THE U.S. PHASEOUT OF HCFCS:

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

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This report presents estimates of the projected quantity of HCFC-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 caps. The analyses presented in this report have been revised based on input received in response to a Notice of Data Availability (NODA, 70 FR 67172) and request for comment issued on November 4, 2005.

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Executive Summary

Hydrochlorofluorocarbons (HCFCs) are a class of chemical compounds that deplete the stratospheric ozone layer, leading to overexposure of 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 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 phaseout 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) began by establishing a schedule for the phaseout of HCFCs with the highest ozone depletion potentials (ODPs), namely HCFC-141b, HCFC-142b, and HCFC-22. 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 are still permitted to service existing equipment.

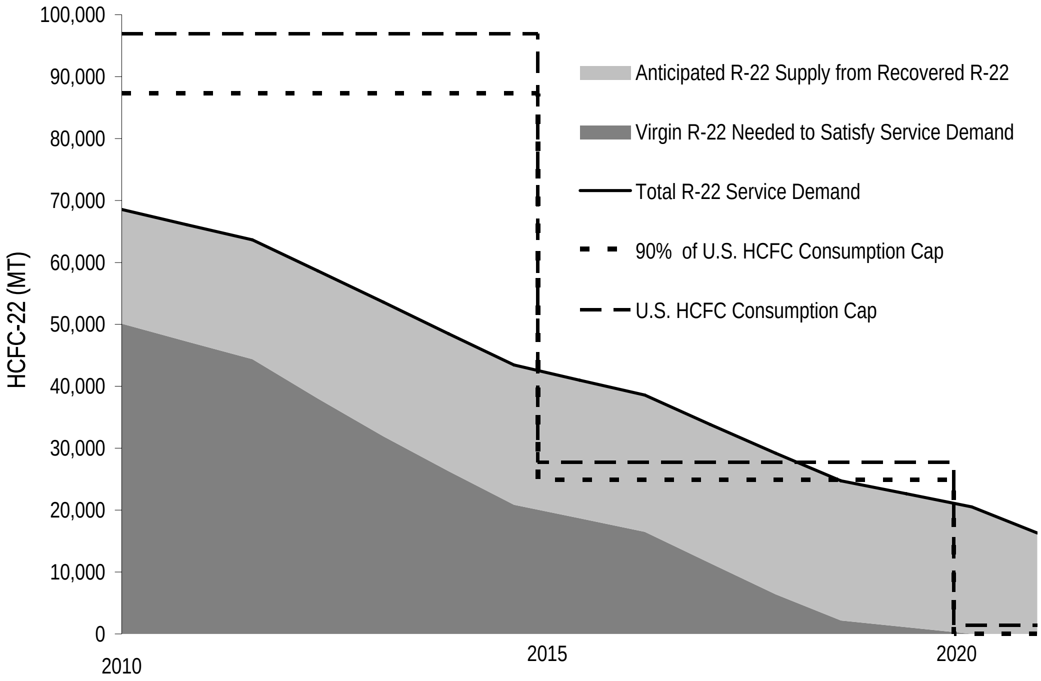
In the United States and worldwide, the primary use of HCFC-22 is as a refrigerant, whereas, the primary use of HCFC-142b is as a blowing agent in the foam industry (UNEP 2003a). While HCFC-142b is also blended with other constituents to form refrigerant blends, its use in the U.S. air-conditioning (AC) and refrigeration industry is minimal, and therefore servicing demand for R-142b,[2] if any, is not presented in this analysis. Estimated consumption of R-22 in the U.S. air-conditioning (AC) and refrigeration industry currently totals approximately 114,900 metric tons and is by far the largest use of an HCFC by any U.S. industry (EPA 2006a). 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 consumption caps.

This report examines the primary sources of R-22 to service equipment after 2010, including (1) the amounts recovered from equipment that are subsequently recycled or reclaimed and (2) the virgin production and import quantities (i.e., consumption) limited under the Montreal Protocol and distributed by EPA through an allowance system.[3] Two servicing 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. Scenario 1 assumes that 50 percent of refrigerant is recovered and available for reuse, while Scenario 2 assumes only 10 percent of refrigerant is recovered and available for reuse.

Figures ES-1a and ES-2a summarize the two servicing demand scenarios 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 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. As shown in both potential consumption cap allocations and in both servicing demand scenarios, total projected R-22 servicing demand is estimated to exceed the consumption cap starting in 2015, and therefore, the use of recovered refrigerant will be necessary to avoid R-22 supply shortages. Scenario 1, which represents a recovery and reuse rate of 50 percent of all available refrigerant (Figure ES-1a), projects that sufficient supplies of recovered refrigerant will be available, while Scenario 2, which assumes a lower recovery and reuse rate of 10 percent (Figure ES-1b), projects insufficient supplies of recovered refrigerant.

[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] 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.
[3] The import of used R-22 as approved by EPA is another source; however, this source is not included in the projections of this analysis.

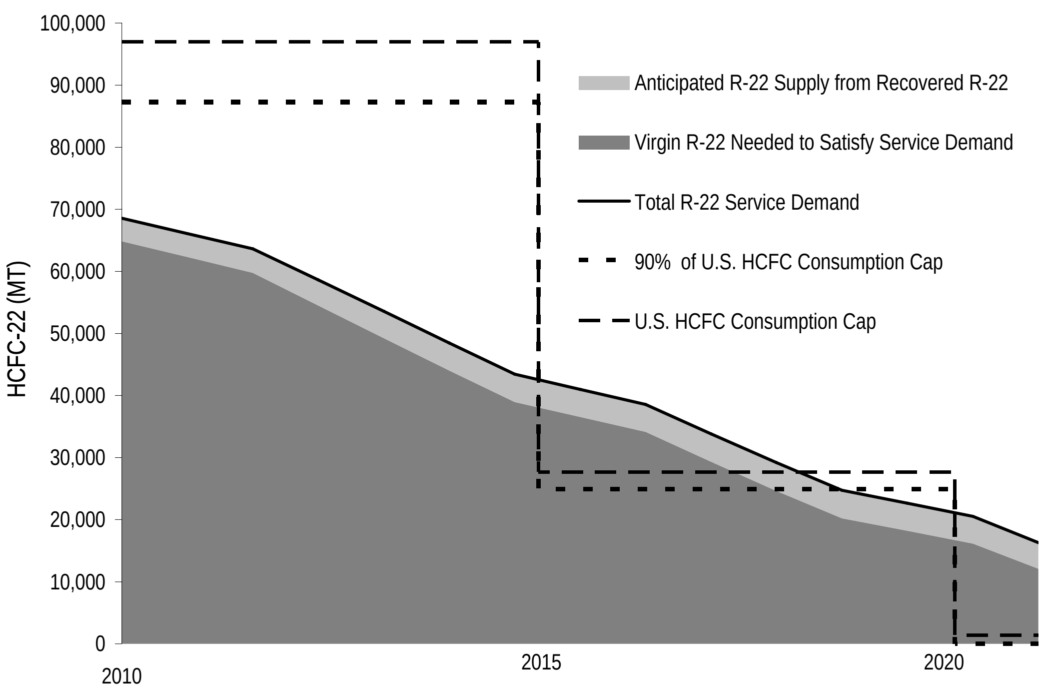
Figure ES-1a: Total Projected R-22 Servicing Demand, Recovery Scenario 1[a,b]



Source: EPA's Vintaging Model (VM IO file_6-30-06_ALL)

[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 cap remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining cap to R-22.

