicians following proper procedures per regulations under CAA sections 608 and 609 and the manufacturers' instructions can prevent significant leakage events during installation and servicing. For example, EPA's regulations under CAA section 608 include requirements for technicians to evacuate the refrigerant charge when opening an appliance to repair certain components in the refrigerant circuit (though certain exceptions apply). Per 40 CFR 82.156(h), the recovered refrigerant may be returned, without recycling or reclaiming, to the same appliance or another appliance of the same owner, unless the appliance is an MVAC or MVAC-like appliance. Under subpart F, if the recovered refrigerant changes ownership, it must be reclaimed by an EPA certified reclaimer (40 CFR 82.154(d)).

7.4.2 Operation Leakage

A small amount of refrigerant leaks over time through small cracks in the system piping and subassemblies. If a leak is detected, a service technician may (or in some situations must[25]) repair the leak and replace the lost refrigerant. Typically, smaller self-contained systems (e.g., residential refrigerators, window air conditioners, commercial reach-in refrigerators) have low annual leak rates because these products receive refrigerant charge in the factory and do not require any refrigerant line connections in the field. Refrigeration and air conditioning equipment that require field installation of refrigerant lines and refrigerant charging, such as residential split-system air conditioners and commercial remote condensing and rack refrigeration systems, typically have higher annual leak rates due to the higher number of field-installed couplings and potentially greater exposure to vibration, temperature variations, corrosion, etc., which can create leaks.

7.4.3 End-of-Life Leakage

Refrigeration and air conditioning equipment eventually reach the end of their useful life through either gradual or catastrophic failure of key components. The full refrigerant charge could be released if the system is physically damaged or if the system is not properly disposed of at the end of its useful life. Self-contained systems can be transported to off-site recyclers that will then recover the remaining refrigerant before disposal of the appliance. Split-system and remote condensing products as well as larger self-contained systems (e.g., chillers) will generally have the refrigerant recovered on-site by technicians before equipment disposal. Regulations under CAA sections 608 and 609 require proper refrigerant recovery either on- or off-site. Feedback from industry is that refrigerant recovery at the end of life, while legally required, is not always practiced in the field, and that variance in actual practice could result in additional releases to the atmosphere at equipment end-of-life. Anecdotal feedback is that recovery is less common from residential and light commercial air conditioning equipment than from commercial refrigeration and larger air conditioning equipment.

7.5 Technician Outreach and Cost Penalty for Returning Refrigerant

Per EPA regulations under section 608 of the CAA at 40 CFR 82.156, with certain limited exceptions, before opening or disposing of an appliance technicians must ensure refrigerant is

[25] If the leak occurs in an appliance that uses an ODS refrigerant and that has a full charge of 50 or more pounds, and if the leak exceeds the applicable leak rate threshold, the regulatory requirements under 40 CFR 82.157, including leak repair requirements, would be triggered.

evacuated from air conditioning or refrigeration equipment to established vacuum levels. Similar requirements apply to persons opening or disposing of small appliances. These recovery requirements may cause technicians to spend time to achieve compliance. As technicians who recover refrigerant are often servicing many systems each day, the recovered refrigerant can be exposed to a range of contaminants on a daily basis. The refrigerant recovered from a given system may be contaminated or mixed with other refrigerants from previous servicing and maintenance by other technicians.

Although some technicians may use different recovery cylinders for different types of refrigerants, there is still the potential for cross-contamination from using the same cylinder to service different refrigerants or using the same hose to hook up to different cylinders. In EPA's interviews with reclaimers in 2018 and 2019, reclaimers noted that there are technology solutions on the horizon, including digital gauges and gauges built into systems, but it could take decades for these to become widely adopted. In conversations with smaller reclaiming operations, it was found that most reclaimers emphasized the importance of outreach to technicians as the fastest way to increase the amount of refrigerant reclaimed, reduce emissions, and reduce contamination (Stratus Consulting 2010).

Technicians are often not made aware when refrigeration and air conditioning equipment has been converted to a new refrigerant, which can lead to contamination. In interviews in 2018 and 2019, EPA learned that, if a contractor is consistently returning mixed gas for reclamation, the reclaimers test it each time and some may start charging costs for disposal, if needed. EPA understands that it may be difficult to pass these costs on to customers since one cylinder can come from multiple jobs and it is not always easy to locate the technician for additional information. If technicians return a contaminated cylinder to a wholesaler or reclaimer, they may be charged a penalty for destruction. In addition, as refrigerants transition, technicians may need to purchase new recovery machines or equipment. For example, recovery machines or equipment that are rated for A2L refrigerants that carry flammability risks may be needed.

