THE U.S. PHASEOUT OF HCFCS:

PROJECTED SERVICING NEEDS IN THE U.S. AIR-CONDITIONING AND REFRIGERATION SECTOR

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REVISED DRAFT REPORT, JUNE 2008

This report presents estimates of the projected quantity of HCFC-22 (also recognized by the American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE) designation, R-22) needed to service air-conditioning and refrigeration equipment and the anticipated installed base of such equipment beyond 2010 in the United States. The objective of this analysis is to provide a resource to assist in the allocation of future HCFC consumption allowances. The analyses presented in this report were first made available for comment in a Notice of Data Availability (NODA, 70 FR 67172) and request for comment issued on November 4, 2005. Revisions to the analysis were made in September 2006 and a revised report was made available for comment at a stakeholder meeting held in Washington DC, at EPA Headquarters. Revisions to the report provided here reflect comments received after September 29, 2006, and include other updates to the modeling and analysis with additional projection scenarios.

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Executive Summary

Hydrochlorofluorocarbons (HCFCs) are a class of chemical compounds that deplete the stratospheric ozone layer, leading to overexposure to ultraviolet (UV) radiation at the earth's surface. Excessive UV radiation damages biological systems and causes malignant melanoma and other skin cancers, cataracts, and harm to certain crops and marine organisms. Reversing the course of stratospheric ozone depletion is crucial to human and environmental health worldwide. As a Party to the Montreal Protocol, the United States is subject to a cap on the consumption of HCFCs—defined as production[1] plus imports minus exports—in an international effort to protect the stratospheric ozone layer (UNEP 2000). Specifically, the United States is obligated to phase out production and consumption of HCFCs by 2030 by making graduated reductions in HCFC consumption by certain dates. In order to meet these interim reduction targets, the U.S. Environmental Protection Agency (EPA) established a schedule for the phaseout of HCFCs starting with those with the highest ozone depletion potentials (ODPs), namely HCFC-141b, HCFC-142b, and HCFC-22.[2] Consumption of HCFC-141b was phased out in 2003. The next phaseout milestone occurs on January 1, 2010, when the production and import of HCFC-142b and HCFC-22 (unless for use in equipment manufactured prior to January 1, 2010) will cease. Under the restrictions, between 2010 and 2020, both the production and import of HCFC-142b and HCFC-22 will still be permitted to service existing equipment.

In the United States and worldwide, the primary use of HCFC-22 is as a refrigerant, whereas the primary use of HCFC-142b is as a blowing agent in the foam industry (UNEP 2003a). While HCFC-142b is also blended with other constituents to form refrigerant blends, its use in the U.S. air-conditioning (AC) and refrigeration industry is minimal, and therefore servicing demand for R-142b[3] is not presented in this analysis. However, a brief section discussing the basic needs for HCFC-142b and other HCFCs is provided. Estimated consumption of R-22 in the U.S. air-conditioning (AC) and refrigeration industry currently totals approximately 110,000 metric tons in 2007and is by far the largest use of an HCFC by any U.S. industry (EPA 2007a). For this reason, and because the allowable servicing of existing equipment between 2010 and 2020 is applicable primarily to the AC and refrigeration industry, this report presents estimates of the projected quantity of R-22 needed to service AC and refrigeration equipment and the anticipated installed base of such equipment beyond 2010. In quantifying future servicing needs and evaluating how these needs can be met, the objective of this analysis is to provide a resource to assist in the allocation of future production and consumption allowances.

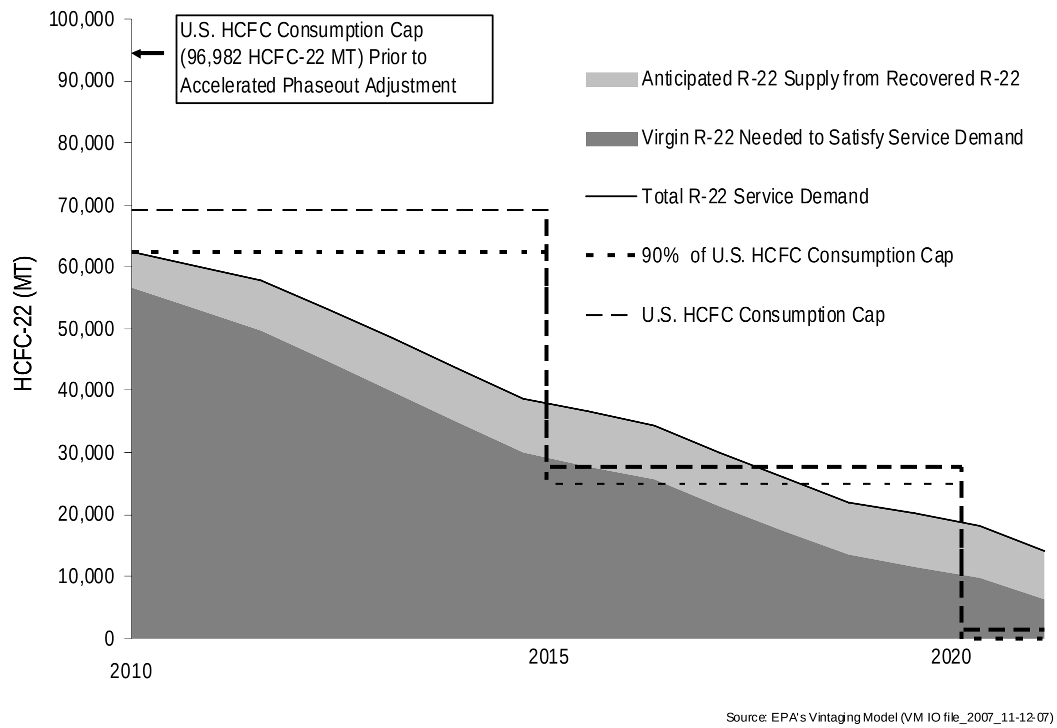
This report examines the primary sources of R-22 to service the installed base of equipment after 2010, including (1) the amounts recovered from equipment that are subsequently recycled or reclaimed for reuse (2) the virgin production and import quantities (i.e., consumption) limited under the Montreal Protocol that may be distributed by EPA through an allowance system.[4] A total of five supply and demand scenarios were analyzed that differ by the quantity of R-22 recovered from equipment at the end-of-life and available to service other equipment still in use. Recovery scenarios representing 10, 15, 20, 50 and 75 percent are presented. For example, "Scenario 10" assumes that 10 percent of refrigerant is recovered and available for reuse at equipment end-of-life.

In September 2007, the United States and other Parties to the Montreal Protocol agreed to strengthen the phaseout schedule for HCFCs in both developed and developing countries. One result of this agreement is that in 2010, the U.S. HCFC production and consumption must be reduced by 75 percent of their respective 1989 baselines. The 2010 production cap represents a new commitment, whereas for the 2010 consumption cap, the agreement results in an additional 10 percent of a reduction than the previous phaseout commitment. The scenarios in this report are analyzed in comparison to the adjusted 2010 reduction step. Figure ES-1 summarizes the supply and demand scenario representing a recovery rate of

[1] Under the Montreal Protocol, production is defined as "the amount of controlled substances produced, minus the amount destroyed…and minus the amount entirely used as feedstock in the manufacture of other chemicals. The amount recycled and reused is not to be considered as production" (UNEP 2000).
[2] An ODP value is a measure of a chemical's relative ability to deplete ozone. A reference level of 1.0 is assigned to CFC-11.
[3] The nomenclature 'R' is typically used to designate chemical compounds used as a refrigerant. Hence, R-22 is synonymous with the use of HCFC-22 as a refrigerant, R-142b with the use of HCFC-142b as a refrigerant, etc.
[4] The import of used R-22 as approved by EPA is another potential source; however, this source is not included in the projections of this analysis.

20 percent of HCFCs from equipment at the end-of-life, in comparison to two theoretical allocations of the U.S. HCFC consumption cap in 2010 and 2015: in the first allocation, it is assumed that 100 percent of the 2010 HCFC cap will be assigned to R-22; in the second, only a portion (i.e., 90 percent) is assigned to R-22, with the remainder set aside to allocate to other HCFCs and/or as a buffer to ensure U.S. compliance with its agreements.

Figure ES-1: Total Projected R-22 Servicing Demand, Recovery Scenario 20[a,b]



[a] Potential consumption cap allocations expressed in R-22 un-weighted metric tons (calculated using an ODP of 0.055 for HCFC-22).
[b] In 2020, a cap equal to 0.5 percent of the U.S. consumption baseline remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining baseline to R-22.

In 2010, EPA can allocate consumption allowances for no more than 3,810 ODP-weighted metric tons. The quantity of 3,810 ODP-weighted metric tons equates to 69,273 metric tons of HCFC-22. This analysis projects that HCFC-22 demand in 2010 will reach approximately 62,500 metric tons (equivalent to 3,438 ODP-weighted metric tons). The analysis demonstrates that without considering the potential need to reserve a portion of the total ODP-weighted cap for other HCFCs (e.g., HCFC-123) it is possible to meet the projected servicing needs for HCFC-22 in 2010. The 3,438 ODP-weighted metric ton demand is approximately 372 ODP-weighted tons below the cap in 2010. As shown in Figure ES-1, the AC and refrigeration industry may face shortage risks starting in 2015 if enough refrigerant is not recovered and reused.[5] However, under scenarios with higher refrigerant recovery, supplies are projected to satisfy future R-22 servicing needs using both recovered refrigerant and limited amounts of virgin refrigerant. Therefore, encouraging the adoption of practices to recover used refrigerant from converted or retired equipment to be returned to the supply chain is necessary to avoid R-22 supply shortfalls within the AC and refrigeration industry.

In addition to recovery practices, several other factors also influence which R-22 demand scenario is more likely. For example, with approximately 150 million AC and refrigeration units projected to be in use in 2010, the sooner new equipment transitions to alternative refrigerants, the better the chance for an adequate R-22 supply to satisfy the forecasted demand. This report explores the following market trends and how they may influence future R-22 servicing demand and available supply estimates, including:

[5] Recovered refrigerant may be recycled and reused in the same owner's equipment; however, if the refrigerant will be used in equipment with different ownership or sold to a new owner, it must first be reclaimed by an EPA-certified refrigerant reclaimer.

- the rate of market transition to alternative refrigerants in the United States;
- R-22 cost;
- assumed equipment leak and servicing loss rates;
- levels of refrigerant recovery for reuse, reclamation, and/or banking; and
- levels of imports of used R-22.

The analysis presented in this report uses EPA's Vintaging Model (EPA 2007a) in conjunction with industry collaboration to inform the quantitative estimates on projected servicing needs. The factors listed above influence supply and demand and are addressed in the quantitative analysis with the exception of R-22 cost and refrigerant banking.

This report provides the basis for further collaboration between EPA and the AC and refrigeration community to ensure that supplies (through reuse) are increased in order to continue to service equipment and achieve the next HCFC phaseout targets without refrigerant shortages.

1. Background: The U.S. HCFC Phaseout Schedule

Title VI of the 1990 Clean Air Act Amendments (CAAA) mandates the development and implementation of regulations to protect the stratospheric ozone layer and ensure U.S. compliance with the *Montreal Protocol on Substances that Deplete the Ozone Layer* (the Protocol). Under the Protocol, the United States and other signatories are obligated to achieve progress toward the total phaseout of the consumption and production of HCFCs, which are ozone-depleting substances (ODS) and have been widely used as refrigerants, solvents, foam blowing agents, and fire suppressants.[6] Consumption is defined as production plus imports minus exports; production is defined as the manufacture of a controlled substance minus amounts destroyed and amounts completely used as feedstock in the manufacture of other chemicals and does not include amounts reused or recycled (UNEP 2000).

In September 2007, the nineteenth Meeting of the Parties to the Montreal Protocol (MOP-19) was held in Montreal, Canada, marking the 20th anniversary of the signing of the Protocol. At the conclusion of the meeting, the Parties agreed upon a strengthened phaseout of HCFCs. The adjustments call for Article 2 countries—the Protocol's identifying term for developed countries—to reduce HCFC consumption from baseline amounts by 75 percent by 2010, 90 percent by 2015, and 99.5 percent by 2020—allowing for 0.5 percent of the baseline for annual servicing over the period 2020-2030.[7] Previously, the 2010 reduction step was 65 percent. The Montreal Adjustment also provides, for the first time, a graduated step-down in HCFC production—a reduction of 75 percent from baseline by 2010, by 90 percent by 2015, by 99.5 percent by 2020 and 100 percent by 2030 (i.e., identical to the graduated step-down in HCFC consumption). Previously the Montreal Protocol had capped, but not provided reductions for, HCFC production.

Table 1-1 presents the HCFC consumption baseline and the graduated reductions (caps) to allowable HCFC consumption for the United States (and all Article 2 countries). The first HCFC phaseout milestone was in 1996, when the HCFC consumption baseline level was established at 1989 ozone-depletion potential (ODP)-weighted HCFC consumption levels plus 2.8 percent of the ODP-weighted 1989 chlorofluorocarbon (CFC) consumption. The second phaseout milestone occurred on January 1, 2004, when HCFC consumption limits were reduced by 35 percent of the above baseline, which will be followed by a 75 percent reduction in 2010, a 90 percent reduction in 2015, a 99.5 percent reduction in 2020, and a complete phaseout of HCFC production and consumption in 2030.

Table 1-1. U.S. HCFC Consumption Phaseout Targets Under the Montreal Protocol

Date	Consumption Cap	ODP Weighted Quantity (ODP-weighted Metric Tons[b])	Quantity Expressed in R-22 Metric Tons[a]
Jan 1, 1996	Consumption baseline at 2.8% of the 1989 ODP-weighted CFC consumption plus 100% of the 1989 ODP-weighted HCFC consumption	15,240	277,091
Jan 1, 2004	35% reduction of the baseline	9,906	180,109
Jan 1, 2010	75% reduction of the baseline	3,810	69,273
Jan 1, 2015	90% reduction of the baseline	1,524	27,709
Jan 1, 2020	99.5% reduction of the baseline	76.2	0 [c]
Jan 1, 2030	100% reduction of the baseline	0	0

[a]Calculated using an ODP of 0.055 for HCFC-22.
[b]An ODP-weighted metric ton takes into account each ODS' relative contribution to ozone depletion. One metric ton equals approximately 2,204 pounds.
[c]In 2020, 0.5 percent of the U.S. consumption baseline remains, but the U.S. phaseout schedule prevents any allocation to R-22.

Table 1-2 details the U.S. phaseout schedule for HCFCs established under the 1990 CAAA to comply

[6] The production and import of other ODS used by these industries, including chlorofluorocarbons, carbon tetrachloride, and methyl chloroform, were phased out in 1996 – halons in 1994 (with limited exemptions).
[7] Article 5 countries—the Protocol's identifying term for developing countries—still follow a later phaseout schedule than Article 2 countries but are now subject to reduction steps of 10 percent by 2015, 35 percent by 2020, 67.5 percent by 2025 and allowing for servicing an annual average of 2.5 percent from 2030-2040.

with the targets set by the Montreal Protocol (as presented in Table 1-2). As shown, the production and import of HCFC-141b, the HCFC with the highest ODP, was banned with limited exemptions beginning January 1, 2003. Also beginning in 2003, an allowance system was established to control the U.S. production and consumption (including import and export) of HCFCs and to apportion consumption allowances amongst HCFCs. An allowance is the privilege for the allowance holder to produce and/or import a quantity on an annual basis limited to the allowance granted. Production and consumption allowances for HCFC-141b (for limited exemptions), HCFC-22, and HCFC-142b were authorized and distributed (on a kilogram basis) to certain companies (EPA 2003a).[8] Therefore, as of 2003, only those companies with allowances were allowed to produce and/or import these HCFCs.

Table 1-2: U.S. HCFC Phaseout Schedule Mandated Under the 1990 CAAA (to Comply with the Protocol)

Date	Restriction
Jan 1, 2003	• Ban on production and import of HCFC-141b
Jan 1, 2010	• Ban on production and import of HCFC-22 and HCFC-142b except for on-going servicing needs in equipment manufactured before January 1, 2010.[a]
Jan 1, 2015	• Ban on introduction into interstate commerce or use of HCFCs except where the HCFCs are used as a refrigerant in equipment manufactured prior to January 1, 2020.[a] • Ban on production or import of HCFCs except where the HCFCs are used as a refrigerant in equipment manufactured prior to January 1, 2020.[a]
Jan 1, 2020	• Ban on remaining production and import of HCFC-22 and HCFC-142b.[a]
Jan 1, 2030	• Ban on remaining production and import of all other HCFCs.[a]

[a]Certain additional exemptions apply, including exemptions for (1) HCFCs used in processes resulting in their transformation or destruction, or (2) pre-authorized import of HCFCs that are recovered and either recycled or reclaimed.
Source: EPA (2003a); EPA (2007b).

Beginning January 1, 2010, U.S. production and import of HCFC-142b and HCFC-22 (unless for use in equipment manufactured prior to January 1, 2010 and where additional exemptions apply) will cease. The final phaseout for HCFC-22 and HCFC-142b is on January 1, 2020, and for all HCFCs on January 1, 2030. Production and consumption allowances must be granted under the allowance system. The U.S. Environmental Protection Agency (EPA) will evaluate the amount of HCFC-22 and HCFC-142b necessary for servicing as well as the need for other HCFCs to ensure that the actual permitted level for all HCFCs does not exceed the U.S.'s international obligation to reduce the production and consumption levels to 75 percent below the respective baseline levels. In addition, EPA will consider the amount of HCFC-22 and HCFC-142b to allow, ensuring that the level will be suitable solely to meet servicing needs of existing equipment.