Figure ES-1b: Total Projected R-22 Servicing Demand, Recovery Scenario 2[a, b]



Source: EPA's Vintaging Model (VM IO file_6-30-06_ALL)

[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 cap remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining cap to R-22.

Under the future scenarios developed in this analysis, the AC and refrigeration industry is potentially facing shortage risks starting in 2015 if enough refrigerant is not recovered and reused.[4] However, under a scenario 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 that recover the highest possible quantity of used refrigerant from converted or retired equipment to be put back into 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 projection scenario is more likely. For example, with approximately 150 million AC and refrigeration units projected to be in use in 2010, the sooner this equipment transitions to alternative refrigerants, the better the chance for a more balanced R-22 supply and demand forecast. This report explores the following other market trends and how they may influence future R-22 servicing demand and available supply estimates:

- Changes in equipment charge sizes to accommodate the 13 SEER energy standard;
- 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;
- Levels of imports of used R-22; and
- Levels of imports of pre-charged R-22 equipment.

The analysis presented in this report uses EPA's Vintaging Model (EPA 2006a) 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.

The projected scenarios highlighted in this analysis provide a basis for further collaboration with the AC and refrigeration community to maximize supplies (through reuse) in order to continue to service equipment as the U.S. achieves the next HCFC phaseout targets.

[4] Recovered refrigerant may be 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.

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

Title VI of the Clean Air Act (CAA) 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 hydrochlorofluorocarbons (HCFCs), which are ozone-depleting substances (ODS) and have been widely used as refrigerants, solvents, foam blowing agents, and fire extinguishants.[5] 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).

Table 1-1 presents the HCFC consumption cap and the graduated reductions to allowable HCFC consumption for the United States (and all non-Article 5[6] countries), as determined for compliance with the Protocol. The first HCFC phaseout milestone was in 1996, when HCFC consumption levels were capped at 1989 ozone-depletion potential (ODP)-weighted HCFC consumption levels plus 2.8 percent of the ODP-weighted 1989 CFC consumption. The second phaseout milestone occurred on January 1, 2004, when HCFC consumption limits were reduced by 35 percent of the above cap, which is to be followed by a 65 percent reduction in 2010, a 90 percent reduction in 2015, a 99.5 percent reduction in 2020, and a complete phaseout in 2030.

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

Date	Consumption Cap	ODP Weighted Quantity	Quantity Expressed in R-22 Metric Tons[a]
Jan 1, 1996	Consumption freeze capped at 2.8% of the 1989 ODP-weighted CFC consumption plus 100% of the 1989 ODP-weighted HCFC consumption	15,240 ODP-metric tons[b]	277,091 metric tons
Jan 1, 2004	35% reduction of the cap	9,906 ODP-metric tons	180,109 metric tons
Jan 1, 2010	65% reduction of the cap	5,334 ODP-metric tons	96,982 metric tons
Jan 1, 2015	90% reduction of the cap	1,524 ODP-metric tons	27,709 metric tons
Jan 1, 2020	99.5% reduction of the cap	76.2 ODP-metric tons	0 metric tons[c]
Jan 1, 2030	100% reduction of the cap	0 ODP-metric tons	0 metric tons

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

Table 1-2 details the U.S. phaseout schedule for HCFCs established under the CAA to comply with the targets set by the Montreal Protocol (as presented in Table 1-1). 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 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 the limited exemptions), HCFC-22, and HCFC-142b were authorized and distributed (on a kilogram basis) to certain chemical manufacturing companies (EPA 2003a).[7] Therefore, as of 2003, only those companies with allowances were allowed to produce and/or import these HCFCs.

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[5] 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).
[6] Article 5 countries, primarily developing countries identified in the Montreal Protocol, are on a later schedule for phasing out ODS.
[7] 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.

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

Date	Affected Substance(s)	Restriction
Jan 1, 2003	HCFC-141b	• No production and no import of HCFC-141b
Jan 1, 2010	HCFC-142b, HCFC-22	• No production and no import of HCFC-142b and HCFC-22, except for on-going servicing needs in equipment manufactured before 1/1/2010
Jan 1, 2015	HCFC-142b, HCFC-22 and All Other HCFCs	• No production and no import of all other HCFCs, except for on-going servicing needs in equipment manufactured before 1/1/2020 • No sale and use of all HCFCs except (1) for use in chemical reactions where the HCFCs are completely used up in the process; (2) reclaimed and recycled HCFCs; or (3) for on-going servicing needs in refrigerant equipment manufactured before 1/1/2020
Jan 1, 2020	HCFC-142b, HCFC-22	• No production and no import of HCFC-142b and HCFC-22
Jan 1, 2030	All Other HCFCs	• No production and no import of any HCFCs

Source: EPA (2003a)

To meet the next phaseout milestone 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) will cease. The phaseout for all other HCFCs, such as HCFC-123, begins on January 1, 2015, when U.S. production and import is restricted except for use as a refrigerant in equipment manufactured before January 1, 2020. The final phase out for all HCFCs occurs on January 1, 2030. Production and consumption allowances for all other HCFCs must still be granted under the allowance system; additionally, the U.S. Environmental Protection Agency (EPA) will re-evaluate HCFC-22 and HCFC-142b allocation levels prior to 2010 and issue allowances at a level that will be suitable solely for the required servicing needs.

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 and (b) HCFCs needed to service equipment beyond 2010. In an effort to prepare for the next phaseout scheduled for the United States, this report presents possible future scenarios on the servicing needs for air-conditioning (AC) and refrigeration equipment that will be in use after 2010. These estimates will aid EPA in allocating future HCFC consumption caps.

This analysis focuses solely on post-2010 R-22 servicing needs in the AC and refrigeration industry, the largest HCFC market and the largest industry sector using HCFCs in the United States. Projections of post 2010 HCFC-142b servicing needs are expected to be marginal and therefore are not explored in this analysis. The largest industry sector using HCFC-142b is the U.S. foam industry, which uses HCFCs to create foam products; furthermore, while HCFC-142b refrigerant blends are approved as acceptable substitutes for CFC refrigerants in some end-uses, the modeling used in this analysis does not project any R-142b servicing demand beyond 2010 for the AC and refrigeration industry.

The remainder of the report is organized as follows:

- Section 2 provides a brief overview of the methodology used in this analysis to project servicing scenarios. A further discussion on the methodologies can be found in Appendix A.
- Section 3 provides an overview of the AC and refrigeration industry and presents current consumption and servicing estimates for all HCFCs used in this sector.
- Section 4 provides projected scenarios for units of R-22 equipment and R-22 servicing needs.
- Section 5 summarizes the key findings of the analysis.
- Appendix A presents the projection methodology and the associated limitations.
- Appendix B provides AC and refrigeration projections by end-use.

2. Methodology Overview

The main tool used to launch the analysis and form the basis for quantitative estimates of current and projected HCFC consumption was EPA's Vintaging Model. 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 each year, and the quantity of the chemical required to manufacture 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.

As an initial step in this analysis of current and projected HCFC use in the United States, an investigation was conducted into the entire HCFC market, covering all end-uses that utilize HCFCs in the AC and refrigeration, foam, solvents, aerosols, and fire protection sectors. This analysis was conducted by compiling estimates from the 2005 version of EPA's Vintaging Model on HCFC consumption for both new manufacturing and the servicing of existing equipment, and the total units of equipment containing HCFCs from 2005 through 2030 by end-use (EPA 2005a). The Vintaging Model data indicated that in 2005, the AC and refrigeration industry represented 96 percent of total HCFC-22 consumption and 86 percent of total HCFC consumption.[8] Therefore, this analysis was narrowed to focus on R-22 servicing needs in the AC and refrigeration industry.