7.6 Advanced Technology Requirements and Need for Technical Training

EPA learned during interviews in 2018 and 2019 that there are more obstacles than opportunities for reclaimers to turn a profit due to technical and business challenges. Further, EPA learned that patents may pose a challenge as reclaimers said they cannot bring blends up to specifications without approval from the patent holder and patent infringement for newer blends presents concern as there may be legal questions as to whether the reclaimer can sell the blend.

From interviews in 2018 and 2019 EPA understands that reclaimers also may face increased costs to invest in technology to separate gases. Advances in the reclamation technologies, such as fractional distillation or a GC, are needed to manage mixed gases. Flammable refrigerants largely require parallel cylinders, testing, and reclamation equipment.

7.7 Destruction of HFCs

Based on interviews in 2018 and 2019, EPA understands that reclaimers often contract out destruction of waste oils, contaminants, and impurities to a waste management company. When determining whether the material can be reclaimed, reclaimers may look at the laboratory data to see what the make-up of the mixed gas is, the level of contamination, and what it would take to separate it to determine whether it is worth the energy and time to reclaim. When determining what can be reclaimed or destroyed, the contamination or the number of gases are important but these are not the only considerations. Some gases are much harder to separate because of their boiling points, among other factors. Mixed gases that cannot be reclaimed may be sent for destruction.

According to some reclaimers interviewed, EPA learned that if highly mixed refrigerants are sent for destruction, the destruction facility may charge a fee and the reclaimer may pass that fee on to the wholesaler or technician. Fees vary based on the refrigerant blend. For example, a refrigerant such as R-410A requires a small fee for disposal, while highly mixed refrigerants with unique compositions typically require a much higher fee. For example, a blend with mixed HCFC-22 could have a buy back offered for which the customer would be paid for the portion of the blend that is HCFC-22 to offset some of the disposal cost of the other contents.

In the 2010 study, when reclaimers were asked whether there were specific industry standards or best practices that could help reduce the amount of refrigerant that must be destroyed or fractionally distilled, they generally responded that outreach to technicians is the best approach to reducing the need to use these methods. They noted that the reason for using these methods is often that the refrigerant is mixed and of a purity that is too low for simple distillation methods, which is typically assumed to be the result of technician negligence or accidents (Stratus Consulting 2010).

8. References

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Appendix A: Subsection (h) of the AIM Act

42 U.S.C. 7675: American innovation and manufacturing

(h) Management of regulated substances

(1) In general

For purposes of maximizing reclaiming and minimizing the release of a regulated substance from equipment and ensuring the safety of technicians and consumers, the Administrator shall promulgate regulations to control, where appropriate, any practice, process, or activity regarding the servicing, repair, disposal, or installation of equipment (including requiring, where appropriate, that any such servicing, repair, disposal, or installation be performed by a trained technician meeting minimum standards, as determined by the Administrator) that involves-

(A) a regulated substance;

(B) a substitute for a regulated substance;

(C) the reclaiming of a regulated substance used as a refrigerant; or

(D) the reclaiming of a substitute for a regulated substance used as a refrigerant.

(2) Reclaiming

(A) In general

In carrying out this section, the Administrator shall consider the use of authority available to the Administrator under this section to increase opportunities for the reclaiming of regulated substances used as refrigerants.

(B) Recovery

A regulated substance used as a refrigerant that is recovered shall be reclaimed before the regulated substance is sold or transferred to a new owner, except where the recovered regulated substance is sold or transferred to a new owner solely for the purposes of being reclaimed or destroyed.

(3) Coordination

In promulgating regulations to carry out this subsection, the Administrator may coordinate those regulations with any other regulations promulgated by the Administrator that involve-

(A) the same or a similar practice, process, or activity regarding the servicing, repair, disposal, or installation of equipment; or

(B) reclaiming.

(4) Inapplicability

No regulation promulgated pursuant to this subsection shall apply to a regulated substance or a substitute for a regulated substance that is contained in a foam.

(5) Small business grants

(A) Definition of small business concern

In this paragraph, the term "small business concern" has the same meaning as in section 632 of title 15.

(B) Establishment

Subject to the availability of appropriations, the Administrator shall establish a grant program to award grants to small business concerns for the purchase of new specialized equipment for the recycling, recovery, or reclamation of a substitute for a regulated substance, including the purchase of approved refrigerant recycling equipment (as defined in section 609(b) of the Clean Air Act (42 U.S.C. 7671h(b))) for recycling, recovery, or reclamation in the service or repair of motor vehicle air conditioning systems.

(C) Matching funds

The non-Federal share of a project carried out with a grant under this paragraph shall be not less than 25 percent.

(D) Authorization of appropriations

There is authorized to be appropriated to carry out this paragraph $5,000,000 for each of fiscal years 2021 through 2023.