1.1 Report Objective

The objective of this report is to present quantitative estimates of the projected amount of (a) units of equipment using HCFCs beyond 2010 in the United States and (b) HCFCs needed to service equipment beyond 2010 in the United States. It estimates R-22 consumption needs for air-conditioning (AC) and refrigeration equipment (the largest HCFC market and the largest industry sector using HCFCs) that will be in use after 2010 and possible future scenarios to meet those needs. Estimates of HCFC-142b and other HCFCs are explored in a limited manner in this analysis. Estimates presented in this report will aid EPA in allocating future allowances. The remainder of the report is organized as follows:

- Section 2 provides a brief overview of the methodology used to project servicing scenarios.
- Section 3 provides an overview of HCFC use in the United States, including projected demand of HCFCs, and an overview of the HCFC demand (other than HCFC-22) by end-use sectors.
- Section 4 provides three projected scenarios recovery and resulting R-22 consumption needs.
- Section 5 summarizes the key findings of the analysis.
- Appendix A presents further information on the projection methodology and its limitations.

[8] The production of one kilogram of HCFC requires the expenditure of one production allowance and one consumption allowance. The import of one kilogram of HCFC requires the expenditure of one consumption allowance. While the import of *used* HCFCs does not require the expenditure of allowances, it does require petition approval by EPA; see Section 4.2.1 for more detail.

- Appendix B provides AC and refrigeration projections by end-use.
- Appendix C provides estimates of R-22 consumption needs based on projected minimum and maximum recovery rates of R-22 for servicing equipment.

2. Methodology Overview

EPA's Vintaging Model was the primary tool used to launch the analysis and form the basis for quantitative estimates of current and projected HCFC consumption. The Vintaging Model estimates the annual chemical emissions from industry sectors that have historically used ODS, including AC, refrigeration, foams, solvents, aerosols, and fire protection. Within these industry sectors, there are over 50 independently modeled end-uses. The model uses information on the market size and growth for each of the end-uses, as well as a history and projections of the market transition from ODS to alternatives. As ODS are phased out, a percentage of the market share originally filled by the ODS is allocated to each of its substitutes. The model tracks emissions of annual "vintages" of new equipment that enter into operation by incorporating information on estimates of the quantity of equipment or products sold, serviced, and retired or converted each year, and the quantity of the compound required to manufacture, charge, and/or maintain the equipment. EPA's Vintaging Model makes use of this market information to build an annual inventory of in-use stocks of equipment and the ODS refrigerant and non-ODS substitutes in each of the end-uses.

According to EPA's Vintaging Model, the AC and refrigeration industry currently represents 97 percent (by mass) of total HCFC-22 consumption and 88 percent (by mass) of total HCFC consumption. Other HCFCs are explored in a limited manner (Section 3) based on the Vintaging Model and industry analysis.

Appendix A includes a discussion of the assumptions used to develop the supply and demand estimates presented in this report and the limitations and caveats inherent in the analysis. Having established initial estimates, EPA contacted a limited number of industry experts were then contacted to corroborate the findings and market dynamics affecting the servicing needs of the AC and refrigeration industry after 2010. Experts included those from the Association of Home Appliance Manufacturers (AHAM); Air-Conditioning, Heating, and Refrigeration Institute (AHRI); Carrier Corporation; Heating, Air-Conditioning & Refrigeration Distributors International (HARDI); Hill Phoenix; Honeywell; a major supermarket chain; and Johnson Controls. EPA used the informal discussions to confirm or modify preliminary estimates obtained from EPA's Vintaging Model for this analysis.

On November 4, 2005, EPA made the preliminary draft version of this report available for comment in a Notice of Data Availability (NODA, 70 FR 67172). EPA received five comments, which are available at EPA's electronic docket at www.regulations.gov (Docket ID number, EPA-HQ-OAR-2003-0130, Dupont 2005, National Refrigerants, Inc. 2006, Honeywell 2006, The Alliance for Responsible Atmospheric Policy 2006, CFC Refimax 2006). Among the comments received, two commenters stated that the overall projected demand of R-22 for servicing AC and refrigeration equipment is reasonable; however, all commenters expressed concern regarding the projections of the supply of R-22 recovered from equipment and subsequently recycled, or reclaimed for reuse that can satisfy future demand. One commenter indicated that the existing business model for R-22 recovery does not encourage the conservation efforts required to meet the scenario presented in the preliminary draft report, nor would the current collection and processing infrastructure support projections of the recovered supply. In response, EPA used the Vintaging Model to test whether demand might exceed supply under some circumstances. EPA developed two scenarios of consumption needs for R-22 were developed based on industry input on the 2005 draft report, which only looked at one scenario.

On September 29, 2006, EPA's Stratospheric Protection Division held a meeting for HCFC stakeholders regarding the next major milestones in the HCFC phaseout. A September 2006 version of this report was issued at that time. EPA has received comments on the report as well as options for a future rulemaking to allocate HCFCs for the control periods of 2010-2014. The version of the report presented here takes into account the most recent set of comments from stakeholders and also provides an updated set of analyses based on the most recent Vintaging Model output. Specifically, while the September 2006 report presented two projection scenarios of the supply of recovered/reclaimed R-22 that can satisfy future demand ("recovery rate"), this version of the report includes the estimates of a recovery rate of 15, 20, and 75 percent in addition to updating the previous scenarios of 10 and 50 percent. Scenarios of 15, 20, and 50 percent recovery rates are closely examined in the report; while Scenarios for 10 and 75 percent are presented in Appendix C.

3. Overview of HCFC Use in the United States

HCFCs have a variety of applications in the foam, aerosol, solvent cleaning, fire protection, and sterilization industry sectors; however, their largest presence is in the AC and refrigeration industries. Although the Montreal Protocol has identified a number of HCFCs under Article 2F, only those listed in Box 3-1are consumed in significant quantities in the United States.

Box 3-1: Summary of Common HCFCs and their End-Use Applications

- *HCFC-141b* –historically used as a blowing agent in rigid polyurethane foams and integral skim foams and in aerosol solvent cleaning applications. Phased out in 2003; however, existing stockpiles and amounts produced under an exemption for specific applications are allowed.
- *HCFC-22* - used as a refrigerant in several applications such as unitary air conditioners, cold storage, retail food refrigeration equipment, chillers, and industrial process refrigeration; see Section 4 for further information. Also used (in smaller quantities) as a blowing agent for certain foam applications.
- *HCFC-123* - used in centrifugal chillers and portable fire extinguishers.
- *HCFC-124* - used in some sterilant mixtures and as a mixture component in some CFC-12 drop-in replacements. Replaces CFC-114 in some heat pumps and special air conditioning equipment.
- *HCFC-142b* - used as a blowing agent in extruded polystyrene boardstock. Also used in small quantities in refrigerant blends as a retrofit refrigerant for applications such as motor vehicle ACs that previously used CFC-12.
- *HCFC-225ca/cb* - used as a solvent, an aerosol solvent, and in small quantities in the adhesives, coatings, and inks sector. HCFC-225 ca/cb is a mixture of the two isomers HCFC-225ca and HCFC-225cb typically in a 45/55% by weight ratio.
- *HCFC-21* – used as a refrigerant in the cooling loops of NASA's Space Shuttle fleet.

Table 3-1. HCFC Atmospheric Lifetime (Years) and Ozone Depletion Potential

HCFC	CAS Number	Atmospheric Lifetime (years)	ODP[a]
HCFC-141b (CH_3CFCl_2)	1717-00-6	9.2	0.11
HCFC-142b (CH_3CF_2Cl)	75-68-3	17.9	0.065
HCFC-22 (CHF_2Cl)	75-45-6	12.0	0.055
HCFC-21 ($CHFCl_2$)	75-43-4	1.7	0.04
HCFC-225cb (CF_2ClCF_2CHClF)	507-55-1	6.2	0.033
HCFC-225ca ($CF_3CF_2CHCl_2$)	422-56-0	2.1	0.025
HCFC-124 (CF_3CHFCl)	2837-89-0	5.8	0.022
HCFC-123 ($CHCl_2CF_3$)	306-83-2	1.3	0.02

[a]ODP values are taken from the Montreal Protocol (UNEP 2003b).

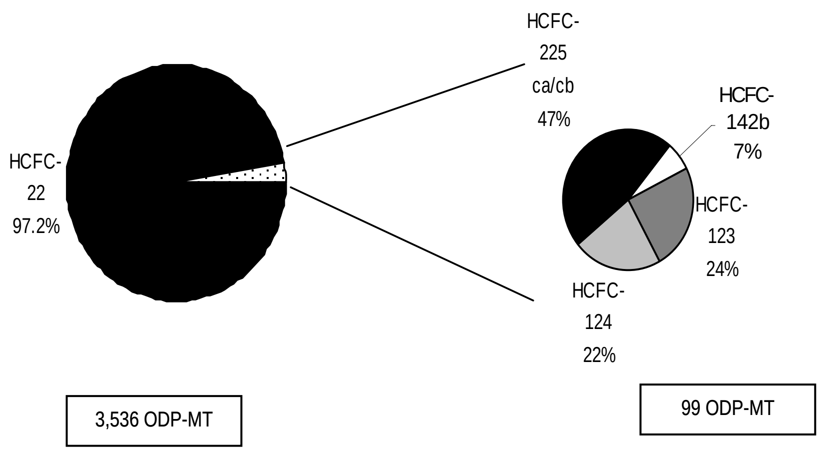
Section 3 is organized into two subsections. Section 3.1 provides a brief discussion of projected demand of HCFCs, including estimates in ODP-weighted metric tons. Section 3.2 presents an overview of the HCFC demand by end-use sectors for HCFCs other than HCFC-22.

3.1 Projected HCFC Demand

HCFC-142b and HCFC-22 production and import will be phased out beginning January 1, 2010 unless for use in, or to provide service to, equipment manufactured prior to January 1, 2010. Servicing use of these two HCFCs is limited to a few applications, including those in the AC and refrigeration, as well as the fire protection sectors, though statutory requirements further limit HCFC servicing in 2015 to refrigerant applications only. In addition to servicing demand, there is demand associated with other HCFCs for other end-use applications not subject to the 2010 phaseout. Projected demand of HCFCs other than HCFC-22 was determined by examining estimates of current demand through various sources, including

EPA's ODS tracking system, input from industry experts, and assumptions from EPA's Vintaging Model on future anticipated trends (EPA 2007a; NASA 2008; U.S. HCFC Manufacturer Representatives 2008). Projected demand of HCFC-22 was estimated based on EPA's Vintaging Model and is further explored in Section 4, which presents projected scenarios of the extent to which HCFC-22 demand (in 2010 and beyond) can be met through supplies of recovered refrigerant. Figure 3-1 demonstrates all projected HCFC demand in 2010 (ODP-weighted); as shown, HCFC-22 servicing needs constitute over 97% percent of all HCFC demand.

Figure 3-1. Total Projected HCFC Demand ODP-Weighted Metric Tons, 2010



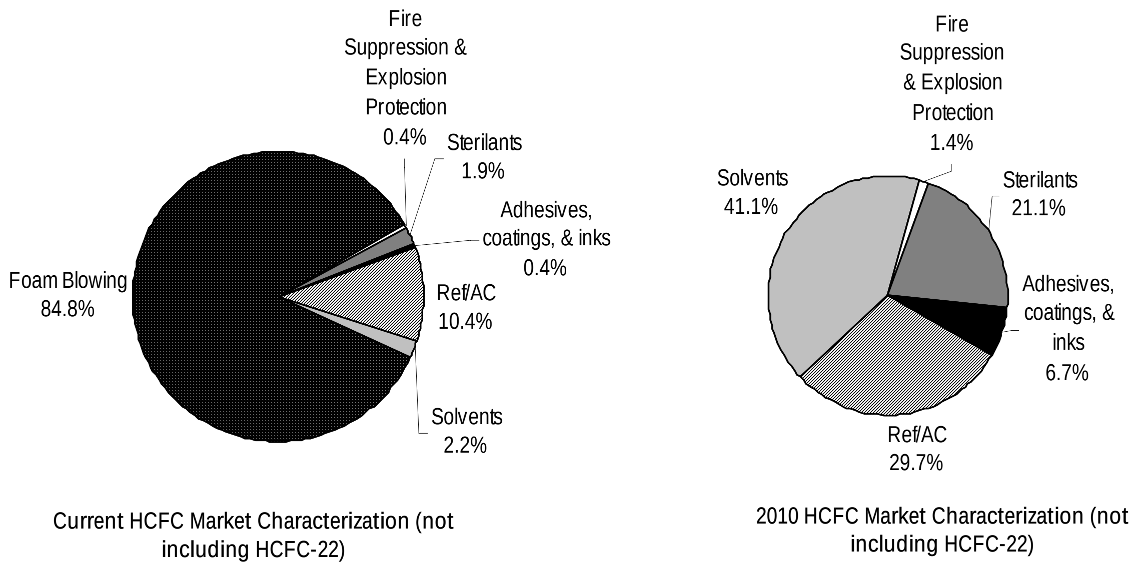
HCFC	ODP-MT Demand
HCFC-22	3,437
HCFC-142b	*7*
HCFC-123	*24*
HCFC-124	*22*
HCFC-225 ca/cb	*46*
Other HCFCs	*99*
Total	3,536

Source: Based on data analysis using EPA, 2007a to develop the HCFC-22 estimate and data analysis using EPA, 2007a, EPA's ODS Tracking System, and U.S. HCFC Manufacturer Representatives, 2008 to develop estimates for other HCFCs.

3.2 HCFCs Other than HCFC-22 by End-Use

As Figure 3-2 illustrates, the largest sector currently using HCFCs (excluding HCFC-22) is the foam industry, followed by the refrigeration and AC, and sterilization industries. In 2010, the largest sector using HCFCs (excluding HCFC-22) is expected to be the solvents industry (at 41%) followed by refrigeration and AC industries (at 30%), and the sterilization industry (at 21%).

Figure 3-2: Estimated HCFC (Excluding HCFC-22) Demand by Industry Sector, ODP-Weighted Metric Tons



Source: Based on data analysis using EPA, 2007a to develop the HCFC-22 estimate and data analysis using EPA, 2007a, EPA's ODS Tracking System, and U.S. HCFC Manufacturer Representatives, 2008 to develop estimates for other HCFCs.

3.2.1 Solvent Cleaning and Adhesives, Coatings, and Inks

Historically CFCs were primarily used in the solvent sector until their phaseout in 1996 under the CAAA of 1990. HCFC-141b was used as a substitute for CFCs in solvent cleaning until its phaseout date on January 1, 2003. HCFC-225ca/cb was chosen by the industry as an alternative, as it has similar characteristics to CFC-113, and is also a replacement for HCFC-141b in aerosol solvent cleaning. HCFC-225ca/cb is a mixture of the two isomers HCFC-225ca and HCFC-225cb, typically in a 45/55% by weight ratio. It was adopted by the solvent industry in 1994, and demand has gradually increased over the years. HCFC-225ca/cb is commonly used in precision cleaning required for sensitive equipment used in aerospace and military applications. HCFC-225ca/cb's "selective solvency, physical properties, and ability to form azeotropes make it ideal for general and precision cleaning, and drying and defluxing applications" (AGA Chemicals 2008).

Production, import and use of HCFC-225ca/cb will be phased out in 2015. Projected demand from 2010 through 2014 for solvent cleaning and adhesives, coatings, and inks is presented in Table 3-2.[9]

Table 3-2: Projected HCFC-225 ca/cb Demand in Solvent Cleaning and Adhesives, Coatings, and Inks, 2010 - 2014 (Metric Tons)

	2010	2011	2012	2013	2014
Solvent Cleaning					
HCFC-225ca/cb	700	800	900	1,000	1,100
Adhesives, Coatings, and Inks					
HCFC-225ca/cb	100	100	100	200	200

Source: Based on data analysis using EPA, 2007a, EPA's ODS Tracking System, and U.S. HCFC Manufacturer Representatives, 2008.

As shown in Table 3-2, demand is estimated to increase up until the 2015 phaseout date. According to solvent industry experts, R&D efforts are underway to identify alternatives to HCFC-225ca/cb, but due to its mild nature and precise characteristics, a suitable replacement has not yet been identified. Currently

[9] It is estimated that use of HCFC-225ca/cb in solvent cleaning equipment can be recovered and reclaimed and subsequently used to meet some of the overall projected demand for HCFC-225ca/cb.

HCFC-225ca/cb occupies a particular niche; it is used to flush clean liquid oxygen systems installed on military aircraft and hospital ships (previously cleaned with CFC-113) and for cleaning the guidance systems of the space shuttles and the space station (UNEP 2007; U.S. HCFC Manufacturer Representatives 2008).

3.2.2 Foam Blowing

Several foam products are manufactured using HCFCs. With the 2003 phaseout of HCFC-141b, HCFC-142b emerged as the dominant HCFC used as a blowing agent during the manufacture of foams in the U.S.[10] HCFC-142b is used as a blowing agent in extruded polystyrene boardstock (building insulation); it is also used to a lesser degree as a blowing agent for polyurethane rigid foams for domestic refrigerators and freezers and to blow foam used for commercial refrigeration. HCFC-142b for use in the foam industry sector, where the notion of servicing existing equipment is not applicable, will be phased out in 2010. Alternatives include several HFCs; in the U.S. HFC-134a, HFC-152a, and HFC-245fa are primarily used as well as CO_2 (water) and hydrocarbons (e.g., propane, butane) (EPA 2006, EPA 2007a).

3.2.3 Fire Extinguishing

Fire-extinguishing applications can be divided into two categories: portable fire extinguishers (e.g., streaming applications) that originally used halon 1211, and total flooding applications that originally used halon 1301 or halon 2402 (EPA 2006). The Significant New Alternatives Policy (SNAP) program has approved the use of HCFC-22, HCFC-123, and HCFC-124 in total flooding and streaming applications[11]; however, only HCFC-123 and HCFC-124 as streaming agents are understood to be used in practice (EPA 2007a). HCFC-123 is the primary constituent in Halotron I (also referred to as HCFC Blend B in EPA regulations). Specifically, the blend, Halotron I, is used in commercial/industrial, maritime, and military applications in the United States (Halotron 2008).