Having established initial estimates, 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. Representatives including those from the Association of Home Appliance Manufacturers (AHAM); Air-Conditioning and Refrigeration Institute (ARI); Carrier Corporation; Heating, Air-Conditioning & Refrigeration Distributors International (HARDI); Hill Phoenix; Honeywell; a member of the Food Marketing Institute; and York were contacted to discuss stationary AC and refrigeration end-uses.[9] The informal discussions were used to confirm or modify preliminary estimates obtained from EPA's Vintaging Model; information gathered from the discussions was in turn used to refine assumptions and inputs in the Model to improve the estimates provided in 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, copies of which are available at EPA's electronic docket (EDocket ID number, OAR-2003-0130, Dupont 2005a, 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 to service AC and refrigeration equipment is reasonable; however, all commenters expressed concern regarding the projections of the supply of recovered/reclaimed R-22 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, additional analysis was conducted using EPA's Vintaging Model to test whether demand might exceed supply under some circumstances. 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.

[8] The recently updated Vintaging Model indicates that the AC and refrigeration industry represents 98 percent of total HCFC-22 consumption and 89 percent of total HCFC consumption (EPA 2006a).
[9] In order to comply with the Paperwork Reduction Act of 1995, fewer than ten people were contacted regarding each information category (44 U.S.C. 3502(3)).

3. Current HCFC Use in Air-Conditioning and Refrigeration Equipment

The AC and refrigeration industry encompasses a wide variety of equipment and employs a diversity of HCFC and other refrigerants. This section is organized as follows:

- Sections 3.1 and 3.2 present an overview of AC and refrigeration end-uses, respectively; and
- Section 3.3 provides an overview of HCFC refrigerants used in the AC and refrigeration industry.

3.1 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 3-1.

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 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, many 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. 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).[10] Although school 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 end-uses.

- *Unitary air-conditioners and heat pumps* include both split systems and packaged units and are designed for air circulating, cooling, cleaning, and dehumidifying in residential and small and large commercial applications.
- *Chillers* regulate the temperature and humidity in offices, hotels, shopping centers, and other large buildings. There are four major types of chillers—centrifugal, scroll, reciprocating, and screw—each of which is named for the type of compressor employed. Often, standard AC systems, such as chillers, are customized to be used for industrial applications. Modifications are made to customize the equipment for unusual circumstances (e.g., protection from flammability, high temperatures, or for outdoor use).
- *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.

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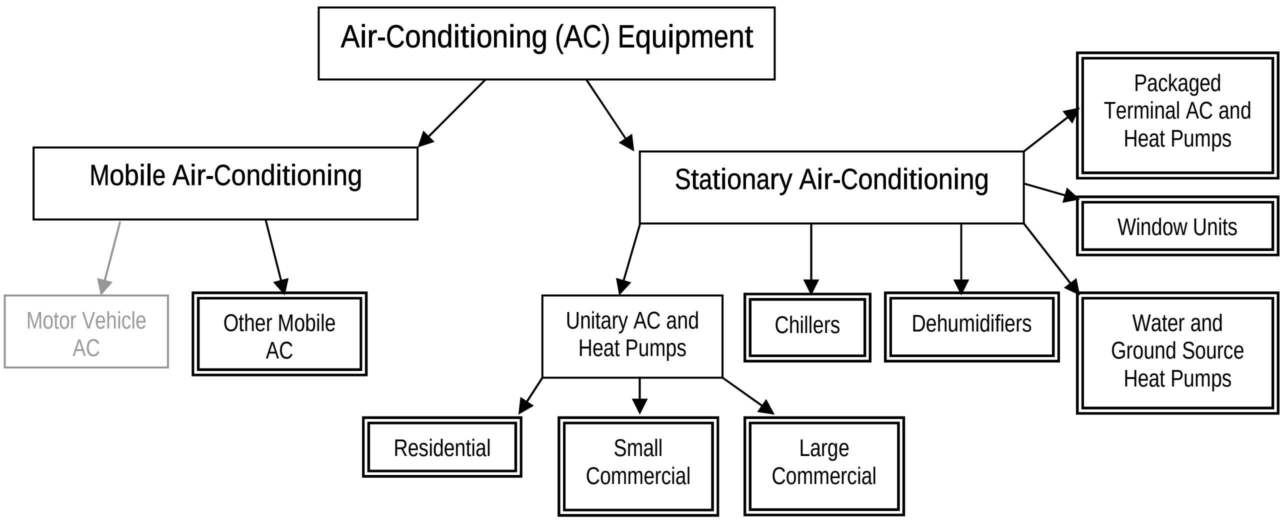
[10] For the purposes of this report, "other mobile AC" does not include ships, planes, RVs, or construction/farm equipment. In the case of boats, some R-22 is used in AC systems (UNEP 2003a), but this consumption is accounted for in this report under stationary AC equipment, such as packaged terminal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

- *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 3-1: Types of Air-Conditioning Systems[a]



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

3.2 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 3-2.

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.

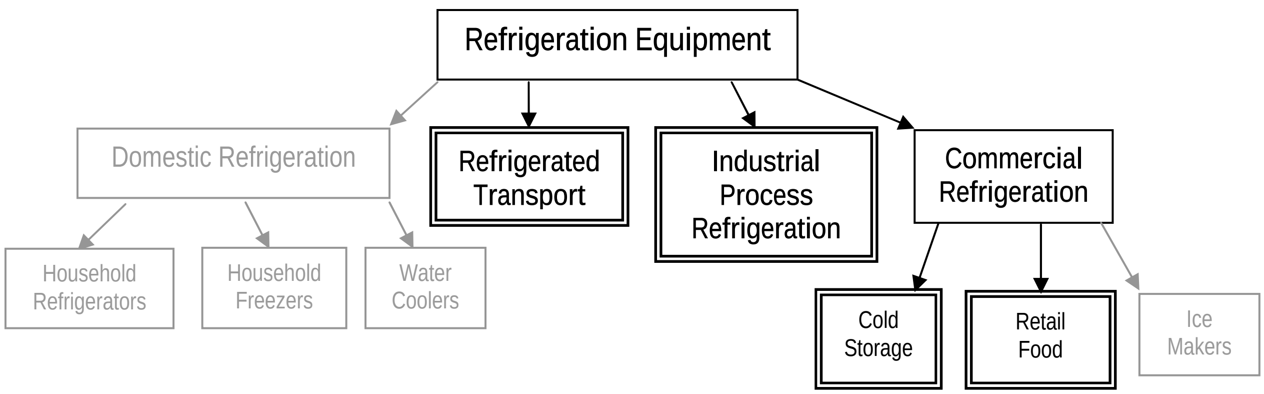
Commercial refrigeration can be further broken down into three end-uses:

- *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 and condensers 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 using 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 3-2: Types of Refrigeration Systems[a]



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

3.3 HCFC Refrigerants

Historically, chlorofluorocarbons (CFCs) were extensively used as refrigerants in the AC and refrigeration industry; 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 approved as substitutes for the controlled CFCs. Table 3-1 lists the Class II ODS used as refrigerants (or components of refrigerant blends), in descending order according to their ODP.[11] Table 3-1 also lists the phaseout schedule for consumption of Class II substances in both new and existing AC and refrigeration equipment, as required under the CAA.

[11] 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.