In 2015, HCFC-123 and HCFC-124 production, import, and use will be phased out for all non-refrigerant uses. Table 3-3 presents projected estimates of HCFC-123 and HCFC-124 demand for fire extinguishing from 2010 to 2014.[12]

Table 3-3: Projected HCFC-123 and HCFC-124 Demand for Fire Extinguishers, 2010 - 2014 (Metric Tons)

Fire Extinguishing: Streaming Agents	2010	2011	2012	2013	2014
HCFC-123	20	10	10	10	10
HCFC-124	50	40	30	30	20

Source: Based on data analysis using EPA, 2007a, EPA's ODS Tracking System, and U.S. HCFC Manufacturer Representatives, 2008.

Alternatives to HCFCs in the fire extinguishing industry include HFCs such as HFC-236fa; the majority of the industry has already transitioned to non-ODS alternatives (EPA 2007a).

3.2.4 Sterilization

HCFCs are used to sterilize medical products. The SNAP program has approved HCFC-124 and blends of HCFC-124, HCFC-22, and ethylene oxide (EtO) as a substitute for the 12/88 blend of EtO and CFC-12 to sterilize equipment that cannot be sterilized using other alternatives (e.g., steam or CO_2/EtO blends).[13]

[10] HCFC-22 is also used mainly to blow pour-froth foam for applications such as insulation of trailers and trucks, roof/wall insulation, and for air infiltration prevention applications. Some quantities of HCFC-22 are used in foams for commercial refrigeration, as well. HCFC-22 use in the foam industry sector will be phased out in 2010.

[11] [HCFC Blend] A (NAF S-III), a mixture containing HCFC-22, HCFC-123, and HCFC-124 (ActivFire 2006), was found acceptable by the SNAP program as a total flooding agent.

[12] It is estimated that HCFC-123 and HCFC-124 used in AC and refrigerant equipment and fire extinguishing equipment can be recovered and reclaimed and subsequently used to meet some of the overall projected demand for these HCFCs.

[13] While HCFC-22 is used in small quantities in the sterilization sector, its use by this industry sector will be phased out in 2010. Additionally, [HCFC Blend] A (NAF S-III), a mixture containing HCFC-22, HCFC-123 and HCFC-124 (ActivFire 2006), was found acceptable by the SNAP program; however, the use of this blend has not been quantified.

Oxyfume® 2000 is one such blend. Also within the family of Oxyfume Sterilants is Oxyfume® 2002 containing a blend of EtO, HCFC-124, and HCFC-22 (Honeywell 2008).

In 2015, HCFC-124 production, import, and use will be phased out for all non-refrigerant uses. Table 3-4 presents projected estimates of HCFC-124 demand for sterilization from 2010 to 2014.[14]

Table 3-4: Projected HCFC-124 Demand for Sterilants, 2010 – 2014 (Metric Tons)

Sterilants	2010	2011	2012	2013	2014
HCFC-124	1,000	1,000	1,000	1,100	1,100

Source: Based on data analysis using EPA, 2007a, EPA's ODS Tracking System, and U.S. HCFC Manufacturer Representatives, 2008.

Alternatives listed as acceptable substitutes by EPA's SNAP program include different blends of IoGas™ containing CF_{3I}, CO_2, and EtO and the Mini-Max Cleaner® (EPA 2008a).

3.2.5 Refrigeration and Air-Conditioning

Historically, CFCs were extensively used as refrigerants in the AC and refrigeration industries; by the 1970s, R-22 and R-502 (a blend of CFC-115 and R-22) were also well established refrigerants. On January 1, 1996, the production and import of CFC refrigerants, classified as Class I controlled [ozone-depleting] substances under the CAA Amendments of 1990, were phased out in the U.S. and other industrialized countries. HCFC refrigerants, which also deplete the ozone layer and are classified as Class II controlled [ozone-depleting] substances under the CAA, were found acceptable as substitutes for the controlled CFCs.

Air-Conditioning End-Uses

AC equipment can be categorized as either mobile or stationary. These broad end-use categories are discussed further below and outlined in Figure 3-3.

Mobile air-conditioning systems include all forms of AC that provide cooling to passenger compartments in all types of moving vehicles. This category can be further broken down into motor vehicle air-conditioning for light-duty vehicles and other mobile air-conditioning systems.

- *Motor vehicle air-conditioning (MVAC)* includes AC in the passenger compartments of light duty vehicles—both cars and trucks (i.e., pick-up trucks, minivans, sport utility vehicles, etc.). A variety of refrigerant blends, some of them including HCFCs, are approved for use in the United States by EPA as replacements for R-12 in MVACs. However, these blends have not been endorsed by vehicle or system manufacturers for such use, thereby capturing only a small and declining share of the retrofit market, which consists mainly of R-134a. R-134a is not an ODS; therefore, the MVAC sector is not discussed further in this analysis.
- *Other mobile air-conditioning* includes AC in the passenger compartments of both buses (including school, transit, and tour buses) and trains (including heavy, light, and commuter rail, and Amtrak trains).[15] Although most bus AC systems converted directly from R-12 to R-134a, the majority of transit buses, tour buses, and trains continue to use R-22 in their AC systems (Sartin Services 2005; Motorcoach Training 2005; WMATA 2005; Amtrak 2005; NJ Transit 2005).

Stationary air-conditioning includes a wide variety of equipment, further categorized into the following six categories.

- *Unitary air-conditioners and heat pumps* include both split systems and packaged units and are designed for air circulating, cooling, cleaning, and dehumidifying and sometimes heating in residential and small and large commercial applications.

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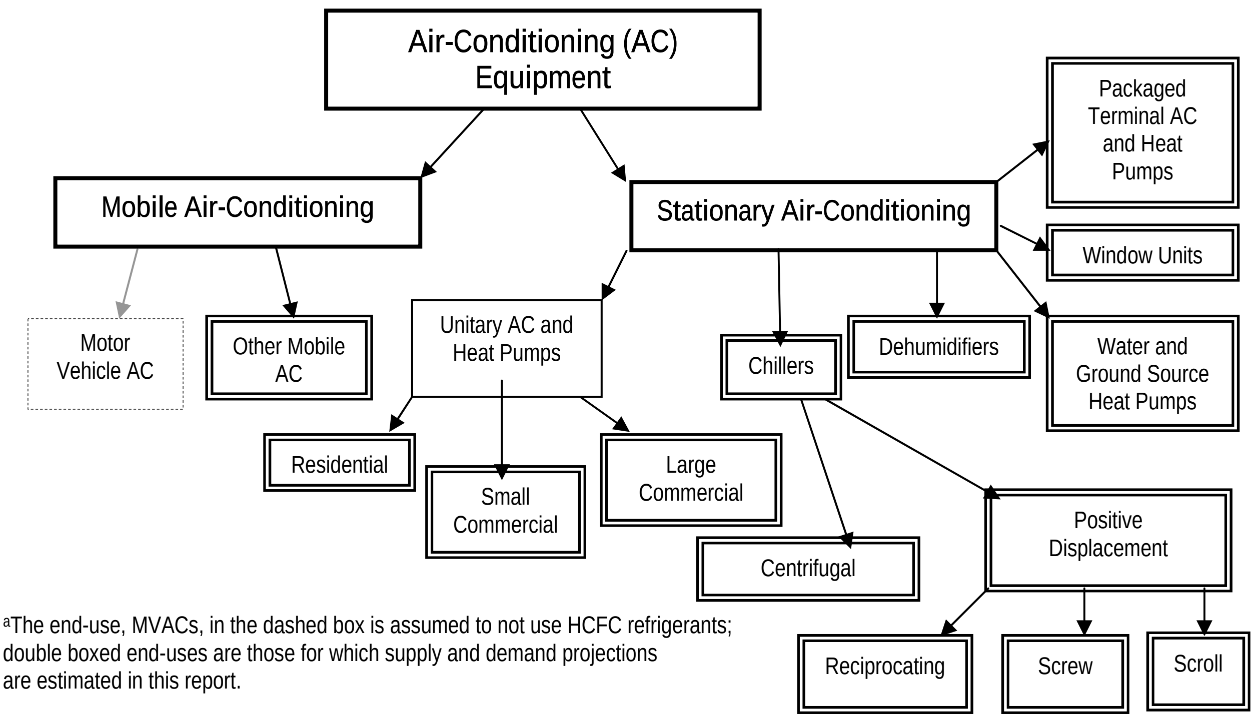
[14] It is estimated that HCFC-124 used in AC and refrigerant equipment and fire extinguishing can be recovered and reclaimed and subsequently used to meet some of the overall projected demand for these HCFCs.

[15] For the purposes of this report, "other mobile AC" does not include ships, planes, RVs, or construction/farm equipment. In the case of boats, some R-22 is used in AC systems (UNEP 2003a), but this consumption is accounted for in this report under stationary AC equipment, such as packaged terminal units or chillers (Cold Ships 2005).

- *Chillers* regulate the temperature and humidity in offices, hotels, shopping centers, and other large buildings. There are two major types of chillers—centrifugal and positive displacement. Centrifugal Chillers are centralized air conditioning systems typically used in larger buildings (e.g., offices, hotels, shopping centers and other large buildings). Positive displacement chillers are smaller than centrifugal chillers, and may be water-cooled or air-cooled. There are three types of positive displacement chillers—1) reciprocating 2) screw, and 3) scroll—each of which is named for the type of compressor employed.
- *Dehumidifiers* are mechanical refrigeration systems designed to remove moisture from the air by drawing air first over cold evaporator coils and then warm condenser coils, causing the moisture in the air to condense onto the cold coils. Examples include indoor pool dehumidifiers and portable units used to dehumidify basements.
- *Water and ground source heat pumps* use fluid circulated in a common piping loop as a heat source/sink to cool and heat air. Water-source heat pumps typically use water pumped from a well, lake, or stream as a heat source/sink. Direct expansion geothermal heat pumps circulate refrigerant through piping in the earth.
- *Window units*, also known as room air-conditioners, are small appliances used to condition the air in a single room.
- *Packaged terminal units* are ACs or heat pumps that are mounted on the wall. They are often used in hotel rooms, dormitories, or classrooms.

Figure 3-3: Types of Air-Conditioning Systems[a]



[a]The end-use, MVACs, in the dashed box is assumed to not use HCFC refrigerants; double boxed end-uses are those for which supply and demand projections are estimated in this report.

Refrigeration End-Uses

Refrigeration equipment can be broken down into four categories: domestic refrigeration, refrigerated transport, industrial process refrigeration, and commercial refrigeration. These categories are described further below and outlined in Figure 3-4.

Domestic refrigeration includes household refrigerators, household freezers, combination refrigerator/freezer units, and water coolers. For the majority of these equipment types, the refrigerants used do not typically include HCFCs or blends containing HCFCs. Older household freezers sometimes employed R-22; however, because these units are viewed as a minor part of the domestic refrigeration market, this end-use is not further analyzed in this report.

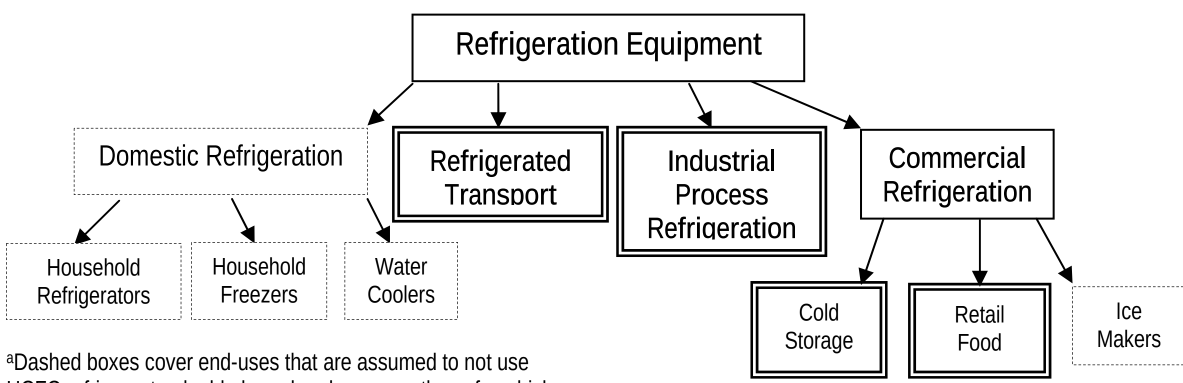
Refrigerated transport includes refrigeration used in equipment that moves products from one place to another and includes refrigerated ship holds, truck trailers (i.e., reefer trucks), railway freight cars, and other shipping containers.

Industrial process refrigeration (IPR) systems are complex, customized systems used to cool process streams in the chemical, food processing, pharmaceutical, petrochemical, and manufacturing industries. This sector also includes industrial ice machines, equipment used directly in the generation of electricity, and ice rinks.

Commercial refrigeration can be further broken down into three end-uses:

- *Cold storage warehouses* are refrigeration systems with varying designs and charge sizes. They are used to store meat, produce, dairy products, and other perishable goods before and after food processing.
- *Retail food systems* are used to refrigerate food in commercial retail establishments, such as grocery stores. These systems can be classified as either centralized or self-contained units. Centralized retail food systems, also known as remote systems, consist of a series of compressors located in a remote machinery room, providing a cooling medium to display cabinets and cold storage rooms in other parts of the building. The most common form of centralized systems circulate refrigerant throughout the store. Alternatives to these types of systems include secondary loop and distributed systems that for the most part use HFC refrigerant blends. Self-contained retail food units, also referred to as stand-alone systems, are factory produced with all the components integrated. Examples include walk-in refrigerators/coolers/freezers, roll-in refrigerators/freezers, under-counter refrigerators/freezers, reach-in refrigerators/freezers, wine and beer coolers, ice cream machines, beverage vending machines, and a variety of stand-alone upright or horizontal display cases (e.g., beverage merchandisers, deli cases).
- *Ice makers* are factory-made units used in commercial establishments to produce ice for consumer use (e.g., in hotels, restaurants, and convenience stores). Ice makers are not further analyzed in this report because they do not typically employ HCFCs or blends containing HCFCs.

Figure 3-4: Types of Refrigeration Systems[a]



[a]Dashed boxes cover end-uses that are assumed to not use HCFC refrigerants; double boxed end-uses are those for which supply and demand projections are estimated in this report.

HCFC-22 represents the majority of the refrigeration and AC market, however, other HCFCs are also used by the refrigeration and air-conditioning industries. A brief discussion of the use of HCFC-142b, HCFC-123, HCFC-124, and HCFC-21 as refrigerants is provided below; in addition, Box 3-2 presents a brief summary of HCFCs uses in refrigerant blends.

The production and import of virgin HCFC-123, HCFC-124, and HCFC-21 is scheduled for phaseout in 2020 for use in new AC and refrigeration equipment, and in 2030 for use in existing AC and refrigeration equipment. The phaseout schedule for HCFC-142b is the same as that for HCFC-22—beginning January 1, 2010, production and import of HCFC-142b will be banned unless for use in equipment manufactured prior to January 1, 2010. The final phaseout for HCFC-142b (and HCFC-22) is on January 1, 2020, and for all HCFCs on January 1, 2030. Table 3-7 presents projected estimates of HCFC refrigerant demand (excluding HCFC-22) for the refrigeration and AC industries in five year increments from 2010 to 2020.

Box 3-2: Summary of HCFCs used in Refrigerant Blends

Often refrigerants are formulated with several substances, such as hydrofluorocarbons (HFCs) or hydrocarbons (e.g., propane, butane, isobutane). HCFC-22 is used as both a stand-alone refrigerant and a component of refrigerant blends. Table 3-5 presents the composition of the more common refrigerant blends containing HCFCs.[1]

Table 3-5: Compositions of Common HCFC Refrigerant Blends

Blend	R-22	R-124	Other
R-401A	53%	34%	13% R-152a
R-402A	38%		60% R-125, 2% propane (R-290)
R-502	48.8%		51.2% CFC-115

End-uses in which these refrigerant blends containing HCFCs are currently used are presented in the table below.

Table 3-6: HCFC-Containing Refrigerant Blends by End-Use

Refrigeration Equipment Type	Refrigerant Type		
	R-401A	R-402A	R-502
Retail Food		x	x
Cold Storage			x
IPR	x		
Refrigerated Transport	x	x	x

Table 3-7: Projected HCFC-124, -123, and -142b Demand for Refrigeration and Air-Conditioning, 2010-2020, (Metric Tons)

HCFC	2010	2015	2020
HCFC-124	<5	<5	<5
HCFC-123	1,200	1,200	1,500
HCFC-142b	100	0	0

Source: Based on data analysis using EPA, 2007a, EPA's ODS Tracking System, and U.S. HCFC Manufacturer Representatives, 2008.

- **HCFC-124 —** HCFC-124 is minimally used as a refrigerant; its primary use is in blends, mainly R-401A, in industrial process and transport refrigeration equipment. As a stand-alone refrigerant, it has found some niche applications that reach high condensing temperatures as well as an alternative for CFC-114 in some naval chillers. The production and import of virgin HCFC-124 is scheduled for phaseout in 2020 for use in new AC and refrigeration equipment, and in 2030 for use in existing AC and refrigeration equipment. However, its use in blends R-401A, R-401B, R-409A, R-414A, R-414B and others is constrained because those blends also contain R-22. HCFC-124 is also a component of R-416A, which does not contain any other ODS.

- **HCFC-123 —** HCFC-123 is used in the refrigeration and AC sector mainly in centrifugal chillers for industrial process refrigeration and commercial comfort AC. The production and import of virgin HCFC-123 is scheduled for phaseout in 2020 for use in new AC and refrigeration equipment, and in 2030 for use in existing AC and refrigeration equipment.

- **HCFC-142b —** In addition to being used in the foam industry, HCFC-142b is also used as a refrigerant, but only as a constituent of a few refrigerant blends. While HCFC-142b refrigerant blends are approved as acceptable substitutes for CFC refrigerants in some end-uses, their use is small and declining. R-409A (composed of HCFC-22/HCFC-124/HCFC-142b) is the most common refrigerant blend using HCFC-142b. However, sales of R-409A are rapidly declining, and are being replaced with R-404A (composed of HFC-125, HFC-134a, and HFC-143a) (U.S. HCFC Manufacturer Representatives 2008). Based on industry estimates, it is assumed that current demand for HCFC-142b as a refrigerant will continue decrease to approximately 100 metric tons in 2010; additionally, it is assumed that demand will continue to decrease to zero by 2015 (U.S. HCFC Manufacturer Representatives 2008).

- **HCFC-21 —** HCFC-21 currently is used by NASA as a refrigerant in the cooling loops of the space shuttle fleet (NASA 2008). Research indicates that NASA is the only industrial user of HCFC-21. NASA's plan is to use the HCFC-21 until shuttle fly-out (2010) and to employ HCFC-21 alternatives in the next generation of space vehicles (NASA 2008). For this analysis, it is assumed that projected demand for HCFC-21 beyond 2010 is zero; however, it is conceivable that NASA may access in-house stockpiles of the refrigerant for potential future uses.

4. Projected R-22 Scenarios

Section 4 presents projections of the number of R-22-containing units of equipment and the associated servicing needs for 2010, 2015, and 2020. R-22 scenarios were developed by investigating various trends that are expected to affect future market needs. Such trends include changes in charge sizes, the transition to alternative refrigerants, changes in refrigerant recovery and reuse practices, R-22 economics, and potential imports of pre-charged equipment.

- Section 4.1 summarizes the projected market size of R-22 containing equipment beyond 2010 in the United States.
- Section 4.2 estimates projected of the quantity of both virgin (i.e., consumption as defined under the Montreal Protocol) and recovered R-22 that will be required to service existing equipment beyond 2010.
- Section 4.3 discusses the factors that may affect estimates of the installed base and servicing needs for R-22 equipment.

Appendix B presents further detail on the estimates provided in Section 4, disaggregating R-22 containing equipment and overall service demand estimates into end-use specific projections.

4.1 R-22 Equipment Used Beyond 2010

The majority of R-22 equipment that is projected to be in use (i.e., within the installed base) from 2010 onward will be used for AC applications, including window units, packaged terminal units, residential and commercial unitary AC, chillers, dehumidifiers, water and ground source heat pumps, and non-light duty mobile AC in buses, trains, etc. As presented in Table 4-1, EPA estimates that approximately 145.6 million units of all such types of AC equipment will be in use in 2010, decreasing by about 41 percent by 2015, and 76 percent (of the amount remaining in 2015) by 2020. EPA estimates that in 2010 there will be approximately 3.8 million units of refrigeration equipment, including retail food, industrial process refrigeration, and transport refrigeration equipment (but not including cold storage warehouses). The installed base of refrigeration equipment is projected to decrease by about 44 percent by 2015 and 56 percent (of the amount remaining in 2015) by 2020. EPA developed these estimates based on the 2007 version of EPA's Vintaging Model (EPA 2007a). Appendix A provides more detail on the methodology used to develop these projections. Appendix B provides projections disaggregated by end-use.

Table 4-1: Projected Number of R-22 Units (2010-2020)[a,b]

Equipment Type	2010	2015	2020
Total AC	145,633,300	86,049,100	20,615,300
Total Refrigeration	3,779,600	2,114,800	930,300
Total	149,412,900	88,163,900	21,545,600

[a] Including units that use blends containing HCFC-22.
[b] Because the estimates for cold storage warehouses are expressed in cubic feet, this equipment type is not included in this table. The projected stock of cold storage warehouse space using R-22 is 231 million ft^3 in 2010, 133 million ft^3 in 2015, and 61 million ft^3 in 2020.
Source: Based on data analysis using EPA, 2007a.

4.2 Projected R-22 Servicing Needs

AC and refrigeration equipment commonly requires servicing, which may include adding refrigerant to account for refrigerant losses that occur over time.[16] While the production and import of HCFC-22 is banned for use in new equipment in 2010, it will still be permitted for servicing and maintenance purposes for equipment manufactured prior to January 1, 2010. Table 4-2 presents projected R-22 demand (including that used in blends) for servicing equipment in 2010, 2015, and 2020. These estimates were developed based on the EPA's Vintaging Model (EPA 2007a). Appendix A provides further detail on the

[16] The servicing need estimates projected in this analysis include refrigerant to replace quantities that leak from operating equipment as well as *de minimis* losses that may occur while servicing operating equipment.

methodology used to develop these projections. Appendix B provides servicing demand projections disaggregated by end-use.

As presented in Table 4-2, it is projected that in 2010, approximately 62,500 metric tons of R-22 will be required to service AC and refrigeration equipment, of which the majority—41,700 metric tons (67%)—will be used to service AC systems. EPA projects that servicing demand for R-22 in AC and refrigeration equipment will decrease to 38,700 metric tons by 2015 and 18,200 metric tons by 2020. Both the 2015 and 2020 projections of servicing demand exceed the U.S. consumption cap for virgin HCFCs for these years; however, a portion of the servicing needs can be met by using recovered refrigerant, thus decreasing the need for virgin R-22.

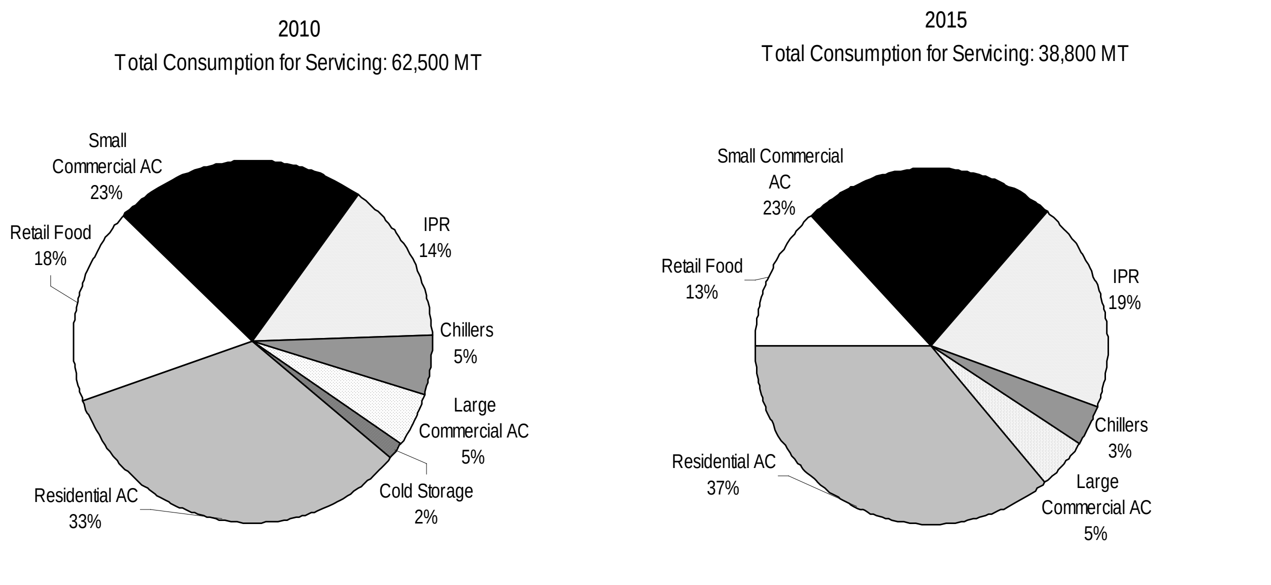
Table 4-2: Projected R-22 Servicing Demand (2010-2020) (Metric Tons)

Equipment Type	2010	2015	2020
Total AC	41,700	25,900	11,300
Total Refrigeration	20,800	12,800	7,000
Overall Total	62,500	38,800	18,200

Source: Based on data analysis using EPA, 2007a.

Figure 4-1displays the breakdown of R-22 servicing demand by AC and refrigeration equipment type for 2010 and 2015. As shown, residential AC, retail food refrigeration equipment, and small commercial AC are projected to account for the majority of the R-22 demand in 2010 and in 2015.

Figure 4-1: R-22 Demand for Servicing Equipment, by End-Use



Source: EPA's Vintaging Model (VM IO file_11-12-07_ALL)

4.2.1 R-22 Sources

Starting in 2010, only existing sources of R-22 and a controlled quantity of virgin R-22 (limited through allowance allocations distributed by EPA) will be available to the AC and refrigeration industry to meet servicing demand.[17] Existing sources of R-22, which can offset the need for virgin R-22, include:

1. R-22 that is recovered and either recycled or reclaimed before reuse. Under EPA regulations at 40 CFR 82.156, refrigerants containing HCFCs must be recovered. After the recovery process, the refrigerant held in the storage container may be:

[17] Virgin R-22 may be stockpiled; however, the extent to which this activity may occur is unknown. A discussion on stockpiling plans is covered in Section 4.3.3.

a. Recycled (i.e., cleaned through the use of recycling equipment) and recharged back into the equipment from which it came;
b. Recycled and used in other equipment of the same owner;
c. Reclaimed (shipped to an EPA-certified reclaimer) prior to resale to a new owner; or
d. Destroyed through the use of environmentally-acceptable technologies that meet the definition of destruction in 40 CFR §82.3 (i.e., liquid injection incineration, reactor cracking, gaseous/fume oxidation, rotary kiln incineration, cement kilns, and radio frequency plasma) (EPA 2003b).

2. Import of used R-22 that companies can acquire, if the import is preauthorized by EPA, through a petition process.

Each of these existing sources of R-22 is described in more detail below.

Recycled R-22

Recovered R-22 is often recycled prior to being used again in equipment. The recycling process cleans the refrigerant for reuse without meeting all the requirements of reclamation, discussed further below. HCFC refrigerants are commonly recovered from a piece of equipment, adequately cleaned, and then recharged into the same piece of equipment using a recycling device (EPA 2003b).

EPA regulations allow for the recharge of used refrigerant without subsequent reclamation for refrigerants that are recovered and charged back into the same appliance or to another appliance if those appliances are owned by the same establishment. Several companies, such as supermarket chains, employ recycling plans through which the refrigerant is recovered when dismantling or converting one establishment's equipment and reused to service equipment at another facility with the same ownership.

Reclaimed R-22

Refrigerants that are resold to be used in other equipment must be reclaimed to a standard level of purity based on the ARI Standard 700, to ensure sufficient purity of the reclaimed refrigerant. EPA certified reclaimers are approved to reprocess used refrigerant to at least the purity level based on the ARI 700 Standard.

Industry representatives have indicated that the current use of reclaimed HCFCs is minimal because virgin R-22 is inexpensive. In 2006, the amount of pure R-22 reclaimed by EPA-certified reclaimers totaled approximately 3,872 metric tons, or 8.54 million pounds (EPA 2007c). Fewer quantities of the refrigerant blend R-502, composed of 48.8 percent R-22 and 51.2 percent CFC-115, are also being reclaimed, with only 52 metric tons, or 114,640 pounds reported for 2006 (EPA 2007c).[18] Reclamation data from 2000 to 2006 is presented in Table 4-3 below.

Table 4-3: Reclaimed R-22 by Year (Metric Tons)[a]

	2000	2001	2002	2003	2004	2005	2006
R-22	3,218	1,960	2,230	1,976	3,280	2,800	3,872
R-502	281	113	150	41	48	25	52

Source: EPA 2007c.

As 2010 approaches, the price of R-22 will likely increase and it is expected that the reclamation of R-22 will also increase (Powell 2004). Recently, wholesalers and manufacturers are looking at different options to improve the development of the reclamation chain, as well as encourage more contractors to return refrigerant by offering better rewards (Powell 2007). Industry representatives are already reporting market signals indicating that several U.S. companies are expecting an eventual surge in R-22 reclamation (Powell 2004; CFC Refimax 2006). Where there is a monetary incentive, distributors are more likely to collect refrigerant and pass it on to reclaimers (HARDI 2005). A more detailed discussion on R-22 economics is provided in Section 4.3, "Factors Affecting Projections."

[18] Feedback received from stakeholders in response to the NODA indicated that because R-502 is an azeotropic blend, it is difficult and expensive to separate R-22 from the blend, and hence such separation is very limited (National Refrigerants 2006).

Imports of Used R-22

Unlike virgin HCFCs, used HCFCs are not subject to Montreal Protocol restrictions on consumption.[19] However, in creating the allocation system for the use of HCFCs, EPA developed a shipment-by-shipment petition process for importing used HCFCs as described in 40 CFR §82.24 (EPA 2003a). The petition process ensures that HCFCs are used (and not newly produced) prior to import. For each shipment of used HCFC greater than five pounds, the importer needs to petition EPA at least 40 working days before the shipment is to leave the country of export. EPA reviews and verifies data in the petition and issues a notice to the importer either permitting or not permitting the import to occur.

Currently, the quantity of used R-22 imports is minimal; however, recently the Agency has received inquires from those interested in pursuing imports of used R-22. The projections in this report do not specifically include the potential future quantities obtained from the import of used R-22 because this analysis indicates that there is sufficient potential to offset future demand for virgin material using domestic sources.

4.2.2 Meeting R-22 Service Demand

Although limited virgin manufacture of HCFC-22 will be allowed to service equipment until 2020 through production and consumption allowances, the analysis performed for this report indicates that, with industry effort, a significant portion of the demand for HCFC-22 for servicing can be met with previously used refrigerant that is recovered and then recycled or reclaimed. Increased amounts of recovered R-22 are a source made available as a result of the venting prohibition EPA has established under Section 608 of CAA (EPA 2004a). In order to determine the potential amounts of used refrigerant available to service equipment, five theoretical scenarios were developed using EPA's Vintaging Model to estimate: 1) the projected amount of recovered R-22 potentially available to meet projected servicing demand of other equipment still in use; 2) the subsequent remaining quantity needed to satisfy the rest of that demand; and 3) the extent to which the remaining demand can be met with allowable quantities of virgin R-22 production. This section presents three of these scenarios and Appendix C presents the other two, which represent minimum and maximum recovery rates analyzed for this report.

In developing the scenarios using EPA's Vintaging Model, the projected amount of recovered R-22 is estimated based on the quantity available from decommissioned or converted equipment. While refrigerant recovered from equipment during servicing activities can also be available for reuse in other equipment, this potential source is not included in these scenarios for several reasons. First, it is projected to be minimal in net terms (i.e., refrigerant recovered during service would likely be returned to the same equipment from which it was recovered). Also, according to industry sources, refrigerant recovered during service events primarily originates from commercial and industrial equipment (i.e., equipment with relatively large charges). Refrigerant is rarely recovered during the servicing of small equipment because these units tend not to be overcharged or leaking (Home Energy Center 2006, Airgas 2006). Additionally, only a small portion of all servicing events conducted on commercial and industrial equipment involve the refrigerant circuit, and when recovering refrigerant to perform repairs is necessary, often only a section of the refrigerant charge is isolated and recovered, not the entire charge.

To estimate refrigerant recovery and reuse, it is assumed that a certain percentage of refrigerant is recovered from decommissioned or converted equipment.[20] It is important to note that not all refrigerant is assumed to be recovered. While EPA has regulations in place prohibiting intentional venting, for the purposes of this analysis, it is appropriate to create scenarios that assume less than the full charge of refrigerant is recovered at equipment end-of-life. For example, in many instances, equipment is disposed of after a catastrophic failure, which might have resulted in a large or even complete loss of the refrigerant. Also, when equipment is removed from service, there can be losses associated with previous leaks and during attempts to recover the remaining refrigerant. It is also possible that owners or

[19] "Used controlled substances" are controlled substances that have been recovered from their intended use systems (which may include controlled substances that have been, or may be subsequently, recycled or reclaimed) (EPA 2003a).

[20] To calculate the amount recovered, the Vintaging Model assumes equipment contains a full charge at disposal and assumes a certain percent of that is recovered. It does not take into account a) refrigerant destroyed after equipment is decommissioned or b) any stockpiling of recovered refrigerant beyond a one-year timeframe. See Appendix A for further details.

technicians disposing of a piece of equipment might not comply with the regulations and vent the refrigerant.

It is then assumed that the entire pool of recovered refrigerant re-enters the market (see Appendix A for more details) and hence offsets the demand for virgin R-22. The three scenarios investigated can be summarized as follows:

- Scenario 15 assumes that by 2010, 15 percent of refrigerant from retired or converted equipment is recovered and reused in equipment (i.e., a 15 percent recovery rate). The remaining 85 percent is not available for reuse.
- Scenario 20 assumes that by 2010, 20 percent of refrigerant from retired or converted equipment is recovered and reused in equipment (i.e., a 20 percent recovery rate). The remaining 80 percent is not available for reuse.
- Scenario 50 assumes that by 2010, 50 percent of refrigerant from retired or converted equipment is recovered and available for reuse in equipment (i.e., a 50 percent recovery rate). The remaining 50 percent is not available for reuse.

Table 4-4 through Table 4-6 summarize the three recovery scenarios in comparison to two options for U.S. HCFC consumption allocations: in the first allocation option, it is assumed that 100 percent of the HCFC consumption caps in 2010 and 2015 will be allocated to R-22; in the second, 90 percent is assigned to R-22 in 2010 and 2015, with the remainder set aside for allocation to other HCFCs and/or as a buffer to ensure U.S. compliance with its agreements. The first recovery scenario, which represents a recovery rate of 15 percent, is summarized in Table 4-4. As shown in both potential consumption allocations, a significant portion of the consumption cap remains available in 2010 beyond the quantity required to satisfy the projected R-22 servicing demand. Additionally, Table 4-4 indicates that in 2015 through 2020 (and beyond), the use of recovered refrigerant will become increasingly necessary to avoid R-22 shortfalls; however, projections indicate that sufficient supplies of recovered refrigerant would *not* be available under a 15% recovery rate scenario starting in 2015.