Table 3-1: Class II ODS Used as Refrigerants

Class II ODS	CAS Number	Atmospheric Lifetime (years)	ODP[a]	Consumption Phaseout (Starting Jan. 1)	
				New Equipment	Existing Equipment
HCFC-142b (CH_3CF_2Cl)[b]	75-68-3	17.9	0.065	2010	2020
HCFC-22 (CHF_2Cl)	75-45-6	12.0	0.055	2010	2020
HCFC-124 (CF_3CHFCl)	2837-89-0	5.8	0.022	2020	2030
HCFC-123 ($CHCl_2CF_3$)	306-83-2	1.3	0.02	2020	2030

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

[b]HCFC-142b is formulated into refrigerant blends; however, these blends have an insignificant market share in the AC and refrigeration industry (ICF Consulting 2005; UNEP 2003a).

The remainder of Section 3.3 provides current estimates of the HCFCs and blends containing HCFCs consumed as refrigerants.

3.3.1 HCFC-22

HCFC-22, also known as R-22, was first commercialized as a refrigerant in the 1930s and has been used continuously since that time (UNEP 2003a; Dupont 2005b; Calm and Domanski 2004). R-22 is the most common HCFC refrigerant used in AC and refrigeration applications.

Potential non-ODS candidates to replace R-22 vary by application and include HFC-134a, R-404A (composed of HFC-125/HFC-143a/HFC-134a), R-407C (composed of HFC-32/HFC-125/HFC-134a), R-410A (composed of HFC-32/HFC-125) and R-507A (composed of HFC-125/HFC-143a).

Table 3-2 presents current estimates of R-22 consumption and the estimated percent of that consumption that is used to service AC and refrigeration equipment. These estimates were developed based on data from EPA's Vintaging Model and information provided by industry contacts (EPA 2006a). Appendix A explains the methodology used to develop these estimates and disaggregates servicing estimates by equipment type. As shown in Table 3-2, current estimated consumption of R-22 for both AC and refrigeration equipment totals approximately 114,900 metric tons. Approximately 66 percent of this consumption is for servicing existing equipment, with the refrigeration industry using a higher percentage of its total consumption to service equipment than the AC industry. The majority of R-22 consumption for servicing is currently attributed to residential and small commercial unitary AC equipment and retail food refrigeration equipment (see Appendix B).

Table 3-2: Summary of U.S. R-22 Consumption (2005)[a]

Equipment Type	Total Consumption for New Manufacturing and Servicing (Metric Tons)	Consumption for Servicing (Metric Tons)	% of Total Consumption for Servicing
Total AC	73,600	43,300	59%
Total Refrigeration	41,300	33,100	80%
Total	114,900	76,400	66%

[a]Quantities of R-22 from blends containing R-22 are factored into these estimates. See Section 3.3.5 for a discussion of blends containing HCFCs.

Since R-22 represents the largest HCFC market in the United States, the projected servicing needs presented in Section 4 focus solely on the use of R-22 and blends containing HCFC-22 in the U.S. AC and refrigeration industry.

3.3.2 HCFC-142b

HCFC-142b, also known as R-142b, is not used as a stand-alone refrigerant but as a constituent of a few ASHRAE-designated refrigerant blends including R-409A (composed of HCFC-22/HCFC-124/HCFC-

142b) and R-406A (composed of HCFC-22/isobutane[R-600a]/HCFC 142b). Although the phaseout schedule for HCFC-142b is the same as that for HCFC-22, current research indicates that other refrigerants are used in the large majority of AC and refrigeration equipment, indicating that blends using R-142b are not commonly used (UNEP 2003a, ICF Consulting 2005, EPA 2006a). Therefore, projected R-142b servicing needs, if any, are not explored in this analysis.

3.3.3 HCFC-123

HCFC-123, also known as R-123, is primarily used as a refrigerant in centrifugal chillers for commercial comfort AC and in industrial process refrigeration. R-123 is the second most commonly used HCFC refrigerant (after R-22), with current overall consumption totaling around 2,000 metric tons—equivalent to about two percent of R-22 consumption. As Table 3-3 indicates, the majority of R-123 is used in AC equipment, specifically for chillers.

The estimates presented in Table 3-3 are drawn directly from the Vintaging Model (EPA 2006a). 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.[12] Because this phaseout occurs later than HCFC-22, servicing needs for HCFC-123 are not explored further in this analysis.

Table 3-3: Summary of R-123 Consumption (2005)

Equipment Type	Total Consumption for New Manufacturing and Servicing (Metric Tons)	Consumption for Servicing (Metric Tons)	% of Total Consumption for Servicing
Total AC	1,400	500	36%
Total Refrigeration	600	<50	9%
Total	2,000	500	25%

3.3.4 HCFC-124

HCFC-124, also known as R-124, is used in blends (mainly R-401A), in industrial process and transport refrigeration equipment. As Table 3-4 shows, in 2005, total consumption of R-124 (used in blends) was estimated to be less than 50 metric tons, all of which was for servicing refrigeration equipment.

The estimates presented in Table 3-4 are taken directly from the Vintaging Model (EPA 2006a). 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.[13] Because this phaseout occurs later than HCFC-22, servicing needs for HCFC-124 are not explored further in this analysis.

[12] In 2015, HCFC-123 production and import will be phased out for all non-refrigerant uses.
[13] In 2015, HCFC-124 production and import will be phased out for all non-refrigerant uses.

Table 3-4: Summary of R-124 Consumption (2005)[a]

Equipment Type	Total Consumption for New Manufacturing and Servicing (Metric Tons)	Consumption for Servicing (Metric Tons)	% of Total Consumption for Servicing
Total AC	0	0	NA
Total Refrigeration	<50	<50	100%
Total	<50	<50	100%

[a]These estimates represent quantities of R-124 from blends containing R-124. See Section 3.3.5 for a discussion of blends containing HCFCs.

3.3.5 HCFC Refrigerant Blends

Often refrigerants are formulated with several HCFCs and other 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 blends. When used in blends, HCFC-124 is used in combination with HCFC-22. HCFC-142b is also typically used with HCFC-22 to formulate refrigerant blends, with the exception of some blends designed to replace R-12 in motor vehicle air conditioning. Table 3-5 presents the composition of the more common refrigerant blends containing HCFCs.[14]

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

Table 3-6 presents the end-uses in which these refrigerant blends containing HCFCs are currently used.

Table 3-6: Common Uses of 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

[14] HCFC consumption data presented in this analysis include quantities consumed in blends by employing the percent composition of the corresponding HCFC constituent(s) of that blend. In order to accurately portray the number of units containing HCFC blends, however, blends are not disaggregated when presenting the number of units of equipment (i.e., a unit running on an HCFC-containing blend counts as one unit).

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.

The remainder of this section is organized as follows:

- Section 4.1 summarizes the projected market size of R-22 containing equipment beyond 2010 in the United States.
- Section 4.2 provides projected estimates 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, it is estimated that approximately 147.5 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 by 2020. It is projected that in 2010 there will be approximately 2.2 million units of refrigeration equipment, including retail food, industrial process refrigeration, and transport refrigeration equipment (but not including cold storage warehouses). The installed base is projected to decrease by about 29 percent by 2015 and 51 percent by 2020. These estimates were developed based on EPA's Vintaging Model, which takes into account recent input received from industry representatives for this and other analyses (EPA 2006a). 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	147,455,700	86,517,700	20,419,100
Total Refrigeration	2,204,100	1,561,000	768,600
Total	149,659,800	88,078,700	21,187,700

[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 cubic feet is 231 million ft^3 in 2010, 133 million ft^3 in 2015, and 61 million ft^3 in 2020.