Table 4-4: Scenario 15: 15% Recovery Rate:
Summary of Projected R-22 Supply, Demand, and Surplus (R-22 Metric Tons)

	2010	2015	2020
Projected R-22 Servicing Demand Summary			
Total R-22 servicing demand	62,500	38,800	18,200
Anticipated R-22 supplied from recovery/reuse	4,500	6,600	6,200
% of total R-22 servicing demand supplied by anticipated recovery/reuse	7%	17%	34%
Estimated virgin R-22 supply needed to satisfy remaining demand	58,000	32,200	12,000
Potential HCFC Consumption Cap Allocations			
Allocate 100% of HCFC Cap to R-22			
Virgin R-22 supply available under cap[b]	69,273	27,709	0[c]
Estimated virgin R-22 supply needed to satisfy remaining demand	58,000	32,200	12,000
Additional virgin R-22 allowable under cap	11,300	**-4,500**	**-12,000**
Allocate 90% of HCFC Cap to R-22			
Virgin R-22 supply available under cap[b]	62,345	24,938	0[c]
Estimated virgin R-22 supply needed to satisfy remaining demand	58,000	32,200	12,000
Additional virgin R-22 allowable under cap	4,300	**-7,300**	**-12,000**

[a] Negative values represent a shortfall of R-22 available under the consumption cap and are in bold.
[b] Expressed in R-22 un-weighted metric tons (calculated using an ODP of 0.055 for HCFC-22).
[c] In 2020, a cap equal to 0.5 percent of the U.S. consumption baseline remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining baseline to R-22.
Source: Based on data analysis using EPA, 2007a.

Table 4-5 summarizes the projections under the second recovery scenario that assumes practices that yield a higher recovery rate of 20 percent. These projections are also compared to two potential U.S. HCFC consumption allocations. As shown, in both allocations, the estimated virgin R-22 supply needed in 2010 can be adequately met with a portion of the HCFC consumption cap remaining. Under this scenario, the quantity of recovered R-22 projected to be available in 2015 and 2020 plus the amount of virgin R-22 production allowable under the cap still remains inadequate to meet the projected servicing demand, consequently leading to R-22 supply shortfalls beginning in 2015.

Table 4-5: Scenario 20: 20% Recovery Rate: Summary of Projected R-22 Supply, Demand, and Shortfall (R-22 Metric Tons)[a]

	2010	2015	2020
Projected R-22 Servicing Demand Summary			
Total R-22 servicing demand	62,500	38,800	18,200
Anticipated R-22 supplied from recovery/reuse	5,900	8,800	8,300
% of total R-22 servicing demand supplied by anticipated recovery/reuse	9%	23%	46%
Estimated virgin R-22 supply needed to satisfy remaining demand	56,600	30,000	9,900
Potential HCFC Consumption Cap Allocations			
Allocate 100% of HCFC Cap to R-22			
Virgin R-22 supply available under cap[b]	69,273	27,709	0[c]
Estimated virgin R-22 supply needed to satisfy remaining demand	56,600	30,000	9,900
Additional virgin R-22 allowable under cap	12,700	**-2,300**	**-9,900**
Allocate 90% of HCFC Cap to R-22			
Virgin R-22 supply available under cap[b]	62,345	24,938	0[c]
Estimated virgin R-22 supply needed to satisfy remaining demand	56,600	30,000	9,900
Additional virgin R-22 allowable under cap	5,700	**-5,100**	**-9,900**

[a] Negative values represent a shortfall of R-22 available under the consumption cap and are in bold.
[b] Expressed in R-22 un-weighted metric tons (calculated using an ODP of 0.055 for HCFC-22).
[c] In 2020, a cap equal to 0.5 percent of the U.S. consumption baseline remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining baseline to R-22.
Source: Based on data analysis using EPA, 2007a.

Table 4-6 summarizes the projections under the third recovery scenario that assumes practices that yield to recovering 50 percent of refrigerant from retired or converted equipment. Projections under this scenario indicate that sufficient supplies of refrigerant would be available to service equipment if 50 percent of refrigerant from retired equipment is recovered and re-enters the pool of refrigerant available to meet demand.

Table 4-6: Scenario 50: 50% Recovery Rate:
Summary of Projected R-22 Supply, Demand, and Shortfall (R-22 Metric Tons)

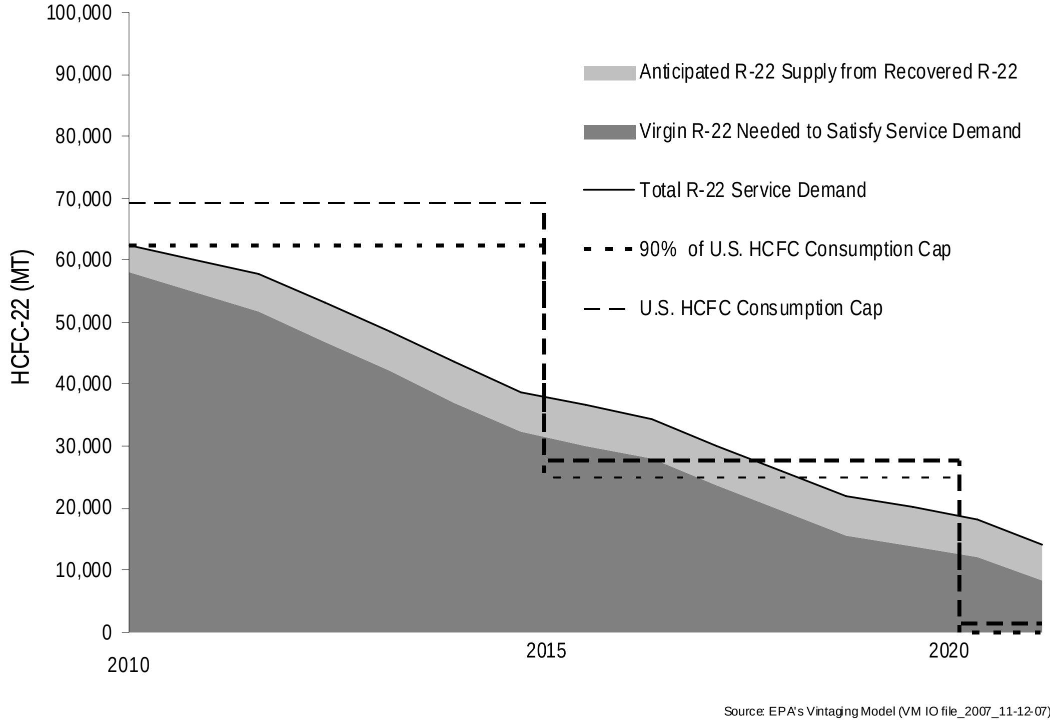
	2010	2015	2020
Projected R-22 Servicing Demand Summary			
Total R-22 servicing demand	62,500	38,800	18,200
Anticipated R-22 supplied from recovery/reuse	14,800	22,000	18,200
% of total R-22 servicing demand supplied by anticipated recovery/reuse	24%	57%	100%
Estimated virgin R-22 supply needed to satisfy remaining demand	47,700	16,800	0
Potential HCFC Consumption Cap Allocations			
Allocate 100% of HCFC Cap to R-22			
Virgin R-22 supply available under cap[a]	69,273	27,709	0[b]
Estimated virgin R-22 supply needed to satisfy remaining demand	47,700	16,800	0
Additional virgin R-22 allowable under cap	21,600	10,900	0
Allocate 90% of HCFC Cap to R-22			
Virgin R-22 supply available under cap[a]	62,345	24,938	0[b]
Estimated virgin R-22 supply needed to satisfy remaining demand	47,700	16,800	0
Additional virgin R-22 allowable under cap	14,600	8,100	0

[a] Expressed in R-22 un-weighted metric tons (calculated using an ODP of 0.055 for HCFC-22).
[b] In 2020, a cap equal to 0.5 percent of the U.S. consumption baseline remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining baseline to R-22.
Source: Based on data analysis using EPA, 2007a.

Figures 4-2a through 4-2c further demonstrate the variability in the projected supply of recovered refrigerant available to meet demand, as well as its subsequent importance in meeting future demand, resulting from the three recovery scenarios. Depending on the recovery practice employed, the potential exists for either a surplus or shortfall to occur in 2015 (Scenario 50 shows a surplus while Scenarios 15 and 20, show a shortfall) and the potential for a shortfall in 2020 (under Scenarios 15 and 20).

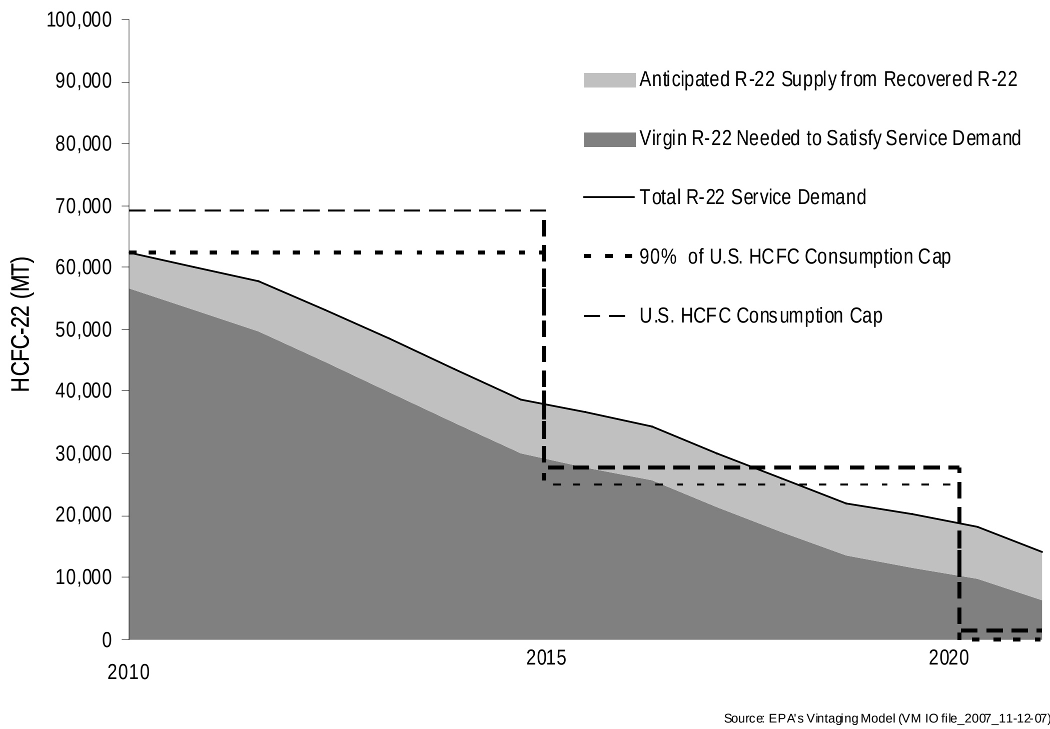
As the market prepares for the next major milestone in the HCFC phaseout, it is important to ensure that R-22 is recovered, recycled, stockpiled, or reclaimed to maximize available R-22 supply and avoid potential shortages. Increased reuse of R-22 will be needed to satisfy future servicing needs that will not be met through virgin supplies alone. The only scenario presented above that avoids shortfalls throughout 2010 to 2020 projects recovered R-22 to be approximately 14,800 metric tons in 2010, followed by 22,000 metric tons in 2015 and 18,200 metric tons in 2020 (i.e., Scenario 50). A lower recovery rate scenario also could provide a no-shortfall situation; for example a recovery rate scenario of 36 percent is the smallest recovery rate necessary to adequately meet demand starting in 2015. For comparison, as noted in Table 4-3, in 2006 a total of 3,872 metric tons of HCFC-22 was reclaimed, which amounts to approximately four percent of total HCFC-22 consumption in 2006 (according to data from EPA's ODS Tracking System). (The amount of refrigerant recovered, recycled and reused without being reclaimed is not known.) If the 2006 level of reclamation remains constant, reclaimed R-22 would fulfill only 26 percent of the supply of R-22 from recovered refrigerant as projected to be available under Scenario 50 in 2010, dropping to approximately 20 percent in 2015 and 2020. A further discussion on recovery practices is provided in Section 4.3.3.

Figure 4-2a: Total Projected R-22 Servicing Demand, Recovery Scenario 15[a,b]



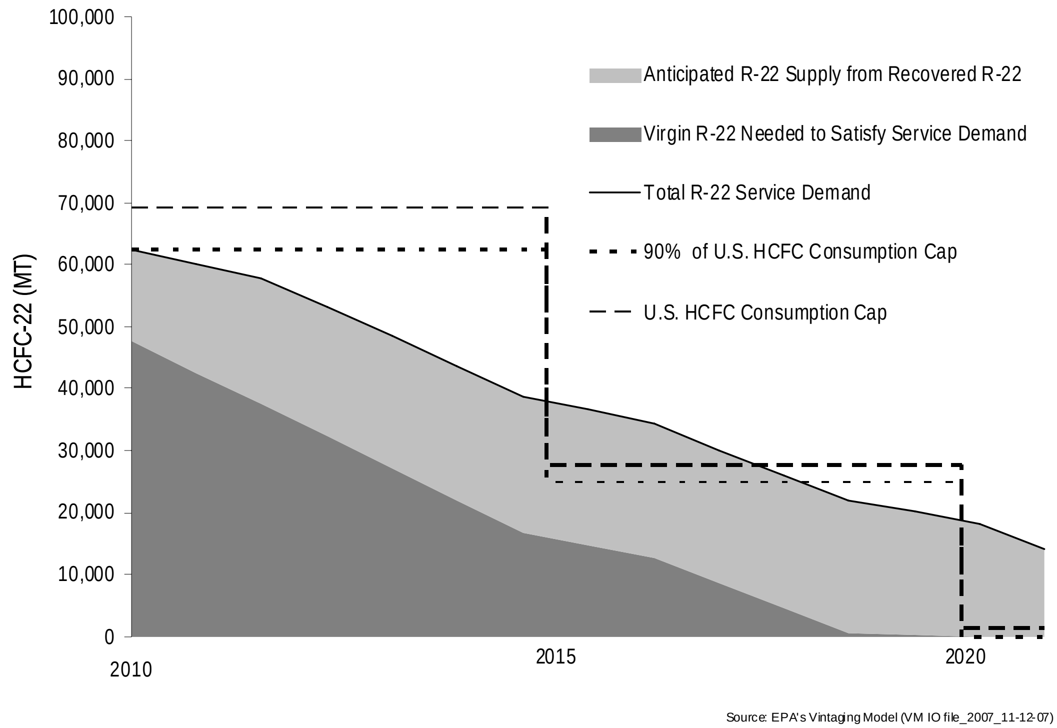
[a] Potential consumption cap allocations expressed in R-22 un-weighted metric tons (calculated using an ODP of 0.055 for HCFC-22).
[b] In 2020, 0.5 percent of the U.S. consumption baseline remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining baseline to R-22.

Figure 4-2b: Total Projected R-22 Servicing Demand, Recovery Scenario 20[a,b]



[a] Potential consumption cap allocations expressed in R-22 un-weighted metric tons (calculated using an ODP of 0.055 for HCFC-22).
[b] In 2020, 0.5 percent of the U.S. consumption baseline remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining baseline to R-22.

Figure 4-2c: Total Projected R-22 Servicing Demand, Recovery Scenario 50[a,b]



[a] Potential consumption cap allocations expressed in R-22 un-weighted metric tons (calculated using an ODP of 0.055 for HCFC-22).
[b] In 2020, 0.5 percent of the U.S. consumption baseline remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining baseline to R-22.

4.3 Factors Affecting Projections

Several market dynamics will have an effect on the projections of future servicing needs for R-22. Certain equipment specification requirements, the transition to alternative refrigerants, the stockpiling of refrigerant as well as equipment manufactured with HCFCs for sale after the phaseout, and the import of equipment pre-charged with HCFC refrigerant can all potentially alter the projected servicing scenarios. Each of these issues is discussed further below.

4.3.1 13 Seasonal Energy Efficiency Ratio (SEER)

In 2001, the U.S. Department of Energy (DOE) published a rule setting a stricter seasonal energy efficiency ratio (SEER) standard for residential unitary ACs and heat pumps. The minimum efficiency standard of residential unitary ACs and heat pumps was raised by 30 percent to a 13 SEER for all such units manufactured for sale on or after January 23, 2006 (DOE 2001; DOE 2004).

According to industry representatives, residential AC equipment will generally require a larger charge size to meet this standard because efficiency improvements are often achieved by increasing the size of the evaporator and condenser, which in turn requires an increase in refrigerant charge (Powell 2004; Honeywell 2005; ARI 2005; Carrier Corporation 2005a). It is not expected that these changes will affect equipment lifetime, leak rates, or the frequency of servicing (ARI 2005). The average central AC unit sold in 2004 was approximately 11.5 SEER, with an average charge size of around 3.4 kilograms (7.5 pounds) (ARI 2005).[21] More recent data for 2007 sales indicate that approximately five out of every six AC units sold to homeowners were 13 SEER through June of 2007 (with the remainder 14 SEER or higher) (Skaer 2007).

[21] Typical factory charges for cooling only equipment are around three kilograms (6.6 pounds); however, the average unit considered accounts for heat pumps, which have a higher charge size and make up between 15 to 25 percent of the residential AC and heat pump market (ARI 2005; Carrier Corporation 2005a).

Consequently, the amount of R-22 contained in new residential AC systems starting in 2006 has increased, resulting in an increase in projected servicing demand (assuming that service and leak losses, as a percentage of the equipment charge, do not change as a result). The projections provided in this analysis incorporate the additional R-22 that is expected to be needed to service higher efficiency residential AC equipment after 2010 (see Appendix A for more details).

4.3.2 Transitioning to Alternative Refrigerants

A wide range of alternative refrigerants found acceptable under EPA's SNAP program is available in the AC and refrigeration sector. Hydrofluorocarbons (HFCs) and HFC-based alternatives, including R-134a, R-410A (composed of HFC-32/HFC-125), R-407C (composed of HFC-32/HFC-125/HFC-134a), R-404A (composed of HFC-125/HFC-143a/HFC-134a), and R-507A (composed of HFC-125/HFC-143a), are currently used in a variety of refrigeration and AC sectors. The pace of transition to equipment production with these alternatives has varied by industry and type of equipment. Several AC and refrigeration equipment manufacturers have indicated that they will completely phaseout the production of equipment that uses R-22 prior to 2010 (York 2005; Hill Phoenix 2005). These plans are consistent with the actions found in the mid-1990s, when the refrigeration and AC industries phased out CFC refrigerants from new production chillers, refrigerators, motor vehicle air conditioners and other products two or more years before the 1996 CFC consumption phaseout. However, recent industry research has indicated that the majority of the equipment manufacturers will delay HCFC transitions until absolutely necessary, with R-22 charged equipment produced until January 1, 2010.

HFC alternatives to R-22 are greenhouse gases (GHGs) with high global warming potentials. Further adding to the uncertainty of transitioning away from R-22 is whether the future refrigerant market may be affected by the potential introduction of climate change legislation in the United States. It remains to be seen how the details of climate legislation may delay or accelerate a transition away from equipment containing HCFC-22 and refrigerant blends containing HCFC-22 and/or HCFC-142b.

In projecting servicing needs, this analysis accounts for delayed transition trends that maintain production of new HCFC-22 equipment until December 31, 2009, discussed in further detail below. Additionally, Appendix A contains the specific transitions used in the modeling for this analysis.

Air-Conditioning Industry

R-134a, R-410A, and R-407C are currently being used to replace R-22 in some new stationary and mobile AC equipment, a trend that is expected to continue as R-22 is phased out. Some mobile AC equipment has been using alternatives since the early 1990s, with some buses and trains using R-134a, and some heavy rail cars using R-407C (WMATA 2005; Amtrak 2005; Motorcoach Training 2005; Greyhound 2005; Carrier Corporation 2005b). Stationary AC equipment using R-410A has been commercially available since 1996 (HARDI 2004), and is expected to dominate the U.S. residential market in the future (EPA 2004b).

Despite the availability of alternatives, more than 90 percent of residential AC split-systems sold in 2004 were still charged with R-22 (Honeywell 2005). According to a survey conducted by Emerson Climate Technologies in November 2007, 40 percent of the contractors and distributors will wait until 2010 to convert their sales to equipment containing alternative refrigerant (Emerson 2007). AC equipment manufacturers indicated that, while the transition to buying commercial equipment that uses alternatives has occurred in the past few years, consumers will likely continue to buy residential equipment that uses R-22 until the phaseout date, especially if R-22 remains cheaper than the alternatives (York 2005).

To be conservative, the projections in this analysis are based on slower transitions to alternatives. For example, new sales of residential AC systems are modeled such that only 10 percent of the market adopts alternatives by the end of 2008 and the remainder of the market transitions completely by the end of 2009 (see Appendix A for more details). A more quickly paced adoption of alternatives by the AC-manufacturer and end-user community will have the effect of lowering the overall servicing demand of R-22 charged equipment post-2010 and lessen the risk of potential shortfalls as projected in Scenarios 15 and 20 of this analysis. Because consumers of residential AC equipment may not be as informed about the phaseout as commercial consumers, equipment manufacturers and dealers can encourage the transition away from R-22 by communicating to consumers the implications of the HCFC phaseout.

Refrigeration Industry

Industry experts have indicated that retail food refrigeration end-uses are transitioning to alternatives more quickly than AC end-uses; the projections in this analysis are based on modeling that reflects this industry's input. The majority of existing U.S. supermarkets still use R-22 in their refrigeration systems, with only a few supermarket chains having converted all of their existing stores to use ODS alternatives (Hill Phoenix 2005; FMI 2004).[22] Although the life expectancy of commercial refrigeration equipment is around 20 years, supermarkets tend to remodel every seven to 10 years, which offers supermarkets the opportunity to install new equipment that uses an alternative more often than the typical equipment lifetime would imply (Hill Phoenix 2005). A source noted in 2005 that within the next five to 10 years, it is anticipated that approximately 200 to 300 existing stores per year will undergo retrofits and transition away from R-22 in the United States (Honeywell 2005); the majority of approximately 34,000 supermarkets in the United States currently use R-22 (EPA 2008b).

In new supermarket construction, the transition away from HCFCs has been occurring at a steady pace, more quickly than that seen in the stationary AC industry. About 65 percent of new stores being constructed are using ODS alternatives—a trend that is growing and expected to continue over time (Hill Phoenix 2005).

4.3.3 Recovery and Reuse Practices

As indicated in the total projected R-22 servicing demand scenarios presented in Section 4.2, recovered R-22 that is recycled, stockpiled, or reclaimed must increase to satisfy future servicing needs that cannot be met through virgin supplies alone. According to the projections of this analysis:

- In 2010, the amount of recovered refrigerant is projected to range from 4,500 to 14,800 metric tons, depending on the percentage of total available refrigerant from retired or converted equipment that is recovered and reused;
- In 2015, when no more than 27,709 metric tons of virgin R-22 production and import is allowed under the cap, overall servicing demand is estimated to reach 38,800 metric tons, therefore requiring at least 11,091 metric tons of recovered R-22. Scenario 50 projects sufficient amounts of recovered material (i.e., 22,000 metric tons) to meet this demand, whereas, the projected quantities under Scenarios 15 and 20 do not (i.e., 6,600 metric tons and 8,800 metric tons, respectively, or, approximately 40 and 20 percent lower than needed to prevent a shortfall).[23]
- In 2020, Scenario 50 projects sufficient supplies of recovered R-22 to meet projected 2020 servicing demand (i.e., 18,200 metric tons). Conversely, the estimated projections of 6,200 metric tons and 8,300 metric tons of recovered R-22 under Scenarios 15 and 20 will not be enough to meet total projected demand, as no virgin manufacture is allowed under the cap.

Although the potential for supply shortages is projected to occur after 2010, thorough maintenance practices during the lifetime of equipment, recovery practices at the time of equipment disposal or decommissioning, and the full penetration of reclaim and reuse practices can greatly reduce the likelihood of future shortfalls.

The use of recovery procedures during the lifetime of equipment and at the time of decommissioning reduces potential losses to a future supply of recovered refrigerant. End-users of AC and refrigeration equipment must have equipment installed by trained technicians. They must also have their equipment properly maintained in order to reduce incidences of major leaks. Service technicians must take efforts to

[22] For example, 56 percent of supermarket refrigeration systems were using R-22 in 2001 within the South Coast Air Quality Management District (SCAQMD), a four county region with a population of 15 million people in southern California (Bivens and Gage 2004). As of 2004, one supermarket chain with over 100 stores reported only 28 percent R-22 out of their entire refrigerant use (FMI 2004).
[23] Note that these numbers are calculated assuming the entire cap is allocated to HCFC-22 production, which is unlikely to occur due to the needs for continued production of other HCFCs.

isolate components or recover refrigerants prior to service as venting (releasing) HCFC (and CFC and HFC) refrigerant when making repairs is illegal. Service practices that involve locating and repairing leaks in lieu of "topping off" leaking systems further ensure future supplies of used refrigerant. As with servicing procedures, the venting of refrigerant during decommissioning is illegal. The AC and refrigeration community, including end-users, service technicians, and all affected stakeholders, must position itself for future phaseouts of HCFCs by using proper recovery techniques and complying with regulations that are in place to promote the growth of recoverable and reusable R-22.

Furthermore, the practice of reusing recovered and reclaimed R-22, while currently minimal (less than 3,900 metric tons of HCFC-22 was reclaimed in 2006), can increase future supplies once fully realized. Should current reclamation levels of R-22 remain constant or not increase significantly, a sufficient supply of reusable refrigerant will *not* be available to meet servicing demand projections. In order to reach the projected supply of recovered refrigerant necessary to meet demand, a four to six-fold increase in current (as of 2006) reclamation levels would be required.[24] Recent industry information indicates the current business model for R-22 reclamation and related infrastructure will not support this projected demand (Honeywell 2006). However, as prices for virgin R-22 increase and reclaimers increase their capacity in anticipation of the future reclamation market, the reclamation market is expected to grow (CFC Refimax 2006). With the potential for an imbalance in future supply and demand, this type of growth in this market is an essential component in the AC and refrigeration industry strategy to prepare for the HCFC phaseout.

4.3.4 Recycling and Stockpiling Plans

As a preparation strategy for the 2010 phaseout, refrigerant recycling plans could evolve into banking or stockpiling plans. With proper storage tanks, a reserve of recycled R-22 can be collected, stored, and accessed to service equipment owned by the same company years later, when R-22 is expected to be less affordable and less available. A report released in 1995 by the Food Marketing Institute (FMI) included a survey issued to supermarket operators on the use of refrigerant management plans (RMP) as a strategy to ensure an adequate supply of CFC refrigerants for use after the December 31, 1995 CFC production phaseout. Of those surveyed, 52 percent were banking recovered CFC refrigerant, an activity adopted primarily by store operators with 11 or more stores (FMI 1995).

Although the extent to which such refrigerant management plans for HCFCs are currently in place is unknown, it is possible that the AC and refrigeration industry will increasingly adopt such plans and bank refrigerant in preparation for the HCFC phaseout, especially those that own a large number of stores. In addition to supermarkets, businesses that operate chillers, industrial process refrigeration, and/ or multiple AC units, as well as other multi-facility operations, also have the opportunity to internally bank refrigerant to meet future servicing needs.

While refrigerant banking is a strategy that companies may pursue, the lack of data has limited the projections in this report from quantifying stockpiles from refrigerant management plans. The banking of refrigerant may impact the results of this analysis by impacting future availability of recovered and reusable refrigerant. Stockpiling refrigerant ensures additional supply for a given user for later years, but there is some concern refrigerant will not be stockpiled due to clogging floorspace needed for more profitable inventory (Dyslin 2006). However, a large end-user stockpiling R-22, which may otherwise re-enter the market after being reclaimed, could result in the premature shortage of reusable refrigerant for other R-22 users (see Appendix A for more information).

Stockpiling of virgin R-22 also may be pursued, particularly prior to 2020 when production is entirely phased out; however, it is premature to state the extent to which this option will be technically and economically viable. As such, projections on future inventories of virgin stockpiles are not explored further in this analysis.

[24] This increase assumes that the demand projected by the Vintaging Model would be met solely by reclaimed refrigerant. Sources other than reclaimed refrigerant could also meet this demand, including recovery, recycling and direct reuse of refrigerant in the owner's equipment (without reclamation), stockpiled refrigerant, and potential supply of refrigerant from used imports.

4.3.5 R-22 Economics

Another factor that affects the projections of R-22 servicing supply and demand is the cost of virgin and reclaimed R-22. The relatively low cost of virgin R-22 is currently weakening the demand for reclaimed refrigerant, which is more expensive in comparison. Over time, as the supply of virgin R-22 decreases, it is expected that the demand for recovered and reclaimed refrigerant as well as R-22 alternatives will increase. To that end, reclaimers of R-22 and manufacturers of R-22 alternatives will experience economies of scale and their prices will fall, causing a shift in pricing structures. However, spot shortages of R-22 may occur, as was seen with the phaseout of CFC-12.

As a result of the increase in demand, along with other economic factors, recent price increases in R-22 have been observed (CFC Refimax 2006). Early market signals, such as this one, will likely encourage an increase in the demand for recovered R-22 and the transition to alternative refrigerants.

4.3.6 Pre-charged Imports

AC equipment pre-charged with HCFCs is currently imported into the United States predominantly from Korea, Brazil, and China. In recent years, there has been a shift to overseas manufacturing; the number of imports of AC equipment into the United States is on the rise (UNEP 2003a; U.S. Census Bureau 2007). Central AC systems from foreign manufacturers such as Samsung, LG, and Haier are entering the U.S. market. Additionally, some U.S. manufacturers are starting to relocate plants to Mexico and other countries (Honeywell 2005), while others import equipment from international manufacturers that is then sold under their labels (HARDI 2005).

Effective January 1, 2010, domestic manufacturers of air-conditioning (AC) and refrigeration appliances will not be able to charge newly manufactured appliances with newly produced or imported HCFC-22 or HCFC-142b, and thus will not be introducing appliances containing these newly produced substances into interstate commerce. However, the regulatory provision does not lead to similar results for AC and refrigeration equipment that has been “pre-charged” with refrigerant before entering the United States. EPA is evaluating the implications of proposing a January 1, 2010 ban that would prohibit the sale or distribution of pre-charged units imported after that date and this analysis inherently assumes a ban on imported pre-charged products beginning in 2010. However, should R-22 pre-charged units continue to enter the United States after 2010, it would have the effect of increasing the overall servicing demand of R-22 charged equipment post-2010, adding further concern to the risk of potential shortfalls as projected in Scenarios 15 and 20 of this analysis. Initial estimates indicate that a projected average annual total of pre-charged R-22 imports could range from 10.7 million to 15 million units. Further details regarding the effects of a ban on import of appliances precharged with HCFCs is available in EPA’s e-docket (See EPA-HQ-OAR-2003-0130).

5. Conclusion

On January 1, 2010, production and import of HCFC-142b and HCFC-22 will be phased out except for on-going service needs for equipment manufactured on or before December 31, 2009. To support development of the allocation levels of HCFC-142b and HCFC-22 that will allow the U.S. to comply with the Montreal Protocol's 2010, 2015, and 2020 reduction steps, this report provides projections on the quantity of R-22 needed for servicing AC and refrigeration equipment manufactured on or before December 31, 2009.

Under the projected scenarios developed in this analysis, the AC and refrigeration industry is facing the potential risk of a shortage of R-22 starting in 2015 if practices to recover and reuse refrigerant are not increased. The findings indicate significant variance in the projected supply of recovered refrigerant available to meet demand depending on the future recovery and reuse of refrigerant. Only under scenarios with higher refrigerant recovery and reuse are supplies projected to satisfy future R-22 servicing needs using both recovered refrigerant and limited amounts of virgin refrigerant.

The total projected HCFC-22 servicing demand in 2010, 2015, and 2020 compared to a 100% allocation of the HCFC consumption cap are summarized below along with concluding points on the implications of the three recovery and reuse scenarios.

- In 2010, a projected servicing demand of 62,500 metric tons, or about 90 percent of the 2010 consumption cap, is estimated. Table 5-1 indicates that approximately 24 percent of this demand could be met with recovered refrigerant if 50 percent of the available refrigerant from decommissioned or converted equipment is recovered and reused; if only 15 percent of the available refrigerant is recovered and reused, only seven percent of the total demand can be met with recovered refrigerant. Similarly, under Scenario 20, only nine percent of the total demand can be met with recovered refrigerant.

Table 5-1: Comparison of HCFC Servicing Demand Projections (Metric Tons) and Necessary Supply Projections by Source (Metric Tons and Percent), 2010

2010	Scenario 15: 15% Recovery Rate	Scenario 20: 20% Recovery Rate	Scenario 50: 50% Recovery Rate
Cap[a]	69,273		
Demand	62,500		
Necessary Supply			
Recovered	4,500 (7%)	5,900 (9%)	14,800 (24%)
Virgin	58,000 (93%)	56,600 (91%)	47,600 (76%)
Shortfall	0(0%)	0(0%)	0(0%)

[a] HCFC consumption cap expressed in R-22 metric tons to represent an allocation of 100 percent of the cap assigned to R-22.
Source: Based on data analysis using EPA, 2007a.

- In 2015, a projected servicing demand of 38,800 metric tons is estimated, which is over the 2015 consumption cap by 40 percent. Under a scenario of higher recovery and reuse (Scenario 50), Table 5-2 indicates that supplies from used R-22 can satisfy enough of the demand such that a shortage of refrigerant supply does not occur. However, in the lower recovery rate scenarios (Scenarios 20 and 15), shortfalls of 2,291and 4,491 metric tons, respectively are projected.

Table 5-2: Comparison of HCFC Servicing Demand Projections (Metric Tons) and Necessary Supply Projections by Source (Metric Tons and Percent), 2015

2015	Scenario 15: 15% Recovery Rate	Scenario 20: 20% Recovery Rate	Scenario 50: 50% Recovery Rate
Cap[a]	27,709		
Demand	38,800		
Necessary Supply			
Recovered	6,600 (17%)	8,800 (23%)	22,000 (57%)
Virgin	32,200 (83%)	30,000 (77%)	16,800 (43%)
Shortfall	4,491 (12%)	2,291 (6%)	0 (0%)

[a] HCFC consumption cap expressed in R-22 metric tons to represent an allocation of 100 percent of the cap assigned to R-22.
Source: Based on data analysis using EPA, 2007a.

- In 2020, a projected servicing demand of 18,200 metric tons is estimated, although no consumption is allowed (Table 5-3:). Under Scenario 50, this demand is projected to be met entirely with recovered refrigerant. However, under scenarios of less recovery (Scenarios 20 and 15), only 34 and 45 percent of this demand is projected to be met with recovered refrigerant, leading to a shortfall of 9,900 and 12,000 metric tons of R-22.

Table 5-3: Comparison of HCFC Servicing Demand Projections (Metric Tons) and Necessary Supply Projections by Source (Metric Tons and Percent), 2020

2020	Scenario 15: 15% Recovery Rate	Scenario 20: 20% Recovery Rate	Scenario 50: 50% Recovery Rate
Cap[a]	0		
Demand	18,200		
Necessary Supply			
Recovered	6,200 (34%)	8,300 (46%)	18,200 (100%)
Virgin	0 (0%)	0 (0%)	0 (0%)
Shortfall	12,000 (66%)	9,900 (54%)	0 (0%)

[a] HCFC consumption cap expressed in R-22 metric tons to represent an allocation of 100 percent of the cap assigned to R-22. In 2020, 0.5 percent of the U.S. consumption baseline remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining baseline to R-22.
Source: Based on data analysis using EPA, 2007a.