4.2 Projected R-22 Servicing Needs

AC and refrigeration equipment commonly require servicing, which may include the need to add refrigerant to account for refrigerant losses that occur over time.[15] While the production and import of HCFC-22 is banned for use in new equipment in 2010, the limited production and import of HCFC-22 will still be permitted for servicing and maintenance purposes for equipment manufactured prior to January 1,

[15] 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.

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 EPA's Vintaging Model, which takes into account recent industry input (EPA 2006a). Appendix A provides further detail on the methodology used to develop these projections. Appendix B provides servicing demand projections disaggregated by end-use.

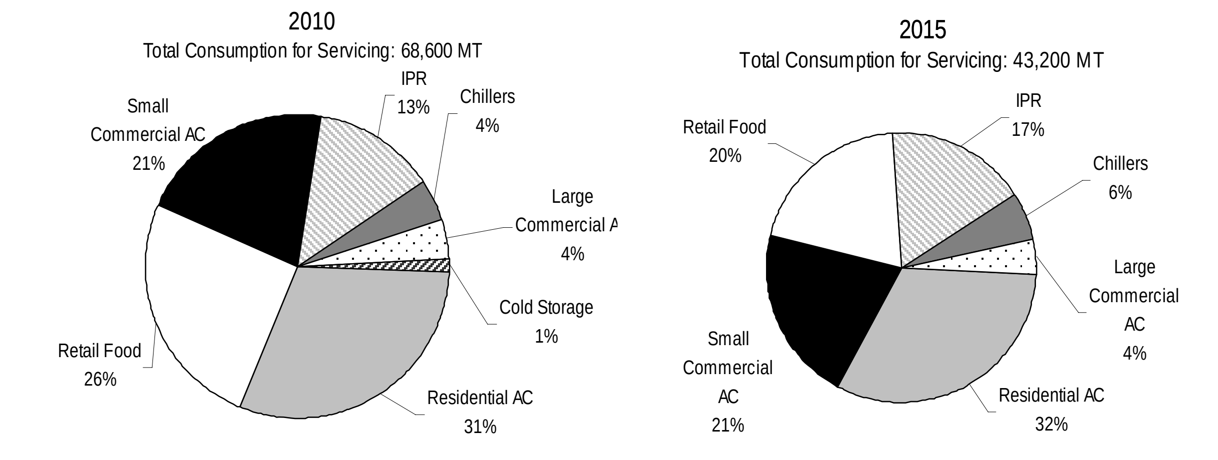
As presented in Table 4-2, it is projected that in 2010, approximately 68,600 metric tons of R-22 will be required to service AC and refrigeration equipment, of which the majority—41,400 metric tons (60%)—will be used to service AC systems. In 2015, servicing demand is projected to reach approximately 43,200 metric tons of R-22 for AC and refrigeration equipment, and in 2020, the projected quantity declines to 20,600 metric tons. 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	41,400	26,800	12,100
Total Refrigeration	27,200	16,400	8,500
Total	68,600	43,200	20,600

Figure 4-1 displays 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 (VMIO file_6-30-06_ALL)

4.2.1 R-22 Sources

Only existing sources of R-22 and a controlled quantity of virgin R-22 (limited through allowance allocations distributed by EPA until 2020) are available to the AC and refrigeration industry to meet servicing demand starting in 2010.[16] Existing sources of R-22, which can offset the need for virgin R-22, include:

[16] 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.

1. Recovered (i.e., recycled or reclaimed) R-22. Under the current codified regulations (EPA 2004a), refrigerants containing HCFCs must be recovered. After the recovery process, the refrigerant held in the storage container may be:
    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 approved 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

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 recovered and charged back into the same appliance[17] or to another appliance *if* those appliances are owned by the same establishment.[18] Several companies, such as supermarket chains, employ recycling plans through which the refrigerant is recovered when dismantling one establishment's equipment and reused to service equipment at another facility with like 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. Refrigerant reclaimers process recovered refrigerant and send samples of the purified refrigerant off-site for purity verification through testing required by the ARI 700 Standard.

Industry representatives have indicated that the current use of reclaimed HCFCs is minimal because virgin R-22 is inexpensive. In 2004, the amount of pure R-22 reclaimed by EPA-certified reclaimers totaled approximately 3,280 metric tons, or 7.23 million pounds (EPA 2006b). 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 48 metric tons, or 105,536 pounds reported for 2004 (EPA 2006b).[19] Reclamation data from 2000 to 2003 is presented in Table 4-3 below.

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

	2000	2001	2002	2003	2004
R-22	3,218	1,960	2,230	1,976	3,280
R-502	281	113	150	41	48

[a]Source: EPA 2006b.

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). 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

[17] Appliance is defined in EPA regulations at 40 CFR §82.152 as any device which contains and uses a refrigerant. Hence, its reference is not limited to household "appliances."
[18] If refrigerant changes ownership, however, that refrigerant must be reclaimed.
[19] Feedback received from stakeholders in response to the NODA indicated that because R-22 is a component of the R-502 azeotropic blend, the ability to separate R-22 from the blend is difficult, expensive, and very limited (National Refrigerants 2006).

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.”

Imports of Used R-22

Unlike virgin HCFCs, there are no Montreal Protocol restrictions on the consumption of used controlled substances.[20] 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 to import 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. The projections in this report do not include the potential future quantities obtained from the import of used R-22; however, this source of used material can offset future demand for virgin production provided that a lack of domestically available used R-22 justifies the need to undergo the strict permit process.

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 large portion of the demand for HCFC-22 for servicing can be met with previously used refrigerant that is recovered and then recycled or reclaimed. Recovered R-22 is a source that is made available as a result of the venting prohibition EPA has established under Section 608 of the CAA of 1990 (EPA 2004a). In order to determine the potential amounts of used refrigerant available to service equipment, two 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.

In developing the scenarios using EPA’s Vintaging Model, the projected amount of recovered R-22 is estimated based on the quantity available from end-of-life 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 as it is projected to be minimal. According to industry sources, refrigerant recovered during service events primarily originates from commercial and industrial equipment; refrigerant is rarely recovered during the servicing of small equipment in the residential sector 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, 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, which varies by scenario, is recovered from discarded equipment.[21] While EPA has regulations in place prohibiting intentional venting, for the purposes of this analysis, it is appropriate to create scenarios that could imply less compliance with the regulations. It is then assumed that the entire pool of recovered refrigerant re-enters the market (see Appendix A for more details) and hence off-sets the demand for virgin R-22 production. The two scenarios investigated can be summarized as follows:

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[20] “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).
[21] The Vintaging Model assumes equipment contains a full charge at disposal and 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.

- Scenario 1 assumes that by 2010, 50 percent of refrigerant from retired equipment is recovered and re-enters the pool of refrigerant available to meet demand (i.e., a 50 percent recovery rate). The remaining 50 percent is not available for reuse.
- Scenario 2 assumes that by 2010, 10 percent of refrigerant from retired equipment is recovered and reused in equipment (i.e., a 10 percent recovery rate). The remaining 90 percent is not available for reuse.

Table 4-4 provides the estimated percentages of the R-22 supply that would be needed to meet demand through (a) recovered refrigerant (i.e., recycled or reclaimed) and (b) new (i.e., virgin) refrigerant.

Table 4-4: Projected R-22 Supply Needed to Meet Demand by Source (Metric Tons)

Scenario	Source	2010	2015	2020
Scenario 1: 50% Recovery Rate	Recovered	27%	52%	100%
	Virgin	73%	48%	0%
Scenario 2: 10% Recovery Rate	Recovered	5%	10%	21%
	Virgin	95%	90%	79%

As presented, there is a significant range between the two scenarios with regard to the percent of R-22 servicing demand that is projected to be needed from virgin manufacture. For example, in 2020, Scenario 2—representing minimal refrigerant recovery at equipment disposal—results in a projected need for virgin refrigerant to fully meet the projected servicing demand. Such consumption is a legal impossibility under the Clean Air Act, as it would put the U.S. out of compliance with the Montreal Protocol, which calls for consumption of HCFCs to drop to 0.5% of the cap beginning in 2020.