Projections of future HCFC refrigerant supply and demand range depending on various market trends as addressed in this report. These projections provide the information necessary for taking initial steps in determining post 2010 servicing needs for R-22 equipment and ensuring that supplies are available by alerting the AC and refrigeration community of the critical need to adequately prepare for future HCFC phaseout dates. Continued collaboration with the AC and refrigeration community is needed to ensure that servicing demand for HCFC-based systems can be met in 2010 and beyond.

Appendix A: Methodology Used to Calculate Projected Servicing Needs

This appendix outlines the methodology used to calculate the projected servicing needs of AC and refrigeration equipment using R-22. This appendix contains three sections:

- Section A.1 provides an overview of EPA's Vintaging Model (EPA 2007a), which was used to establish the estimates of units of equipment using R-22 and R-22 servicing demand beyond 2010.
- Section A.2 details the assumptions used in a supplemental analysis that investigated the projected market of pre-charged AC imports and the associated servicing needs.
- Section A.3 discusses the limitations to the servicing projections presented in this report.

A.1 EPA's Vintaging Model

EPA's Vintaging Model was developed as a tool for estimating the annual chemical emissions from industrial sectors that have historically used ODS in their products. Emissions are estimated from the following end-use sectors: 1) Air-Conditioning and Refrigeration; 2) Foams; 3) Aerosols; 4) Solvents; 5) Fire-Extinguishing; and 6) Sterilants. Within these sectors, there are over 50 independently modeled end-uses. The model requires information on the market growth for each of the end-uses, as well as a history and projection of the market transition from ODS to alternatives. As ODS are phased out, a percentage of the market share originally filled by the ODS is allocated to substitutes.

The model, named for its method of tracking the emissions of annual "vintages" of new equipment that enter into service, is a "bottom-up" model. This means it models the consumption of controlled ozone-depleting substances and their substitutes based on:

1) Estimates of the quantity of equipment or products sold, serviced, and retired or converted each year, and
2) The quantity of the chemical required to manufacture and/or maintain the equipment.

The model makes use of this market information to build an inventory of in-use stocks of equipment and quantities of ODS/ODS substitutes in each of the end-uses.

Box A-1: Developing and Maintaining EPA's Vintaging Model

The Vintaging Model synthesizes data from a variety of sources, including:

- The ODS Tracking System and submissions to the SNAP program both maintained by the U.S. EPA Stratospheric Protection Division;
- Published literature from the United Nations Environment Programme (UNEP) Technical Options Committees, the Alternative Fluorocarbons Environmental Acceptability Study (AFEAS), and those provided in industry-related and EPA conference proceedings (such as the Earth Technologies Forum); and
- Numerous companies and trade associations, such as the Alliance for Responsible Atmospheric Policy, the Air-Conditioning and Refrigeration Institute, the Association of Home Appliance Manufacturers, and the American Automobile Manufacturers Association.

In some instances the unpublished information that the U.S. EPA uses in the model is classified as Confidential Business Information (CBI). The annual emissions inventories of chemicals are aggregated in such a way that CBI cannot be inferred.

The Vintaging Model is continually updated to improve assumptions and modeling techniques and refine inputs based on information learned from these sources. In both 2006 and 2007, the model was updated based on information obtained from industry. As such, the methodology used in the preliminary 2005 draft report of this analysis, which required adjusting initial estimates from the Vintaging Model, was replaced with a methodology that relies solely on straight model output for the revised analysis. Also, the assumptions and results from major air-conditioning and refrigeration end-uses were presented at the April 2007 Spring Meetings of the Air-Conditioning and Refrigeration Institute (ARI). Additional revisions were made to the model based on comments received on those presentations. Straight model output was used to update this report in December, 2007.

Emissions are estimated by applying annual leak rates, service emission rates, and disposal emission rates to consumption data for each vintage of equipment. Emissions from AC and refrigeration equipment are split into two categories: emissions during equipment lifetime and disposal emissions. This first category, emissions during equipment lifetime, includes the amount of compound leaked during equipment operation and the amount of compound emitted during service. Consumption required to service or refill equipment is driven by the demand to replace such losses, and therefore, emissions during the lifetime of equipment are equal to consumption for servicing (since it is assumed that all leaked refrigerant is eventually replaced). Emissions, and therefore, consumption from leakage and servicing can be expressed as follows:

$$\mathbf{Es_j = (l_a + l_s) \times \Sigma\, Qc_{j-i+1} \text{ for } i=1 \rightarrow k}$$

Where:

Es =	Emissions from Equipment Serviced. Emissions in year j from normal leakage and servicing of equipment.
la =	Annual Leak Rate. Average annual leak rate during normal equipment operation (expressed as a percentage of total chemical charge).
ls =	Service Leak Rate. Average leakage during equipment servicing (expressed as a percentage of total chemical charge).
Qc =	Quantity of Chemical in New Equipment. Total amount of a specific chemical used to charge new equipment in a given year by weight.
i =	Counter, runs from 1 to lifetime (k).
j =	Year of emission.
k =	Lifetime. The average lifetime of the equipment.

The assumptions used in this calculation range by equipment and refrigerant, and vintage, reflecting that, as new technologies replace older ones, improvements in their leak, service, and disposal emission rates are assumed to occur.

For the purpose of this analysis, the following data from EPA's Vintaging Model were compiled and summarized for the AC and refrigeration sector:

1) <u>Consumption for Servicing</u>, which is equal to the demand to service (i.e., refill) existing equipment. These data are back-calculated using service and leak emissions because the quantity emitted during the lifetime of equipment drives the demand to replace such losses. These estimates are further distinguished between consumption of virgin and recycled/reclaimed chemical. The model assumes that a certain percentage of refrigerant, which varies by end-use, is recovered from discarded equipment. The model then assumes a "best-case" scenario in which all recovered and re-usable refrigerant re-enters the market. See Section A.3 for further discussion on this "recovery pool."

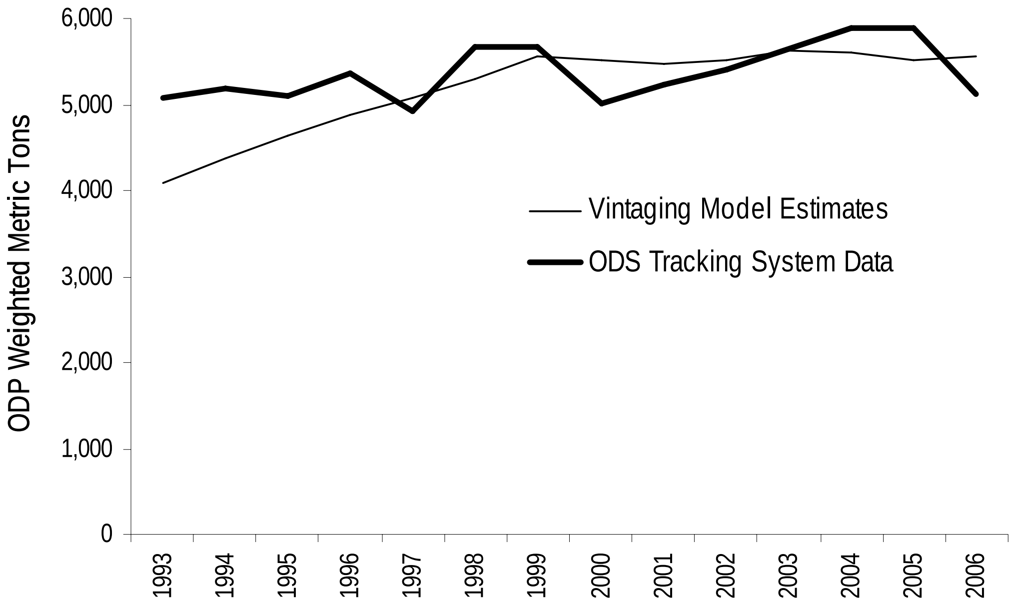
2) <u>Number of Units of Equipment</u>, which is equal to, for "*year X"*", the number of units existing in "*year* X-1" plus the number of new units produced in "*year X"* minus the number of units disposed in "*year X"*.

   For example:

   No. of Units in 1999 = No. of Units in 1998 + New Units in 1999 – Units Disposed in 1999

Historical data estimated by EPA's Vintaging Model is often cross-checked with actual historical data from EPA's ODS Tracking System, which tracks actual ODS production and consumption (including import and export) by U.S. companies. The Model's virgin manufacture parameter is considered to be most comparable to the Montreal Protocol's definition of consumption (i.e., production plus imports minus exports minus destruction). In EPA's Vintaging Model, the Virgin Manufacture parameter is calculated to be any need for consumption (either for new equipment or servicing) that cannot be met through recycled or recovered material; no distinction is made in the Vintaging Model between whether that need is met through domestic manufacturing or imports. As shown in Figure A-1, estimates from the model generally align rather well to actual consumption from 1993 to 2006.

Figure A-1: Comparison of EPA's Vintaging Model Estimates for Virgin Manufacture and ODS Tracking System Data for HCFC-22 Consumption



Source: EPA's ODS Tracking System, Vintaging Model (VM IO file_11-12-07)

Table A-1 presents the input assumptions used to develop the projections presented in this report. The loss rates represent the percent of the total charge that leaks in a given year plus the amount, on an annual basis, emitted at service, expressed as a percentage of total chemical charge. Because the amount lost from leaks and servicing is annualized, equipment is assumed to reach the end of its lifetime with a full charge.[25] EPA's Vintaging Model then applies a "recovery rate," which refers to the percent of total charge of the equipment that is recovered and reused at the time of disposal. These recovery rates represent averages, intended to capture the range of possible practices occurring at disposal.

Growth rate assumptions are also provided in Table A-1. The growth rates refer to the growth of the consumption market for each end-use as a whole and are not specific to the refrigerant. When the transition to different equipment and different refrigerants occur, the input assumptions are adjusted to account for these changes.

[25] For the majority of equipment types, the assumption that equipment contains a full charge at the end of life is theoretically applicable. In order to ensure proper and continual functioning of equipment, homeowners and businesses typically have their air-conditioning and refrigeration systems serviced regularly. Technicians will check these systems for leaks using proper techniques and if a loss of refrigerant is found, will refill the system to ensure it is functioning efficiently after repairing any leaking seals or damaged components. Note that this assumption may not be appropriate for smaller equipment types such as window units but must be applied consistently for modeling purposes.

Table A-1: Input Assumptions, Years 2005 to 2020

Current Refrigerant	Equipment Type and Original ODS Refrigerant	Charge Size[a]	Loss Rate	Growth Rate[b]	Recovery Rate	Lifetime (Years)
AC Equipment						
R-22	HCFC-22 Residential Unitary A/C (2005-2006)	3	12%	1.9%	35%	15
R-22	HCFC-22 Residential Unitary A/C (2006-2020)	5	12%	1.9%	35%	15
R-22	R-22 Small Commercial Unitary AC	8	11%	2.5%	40%	15
R-22	R-22 Large Commercial Unitary AC	15	10%	2.5%	40%	15
R-22	R-22 Water & Ground Source Heat Pumps	4	5%	2.5%	57%	20
R-22	R-22 Dehumidifiers	0	1%	0.2%	50%	11
R-22	R-22 Packaged Terminal Units	1	5%	2.5%	35%	12
R-22	R-22 Window Units	1	1%	5.0%	50%	12
R-22	R-12 School & Tour Buses	5	10%	2.6%	50%	12
R-22	R-22 Transit Buses	8	44%	2.6%	50%	12
R-22	R-22 Trains	22	44%	2.6%	50%	5
R-22	R-11 Centrifugal Chillers	700	5%	0.5%	80%	25
R-22	R-12 Centrifugal Chillers	721	5%	0.5%	80%	27
R-22	Reciprocating Chillers	230	1%	0.2%	80%	20
R-22	Screw Chillers	300	1%	0.5%	80%	20
R-22	Scroll Chillers	240	1%	0.5%	80%	20
R-22	R-500 Chillers	926	5%	0.5%	80%	27
Refrigeration Equipment						
R-22	R-12 Cold Storage	<0.01	20%	2.5%	80%	20
R-22	R-22 Cold Storage	<0.01	20%	2.5%	80%	20
R-22	R-502 Cold Storage	<0.01	20%	2.5%	80%	20
R-502	R-502 Cold Storage	<0.01	25%	2.5%	80%	20
R-22	CFC-12 Large Retail Food	1,800	30%	1.7%	80%	15
R-502	CFC-12 Large Retail Food	1,800	33%	1.7%	80%	15
R-502	R-502 Large Retail Food	1,800	33%	1.7%	80%	15
R-22	R-502 Large Retail Food	1,800	30%	1.7%	80%	15
R-22	HCFC-22 Medium Retail Food	3	8%	1.7%	80%	20
R-22	R-12 Small Retail Food	1	8%	1.7%	35%	20
R-22	R-12 Transport	8	28%	2.5%	35%	12
R-402A	R-12 Transport	8	28%	2.5%	35%	12
R-401A	R-502 Transport	8	28%	2.5%	10%	12
R-502	R-502 Transport	8	33%	2.5%	10%	12
R-22	R-11 Industrial Process Refrigeration	952	10%	2.5%	80%	25
R-22	R-12 Industrial Process Refrigeration	992	10%	2.5%	80%	25
R-401A	R-12 Industrial Process Refrigeration	850	5%	2.5%	90%	25
R-22	R-22 Industrial Process Refrigeration	9,100	12%	2.5%	80%	25

Source: VM IO File_11-12-2007

[a] Charge size presented in kilograms. Cold storage charge size presented in kilograms/cubic foot.

[b] The growth rate applies to new consumption/virgin manufacture. For example, in the window units market, any year's consumption is five percent greater than the previous year's consumption.

Table A-2 presents the assumptions used to model the transition from R-22 to alternatives for each end use. Only those end-uses that have been using R-22, or have in whole or in part transitioned to use R-22, are shown. The first column of the table presents the R-22 equipment types by the refrigerants that they originally used. The second column presents the refrigerants that enter the market and are used in new equipment in place of R-22.[26] These refrigerants begin to enter the new-equipment market in the year presented in the fourth column and fully penetrate this market by the date presented in the fifth column. The final column indicates the percent of the R-22 new-equipment market that the given substitute refrigerant replaces by the transition end date. All transitions are assumed to occur linearly between the transition start and end dates. By combining multiple transitions to different refrigerants and over different time periods, the Vintaging Model mimics actual, non-linear transitions that may occur.

Table A-2: Transition to Alternatives Assumptions of EPA's Vintaging Model for R-22 Refrigeration and AC Equipment[a]

1	2	3	4	5
R-22 Equipment Type and Original ODS Refrigerant	Substitute	Start Date	End Date	Market Penetration of Substitute[b]
HCFC-22 Residential Unitary AC	R-407C	2006	2009	1%
		2009	2010	5%
	R-410A	2001	2005	5%
		2006	2009	8%
		2009	2010	81%
HCFC-22 Small Commercial Unitary AC	R-410A	1996	2000	3%
		2001	2005	18%
		2006	2009	8%
		2009	2010	71%
HCFC-22 Large Commercial Unitary AC	R-407C	2006	2009	1%
		2009	2010	5%
	R-410A	2001	2005	5%
		2006	2009	9%
		2009	2010	81%
HCFC-22 Water & Ground Source Heat Pumps	R-407C	2000	2006	5%
		2006	2009	3%
		2009	2010	23%
	R-410A	2001	2006	5%
		2006	2009	5%
		2009	2010	41%
	R-134a	2000	2009	2%
		2009	2010	18%
HCFC-22 Dehumidifiers	R-134A	1997	1997	89%
	R-410A	2007	2010	11%
HCFC-22 Packaged Terminal Units	R-410A	2006	2009	10%
		2009	2010	90%
HCFC-22 Window Units	R-407C	2003	2009	3%
		2009	2010	35%
	R-410A	2003	2009	7%
		2009	2010	55%
CFC-12 Tour Buses	R-134A	2006	2007	100%
HCFC-22 Transit Buses	R-134A	1995	2009	100%
HCFC-22 Trains	R-134a	2002	2009	50%
	R-407	2002	2009	50%

[26] These transition assumptions are for new equipment only; they do not imply that the original equipment was retrofitted to the alternative refrigerants.

1	2	3	4	5
R-22 Equipment Type and Original ODS Refrigerant	Substitute	Start Date	End Date	Market Penetration of Substitute[b]
CFC-12 Cold Storage	R-404A	1996	2010	75%
	R-507A	1996	2010	25%
HCFC-22 Cold Storage	R-404A	1996	2009	8%
		2009	2010	68%
	R-507A	1996	2009	3%
		2009	2010	23%
R-502 Cold Storage	R-404A	1996	2010	38%
	R-507A	1996	2010	12%
	Other	1996	2010	50%
CFC-11 Industrial Process Refrigeration	R-134A	1995	2010	100%
CFC-12 Industrial Process Refrigeration	R-134A	1995	2010	15%
	R-404A	1995	2010	50%
	R-410A	1999	2010	20%
	R-507A	1995	2010	15%
HCFC-22 Industrial Process Refrigeration	R-134A	1995	2009	2%
		2009	2010	14%
	R-404A	1995	2009	5%
		2009	2010	45%
	R-410A	1999	2009	2%
		2009	2010	18%
	R-507A	1995	2009	2%
		2009	2010	14%
CFC-12 Retail Food	R-404A	2000	2009	8%
	R-507A	2000	2009	3%
	R-134a	1993	1995	90%
HCFC-22 Retail Food	R-404A	1995	2000	18%
		2000	2005	32%
		2005	2010	18%
	R-507A	1995	2000	8%
		2000	2005	14%
		2005	2010	12%
R-502 Retail Food	R-404A	1995	2000	18%
		2000	2005	32%
		2005	2010	18%
	R-507A	1995	2000	8%
		2000	2005	14%
		2005	2010	12%
CFC-12 Transport	R-134A	1995	1999	100%
R-502 Transport[c]	R-134A	1993	1995	55%
	R-404	1993	1995	45%
HCFC-22 Screw Chillers	R-134a	2000	2009	9%
		2009	2010	81%
	R-407C	2000	2009	1%
		2009	2010	9%
HCFC-22 Scroll Chillers	R-134a	2000	2009	9%

1	2	3	4	5
R-22 Equipment Type and Original ODS Refrigerant	Substitute	Start Date	End Date	Market Penetration of Substitute[b]
		2009	2010	81%
	R-407C	2000	2009	1%
		2009	2010	9%
CFC-12 Reciprocating Chillers	R-410	2010	2020	40%
CFC-11 Centrifugal Chillers	R-134A	2000	2010	100%
CFC-12 Centrifugal Chillers	R-134A	2000	2010	100%
R-500 Chillers	R-134A	2000	2010	100%

Source: VM IO File_11-12-2007

[a] Interim transitions (e.g., from a CFC to HCFC-22 to HFCs) are not shown. For example, the retail food new-equipment market that originally used R-12 first transitioned from R-12 to R-502 and then to R-22. Then, between 1995 and 2010, 67 percent of the R-22 new-equipment market is assumed to transition to R-404A and the remaining 33 percent to R-507A.

[b]The market penetration of the substitute represents the percent of the R-22 new-equipment market that is replaced by the substitute refrigerant.

[c]The R-502 transport refrigeration market transitions directly to R-134a and R-404A. There is no interim transition to R-22.

A.2 Limitations and Caveats

This analysis utilized the best data available from various sources. However, when making projections several assumptions are required. EPA's Vintaging Model was used to determine the quantities of R-22 from existing (recycled or reclaimed) sources that can meet post-2010 servicing needs and the remaining quantities required through virgin manufacture. For a given year, the model assumes that a certain percentage of refrigerant, which varies by end-use, is recovered from discarded equipment, while the remainder is emitted. The model aggregates the quantities recovered but does not distinguish the "pool" of refrigerant between quantities that are reclaimed versus those that are recycled. The model then assumes that the entire pool of recovered refrigerant re-enters the market within the same year; any additional demand for refrigerant, above that which is thus assumed to be met by recovered refrigerant, is calculated to be virgin manufacture. It is important to note that the recovery pool and the remaining virgin manufacture can be evaluated only at the most aggregate level, across all end-uses, and not at the end-use level, as the model does not serve to differentiate between virgin and recycled refrigerant when calculating demand for each end-use. This model attribute reflects a more realistic scenario in that reclaimers are not likely to only sell back to the end-use market sector from which the used refrigerant originated; rather, reclaimed refrigerant can be retailed to the overall AC and refrigeration industry.

Under this modeled approach, the following caveats should be noted:

- The model does not consider the quantity of refrigerant that companies send off for destruction (generally through incineration) after equipment is decommissioned. Although the quantities of destroyed refrigerant are very small, they are *not* subtracted from the recovered pool, so the quantity available for reuse may be slightly overestimated in the model.
- The model does not account for any stockpiling of recovered refrigerant beyond a one-year timeframe, as discussed in Section 4.3. To the extent that stockpiling activities occur over the next few years, the quantity of recovered refrigerant modeled as re-entering the market may be overestimated in earlier years (i.e., when refrigerant is banked), and the quantity modeled as re-entering the market in later years may be underestimated (i.e., when the accumulated bank is accessed as a source).

Appendix B: HCFC Projections by End-Use

This Appendix provides estimates of the projected installed base of R-22 equipment by end-use and the projected quantities of R-22 needed to service AC and refrigeration equipment. Descriptions of end-uses are provided in Section 3 of the report. For the purpose of this analysis, data on HCFC blend consumption for servicing are divided among the corresponding HCFC constituent(s) of that blend, according to the percent composition. However, in order to accurately portray the number of units containing R-22, blends are not disaggregated when presenting the number of units of equipment (i.e., a unit running on a blend containing HCFC-22 counts as one unit).

Table B-1 presents the number of units of equipment using R-22 (or a blend containing R-22) that are estimated to be in use in 2010, 2015, and 2020; current estimates representing 2007 also are provided. These estimates were developed based on EPA's Vintaging Model, which takes into account recent input from industry representatives (EPA 2007a). Sections 3.1 and 3.2 provide an overview of these AC and refrigeration end-uses.

Table B-1: Estimated Number of R-22 Units Installed[a]

Equipment Type	2007	2010	2015	2020
Window Units	75,031,300	74,178,600	41,559,500	4,102,700
Packaged Terminal Units	2,719,200	2,478,800	1,355,100	123,100
Residential Unitary AC	51,500,000	46,884,600	29,197,700	10,709,100
Small Commercial Unitary AC	18,821,200	17,097,500	10,666,800	4,291,400
Large Commercial Unitary AC	1,982,200	1,849,900	1,208,600	505,200
Chillers	417,500	443,900	326,300	202,800
Dehumidifiers	1,453,300	1,282,100	670,200	0
Water & Ground Source Heat Pumps	1,445,700	1,392,000	1,058,200	681,000
Other Mobile AC	44,900	25,900	6,700	0
Subtotal AC	153,415,300	145,633,300	86,049,100	20,615,300
Retail Food	4,452,900	3,770,900	2,107,300	924,700
Refrigerated Transport	4,900	0	0	0
Industrial Process Refrigeration	8,500	8,700	7,500	5,600
Subtotal Refrigeration	4,466,300	3,779,600	2,114,800	930,300
Total	157,881,600	149,412,900	88,163,900	21,545,600

[a]Cold Storage is not shown in this table because the model estimates this end-use based on cubic feet of storage, rather than number of units.

Table B-2 presents the metric tons of R-22 estimated to be needed to service AC and refrigeration equipment in 2010, 2015, and 2020; current estimates representing 2007 also are provided.

Table B-2: Projected R-22 Servicing Demand (Metric Tons)

Equipment Type	2007	2010	2015	2020
Window Units	300	300	100	<50
Packaged Terminal Units	100	100	<50	<50
Residential Unitary AC	21,700	20,700	13,500	6,100
Small Commercial Unitary AC	15,600	14,100	8,800	3,500
Large Commercial Unitary AC	3,000	2,800	1,800	800
Chillers	3,300	3,300	1,300	700
Dehumidifiers	<50	<50	<50	0
Water & Ground Source Heat Pumps	300	300	200	100
Other Mobile AC	200	100	<50	0
Total AC	44,500	41,700	25,900	11,300
Cold Storage	1,100	1,100	800	600
Retail Food	14,300	10,900	4,900	1,100
Refrigerated Transport	<50	0	0	0
Industrial Process Refrigeration	8,800	8,900	7,200	5,400
Total Refrigeration	24,200	20,800	12,800	7,000
Total	68,700	62,500	38,800	18,200

Appendix C: Additional "Recovery Rate" Scenarios

This report closely examines three scenarios of the potential amounts of used and recovered refrigerant available to service equipment—Scenarios 15, 20, and 50, which assumes that 15, 20, and 50 percent of refrigerant from retired or converted equipment is recovered and reused in equipment while the remainder is not available for reuse, respectively. Appendix C includes two additional scenarios, representing the lower and higher recovery rates of 10 and 75 percent, respectively.

Tables C-1and C-2 summarize the low (Scenario 10) and high (Scenario 75) scenarios in comparison to two U.S. HCFC consumption cap allocations. As shown in Table C-2, the projection of recovered supply under a 10% recovery rate scenario is insufficient to meet demand in 2015 and 2020 leading to shortfalls.

Table C-1: Scenario 10: 10% Recovery Rate: Summary of Projected R-22 Supply, Demand, and Surplus (R-22 Metric Tons)[a]

	2010	2015	2020
Projected R-22 Servicing Demand Summary			
Total R-22 servicing demand	62,500	38,800	18,200
Anticipated R-22 supplied from recovery/reuse	3,000	4,400	4,200
% of total R-22 servicing demand supplied by anticipated recovery/reuse	5%	11%	23%
Estimated virgin R-22 supply needed to satisfy remaining demand	59,500	34,400	14,100
Potential HCFC Consumption Cap Allocations			
Allocate 100% of HCFC Cap to R-22			
Virgin R-22 supply available under cap[b]	69,273	27,709	0[c]
Estimated virgin R-22 supply needed to satisfy remaining demand	59,500	34,400	14,100
Additional virgin R-22 allowable under cap	9,800	**-6,700**	**-14,100**
Allocate 90% of HCFC Cap to R-22			
Virgin R-22 supply available under cap[b]	62,345	24,938	0 [c]
Estimated virgin R-22 supply needed to satisfy remaining demand	59,500	34,400	14,100
Additional virgin R-22 allowable under cap	2,800	**-9,500**	**-14,100**

[a] Negative values represent a shortfall of R-22 available under the consumption cap and are in bold.
[b] Expressed in R-22 un-weighted metric tons (calculated using an ODP of 0.055 for HCFC-22).
[c] In 2020, 0.5 percent of the U.S. consumption baseline remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining baseline to R-22.
Source: Based on data analysis using EPA, 2007a.

As shown in Table C-2, the projection of recovered supply under a 75% recovery rate scenario illustrates that industry should have adequate supply if 75 percent of refrigerant from retired or converted equipment is recovered and re-enters the pool of refrigerant available to meet demand.

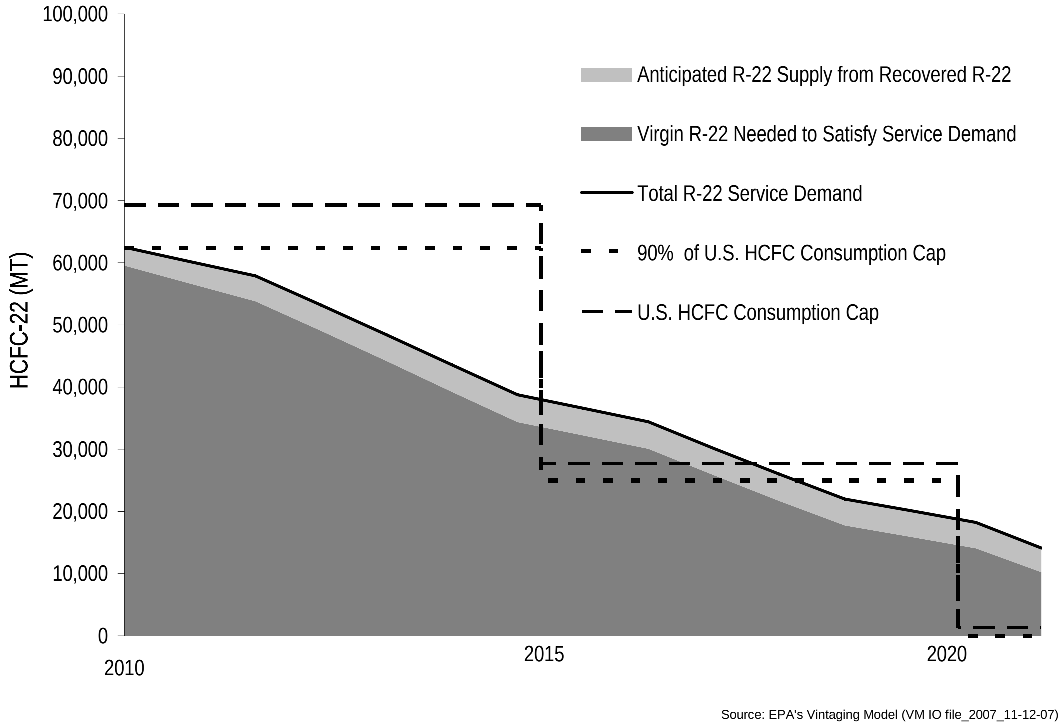
Table C-2: Scenario 75: 75% Recovery Rate: Summary of Projected R-22 Supply, Demand, and Surplus (R-22 Metric Tons)

	2010	2015	2020
Projected R-22 Servicing Demand Summary			
Total R-22 servicing demand	62,500	38,800	18,200
Anticipated R-22 supplied from recovery/reuse	22,300	33,000	31,200
% of total R-22 servicing demand supplied by anticipated recovery/reuse	36%	85%	>100%
Estimated virgin R-22 supply needed to satisfy remaining demand	40,200	5,800	0
Potential HCFC Consumption Cap Allocations			
Allocate 100% of HCFC Cap to R-22			
Virgin R-22 supply available under cap[a]	69,273	27,709	0[b]
Estimated virgin R-22 supply needed to satisfy remaining demand	40,200	5,700	0
Additional virgin R-22 allowable under cap	29,100	22,000	0
Allocate 90% of HCFC Cap to R-22			
Virgin R-22 supply available under cap[a]	62,345	24,938	0[b]
Estimated virgin R-22 supply needed to satisfy remaining demand	40,200	5,700	0
Additional virgin R-22 allowable under cap	22,100	19,200	0

[a] Expressed in R-22 un-weighted metric tons (calculated using an ODP of 0.055 for HCFC-22).
[b] In 2020, 0.5 percent of the U.S. consumption baseline remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining baseline to R-22.
Source: Based on data analysis using EPA, 2007a.

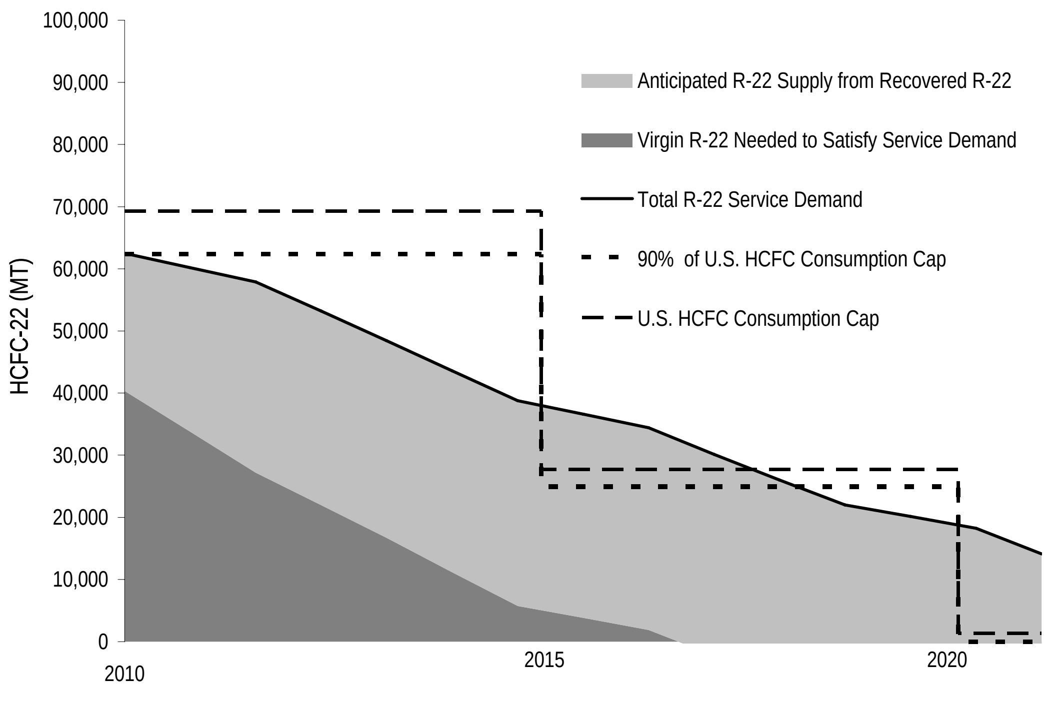
Figures C-1 and C-2 illustrate the information provided in Tables C-2 and C-3.

Figure C-1: Total Projected R-22 Servicing Demand, Recovery Scenario 10[a, b]



[a] Potential consumption cap allocations expressed in R-22 un-weighted metric tons (calculated using an ODP of 0.055 for HCFC-22).
[b] In 2020, 0.5 percent of the U.S. consumption baseline remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining baseline to R-22.

Figure C-2: Total Projected R-22 Servicing Demand, Recovery Scenario 75[a, b]



[a] Potential consumption cap allocations expressed in R-22 un-weighted metric tons (calculated using an ODP of 0.055 for HCFC-22).
[b] In 2020, 0.5 percent of the U.S. consumption baseline remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining baseline to R-22.

Table C-3 provides a summary of all five scenarios presented in this report to illustrate how recovered and virgin projected servicing supplies range with respect to meeting demand based on the different rates of recovery analyzed.

Table C-3: Comparison of HCFC Servicing Demand Projections (Metric Tons) and Necessary Supply Projections by Source (Metric Tons and Percent), 2010, 2015, 2020

Year	Cap[a]	Demand	Recovery Rate Scenarios	*Necessary Supply* Recovered	Virgin	Shortfall
2010	69,273	62,500	Scenario 10	3,000 (5%)	59,500 (95%)	0 (0%)
			Scenario 15	4,500 (7%)	58,000 (93%)	0 (0%)
			Scenario 20	5,900 (9%	56,600 (91%)	0 (0%)
			Scenario 50	14,800 (24%)	47,700 (76%)	0 (0%)
			Scenario 75	22,300 (36%)	40,200 (64%)	0 (0%)
2015	27,709	38,800	Scenario 10	4,400 (11%)	34,400 (89%)	6,691 (17%)
			Scenario 15	6,600 (17%)	32,200 (83%)	4,491 (12%)
			Scenario 20	8,800 (23%)	30,000 (77%)	2,291 (6%)
			Scenario 50	22,000 (57%)	16,800 (43%)	0 (0%)
			Scenario 75	33,000 (85%)	5,700 (15%)	0 (0%)
2020	0	18,200	Scenario 10	4,200 (23%)	14,100 (77%)	14,100 (77%)
			Scenario 15	6,200 (34%)	0 (0%)	12,000 (66%)
			Scenario 20	8,300 (46%)	0 (0%)	9,900 (54%)
			Scenario 50	18,200 (100%)	0 (0%)	0 (0%)
			Scenario 75	31,200 (>100%)	0 (0%)	0 (0%)

[a] HCFC consumption cap expressed in R-22 metric tons to represent an allocation of 100 percent of the cap assigned to R-22. In 2020, 0.5 percent of the U.S. consumption baseline remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining baseline to R-22.
Source: Based on data analysis using EPA, 2007a.

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