Table 4-5 and Table 4-6 summarize the two recovery scenarios in comparison to two U.S. HCFC consumption cap allocations: in the first allocation, it is assumed that 100 percent of the HCFC cap in 2010 and 2015 will be assigned to R-22; in the second, only a portion (i.e., 90 percent) is assigned to R-22 in 2010 and 2015, with the remainder set aside for allocation to other HCFCs. The first recovery scenario, which represents a recovery rate of 50 percent, is summarized in Table 4-5. As shown in both potential consumption cap 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 4-5 indicates that in 2015 through 2020 (and beyond), the use of recovered refrigerant will be necessary to avoid R-22 shortfalls; however, projections indicate that sufficient supplies of recovered refrigerant would be available under a 50% recovery rate scenario.

Table 4-5: Scenario 1: 50% 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	68,600	43,400	20,500
Anticipated R-22 supplied from recovery/reuse	18,500	22,600	20,500
Estimated virgin R-22 supply needed to satisfy remaining demand	50,100	20,900	0
Potential HCFC Consumption Cap Allocations			
Allocate Full HCFC Cap to R-22			
Virgin R-22 supply available under cap[a]	96,982	27,709	0[b]
Estimated virgin R-22 supply needed to satisfy remaining demand	50,100	20,900	0
Additional virgin R-22 allowable under cap	46,882	6,809	0
Allocate 90% of HCFC Cap to R-22			
Virgin R-22 supply available under cap	87,284	24,938	0[b]
Estimated virgin R-22 supply needed to satisfy remaining demand	50,100	20,900	0
Additional virgin R-22 allowable under cap	37,184	4,038	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 cap remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining cap to R-22.

Table 4-6 summarizes the projections under the second recovery scenario that assumes practices that yield a lower recovery rate of 10 percent. These projections are also compared to two potential U.S. HCFC consumption cap allocations. As shown, in both cap allocations, the estimated virgin R-22 supply needed in 2010 can be adequately met with a portion of the HCFC consumption cap remaining. However, in 2015 and 2020, the quantity of recovered R-22 projected under this scenario plus the amount of virgin R-22 production allowable under the cap is not adequate to meet the projected servicing demand, consequently leading to R-22 supply shortfalls.

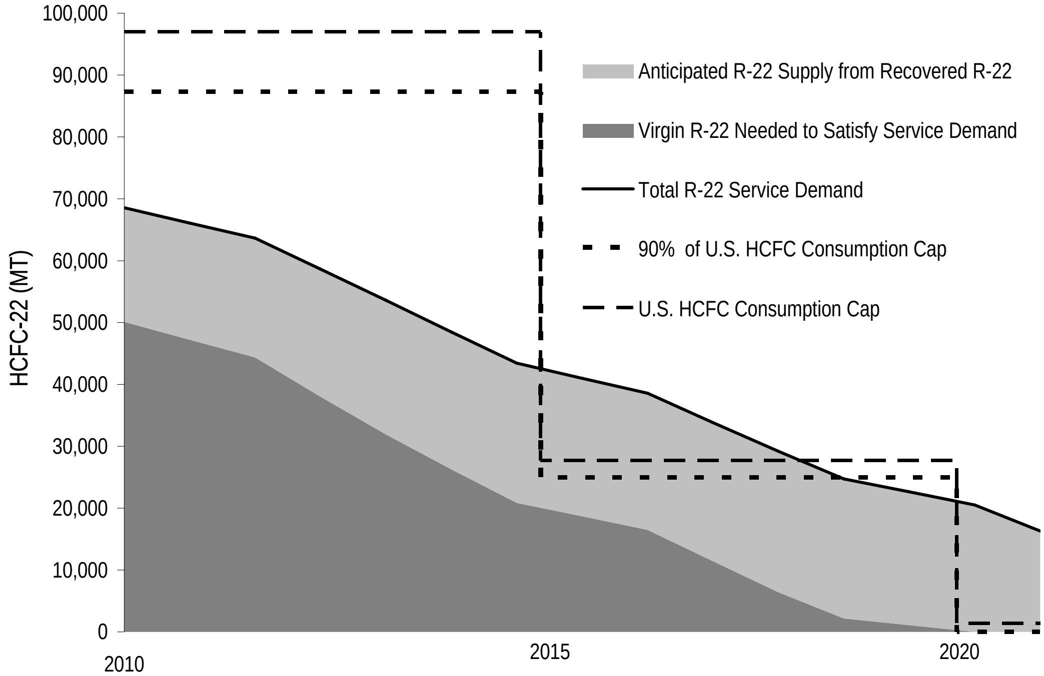
Table 4-6: Scenario 2: 10% Recovery Rate:
Summary of Projected R-22 Supply, Demand, and Shortfall (R-22 Metric Tons)[a]

	2010	2015	2020
Projected R-22 Servicing Demand Summary			
Total R-22 servicing demand	68,600	43,400	20,500
Anticipated R-22 supplied from recovery/reuse	3,700	4,500	4,400
Estimated virgin R-22 supply needed to satisfy remaining demand	64,900	38,900	16,200
Potential HCFC Consumption Cap Allocations			
Allocate Full HCFC Cap to R-22			
Virgin R-22 supply available under cap[b]	96,982	27,709	0[c]
Estimated virgin R-22 supply needed to satisfy remaining demand	64,900	38,900	16,200
Additional virgin R-22 allowable under cap	32,082	**-11,191**	**-16,200**
Allocate 90% of HCFC Cap to R-22			
Virgin R-22 supply available under cap[b]	87,284	24,938	0[c]
Estimated virgin R-22 supply needed to satisfy remaining demand	64,900	38,900	16,200
Additional virgin R-22 allowable under cap	22,384	**-13,962**	**-16,200**

[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 cap remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining cap to R-22.

Figures 4-2a and 4-2b further demonstrate the significant variability in the projected supply of recovered refrigerant available to meet demand resulting from the two recovery scenarios. Depending on the recovery practice employed, the potential exists for either a surplus or shortfall to occur in 2015 (Scenario 1 and 2, respectively) and the potential for a shortfall in 2020 (Scenario 2).

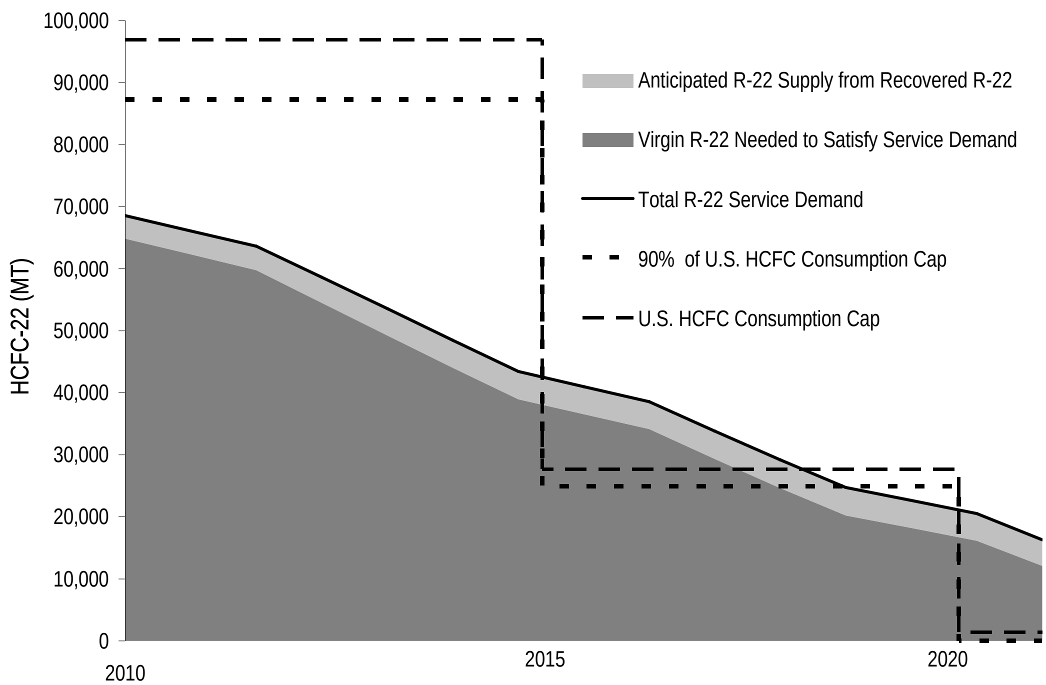
Figure 4-2a: Total Projected R-22 Servicing Demand, Recovery Scenario 1[a,b]



Source: EPA's Vintaging Model (VM IO file_6-30-06_ALL)

[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 cap remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining cap to R-22.

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



Source: EPA's Vintaging Model (VM IO file_6-30-06_ALL)

[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 cap remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining cap to R-22.

As the market prepares for the phaseout, it is critical to ensure that recovered R-22 is recycled, stockpiled, or reclaimed to maximize available R-22 supply and avoid the risk of potential shortages. Increased reuse of R-22 will be needed to satisfy future servicing needs that cannot be met through virgin supplies alone. It is projected that the minimum amount of recovered R-22 needed to meet servicing demand must be approximately 18,500 metric tons in 2010, followed by 22,600 metric tons in 2015 and 20,500 metric tons in 2020 (i.e., Scenario 1). For comparison, as noted in Table 4-3, in 2004 a total of 3,280 metric tons of HCFC-22 was reclaimed, which amounts to approximately three percent of total HCFC-22 consumption in 2004 (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 2004 level of reclamation remains constant, reclaimed R-22 would fulfill only 18 percent of the supply of R-22 from recovered refrigerant projected to be required under Scenario 1 in 2010, dropping to approximately 15 percent in 2015 and 2020. A further discussion on recovery practices is provided in Section 4.3.3.

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)

The U.S. Department of Energy (DOE) published a rule in January 2001 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).[22] In 2006, the charge size for central ACs is expected to have increased by approximately 30 to 50 percent (to approximately 4.4 to 5.1 kilograms [9.7 to 11.2 pounds]) because of the changes to the energy efficiency standards (Carrier Corporation 2005a).

Consequently, the amount of R-22 contained in new residential AC systems starting in 2006 will increase, 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 approved under EPA's Significant New Alternatives Policy (SNAP) program are available in the AC and refrigeration sector. R-134a, R-410A, R-407C, R-404A, and R-507A 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 industry phased out CFC refrigerants

[22] 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).

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. In projecting servicing needs, this analysis accounts for delayed transition trends, 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 have 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). Some industry representatives have indicated that the change to 13 SEER for residential ACs and heat pumps in 2006 will accelerate the rate of conversions to R-410A, with the production of residential equipment using R-410A possibly surpassing new equipment charged with R-22 between 2006 and 2007 (Powell 2004).

Nonetheless, the transition to alternatives for AC equipment is beginning slowly. Despite the availability of alternatives, more than 90 percent of new AC systems sold in 2004 were still charged with R-22 (RTOC 2003; Honeywell 2005). AC equipment manufacturers indicated that, while the transition to buying commercial equipment that uses alternatives will occur in the next few years, consumers will 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, 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 Scenario 2 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 will transition to alternatives more quickly than AC end-uses; the projections in this analysis are based on modeling that reflects this industry's input. Currently, the majority of existing U.S. supermarkets use R-22 in their refrigeration systems, with only a few supermarket chains having converted existing stores to use ODS alternatives (Hill Phoenix 2005; FMI 2004).[23] 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). For the next five to 10 years, it is anticipated that approximately 200 to 300 stores per year will transition away from R-22 in the United States (Honeywell 2005).
In new supermarket construction, the transition away from HCFCs is occurring more quickly. Currently, 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).

[23] 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).

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 3,700 to 18,500 metric tons, depending on the percentage of total available refrigerant from retired 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 43,400 metric tons, therefore requiring at least 15,690 metric tons of recovered R-22. Scenario 1 projects sufficient amounts of recovered material (i.e., 22,600 metric tons) to meet this demand, whereas, the projected quantity under Scenario 2 (the minimal recovery scenario) does not (i.e., 4,500 metric tons, or, approximately 70 percent lower than needed to prevent a shortfall).
- In 2020, Scenario 1 projects sufficient supplies of recovered R-22 to meet projected 2020 servicing demand (i.e., 20,500 metric tons). Conversely, the estimated projection of 4,400 metric tons of recovered R-22 under Scenario 2 (the minimal recovery scenario) 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, 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 isolate components or recover refrigerants prior to service as venting (releasing) any refrigerant when making repairs is illegal. Furthermore, 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 refrigerant 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 (only 3,280 metric tons of HCFC-22 was reclaimed in 2004), 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 six to seven-fold increase in current (as of 2004) 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.

[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.

4.3.4 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 (FMI 1995). 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 central AC, as well as large 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; 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.

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 lower cost of virgin R-22 is currently weakening the demand for reclaimed refrigerant, which is subsequently more expensive. 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 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.

Recent industry information indicates that R-22 is relatively less available in 2006, most likely in part because of the change to 13 SEER. As a result, recent price increases 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 more than doubled between 2001 and 2003 (Honeywell 2005; UNEP 2003a). For example, the current demand for room ACs, such as window units, through-the-wall, split, and mini-split systems, which predominately use R-22 (some new units are also being charged with R-407C and R-410A), is being met almost entirely through foreign manufacture (AHAM 2005). Central AC systems from foreign manufacturers such as Samsung, LG, and HAIER are also 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).

To project the impact of pre-charged imports on future servicing demand for R-22 equipment, servicing estimates were calculated assuming that pre-charged imports will continue to enter the U.S. market after 2010. Projected estimates of pre-charged imports were developed through a scenario using EPA's Vintaging Model that assumed the entire window unit and dehumidifier market and a small portion of the residential unitary AC and packaged terminal unit market will be imported and will continue to use R-22 after 2010. Further details regarding the assumptions used to project imports are provided in Appendix A. Given the assumptions used, Table 4-7 and Table 4-8 show the breakdown of equipment types containing R-22 that are assumed to enter the U.S. market from 2010 to 2020 and the associated servicing needs that will result from these imports. The projected estimates of units of pre-charged imports in Table 4-6 are in addition to the total projected estimates of units of equipment presented in Section 4.1.

Table 4-7: Projected Units of Imported Pre-charged R-22 Equipment

Air-Conditioning Equipment Type	2010	2015	2020
Window Units	9,572,800	12,217,600	15,593,200
Dehumidifiers	3,762,100	3,857,100	3,954,500
Packaged Terminal Units	28,000	31,700	35,900
Residential Unitary AC	314,900	345,900	380,100
Total	13,677,800	16,452,300	19,963,700

The projected servicing estimates for imports presented in Table 4-8 are in addition to the total projected servicing estimates presented in Section 4.2.

Table 4-8: Projected R-22 Service Needs for Pre-charged Imports (Metric Tons)

Air-Conditioning Equipment Type	2010	2015	2020
Window Units	100	300	500
Dehumidifiers	<50	<50	<50
Packaged Terminal Units	<50	<50	<50
Residential Unitary AC	300	1,200	2,200
Total	400	1,500	2,700

As shown, above, an estimated 13.7 million units of pre-charged AC equipment are projected to enter the United States in 2010, growing to 16.5 million in 2015, and 20 million in 2020; this translates into a projected servicing need of approximately 400 metric tons in 2010, 1,500 metric tons in 2015, and 2,700 metric tons in 2020.

Table 4-9 presents a scenario of projected servicing needs for all AC and refrigeration equipment assuming imports of window units, dehumidifiers, packaged terminal units, and residential unitary AC units pre-charged with R-22 continue to enter the U.S. market after the end of 2009.

Table 4-9: Projected R-22 Servicing Scenario for all AC and Refrigeration Equipment (Including Imports) (Metric Tons)

Servicing Scenarios	2010	2015	2020
Servicing Needs of Domestically Manufactured Equipment and Equipment Imported Before 2010	68,600	43,200	20,600
Servicing Needs of Equipment Imported After 2009	400	1,500	2,700
Total Servicing Needs Including Imports	69,000	44,700	23,300

As shown in Table 4-9, the projected quantities of R-22 required to service pre-charged post-2009 imports comprise only one percent of the total servicing needs in 2010, growing to three percent in 2015 and twelve percent in 2020. For the purpose of this analysis, import projections are based on the type and amount of equipment currently imported; however, if higher percentages of these types (particularly residential unitary AC) are imported, or if the import trend extends to other AC and refrigeration equipment types, particularly those with higher charge sizes, leak rates, and service rates (e.g., retail food equipment), the demand for R-22 for servicing will increase.

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 maximized. However, because of the uncertainty associated with the future recovery and reuse of refrigerant, the findings indicate significant variance in the projected supply of recovered refrigerant available to meet demand. Under a scenario with higher refrigerant recovery and reuse, supplies are projected to satisfy future R-22 servicing needs using both recovered refrigerant and limited amounts of virgin refrigerant.

The total projected servicing demand in 2010, 2015, and 2020 as compared to an allocation of 100 percent of the HCFC consumption cap are summarized below along with concluding points on the implications of the two recovery and reuse scenarios.

- In 2010, a projected servicing demand of 68,600 metric tons, or about 70 percent of the consumption cap, is estimated. Table 5-1 indicates that approximately 27 percent of this demand could be met with recovered refrigerant if 50 percent of the available refrigerant from discarded equipment is recovered and reused; if only 10 percent of the available refrigerant is recovered and reused, only five 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 1: 50% Recovery Rate	Scenario 2: 10% Recovery Rate
Cap[a]	96,982	
Demand	68,600	
Necessary Supply		
Recovered	18,500 (27%)	3,700 (5%)
Virgin	50,100 (73%)	64,900 (95%)
Shortfall	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 2015, a projected servicing demand of 43,400 metric tons is estimated, which is over the consumption cap by 57 percent. Under a scenario of higher recovery and reuse, 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 scenario, a shortfall of approximately 11,000 metric tons is 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 1: 50% Recovery Rate	Scenario 2: 10% Recovery Rate
Cap[a]	27,709	
Demand	43,400	
Necessary Supply		
Recovered	22,600 (52%)	4,500 (10%)
Virgin	20,900 (48%)	27,709 (64%)
Shortfall	0 (0%)	11,191 (26%)

[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, a projected servicing demand of 20,500 metric tons is estimated, although no consumption is allowed (Table 5-3). Under a scenario of higher recovery, this demand is projected to be met entirely with recovered refrigerant. However, under a scenario of minimal recovery, only 21 percent of this demand is projected to be met with recovered refrigerant, leading to a shortfall of over 16,000 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 1: 50% Recovery Rate	Scenario 2: 10% Recovery Rate
Cap[a]	0	
Demand	20,500	
Necessary Supply		
Recovered	20,500 (100%)	4,400 (21%)
Virgin	0 (0%)	0 (0%)
Shortfall	0 (0%)	16,200 (79%)

[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 cap remains; however, the phaseout schedule in 2020 prevents any allocation of the remaining cap to R-22.

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. Further 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 2006a), 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 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 Significant New Alternatives Policy (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 2006, the model was updated based on information obtained from industry during the research phase of this analysis in 2005. As such, the methodology used in the preliminary 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.

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 chemical leaked during equipment operation and the amount of chemical 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."

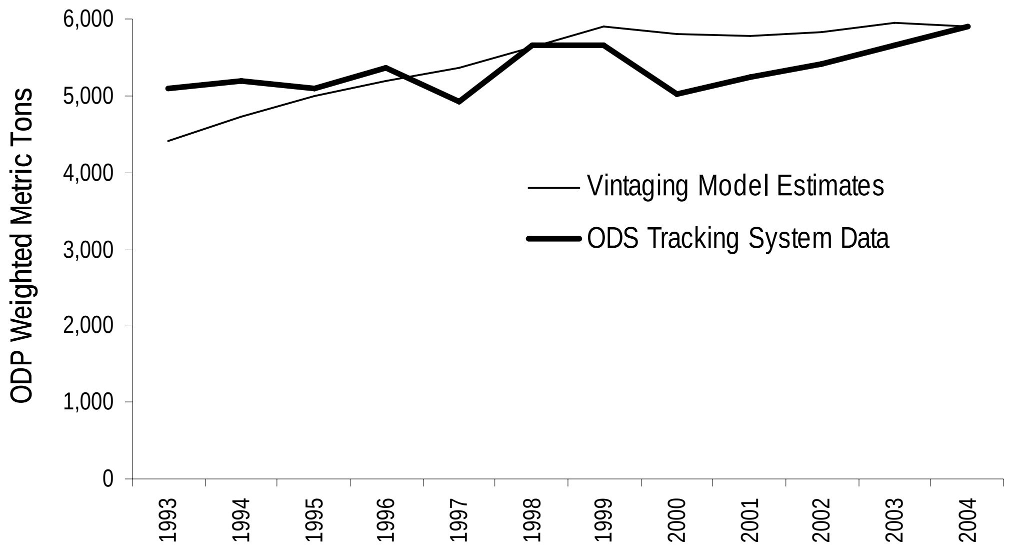
2) <u>Number of Units of Equipment</u>, which is equal to, for "*year X*"", the number of units existing in "*year* X-1" plus the number of new units produced in "*year X"* minus the number of units disposed in "*year X"*.

   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 2004.

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_6-30-06_ALL)

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	R-11 Centrifugal Chillers	700	14.1%	0.5%	51%	25
R-22	R-12 Centrifugal Chillers	720.8	8.0%	0.5%	51%	27
R-22	R-22 Chillers	1,818	8.3%	0.5%	51%	20
R-22	R-500 Chillers	926.1	10.9%	0.5%	51%	27
R-22	R-22 Residential Unitary AC (2005-2006)	3.4	11.9%	1.9%	57%	15
R-22	R-22 Residential Unitary AC (2006-2020)	4.8	11.9%	1.9%	63%	15
R-22	R-22 Small Commercial Unitary AC	7.5	11.0%	2.5%	57%	15
R-22	R-22 Large Commercial Unitary AC	15	10.2%	2.5%	57%	15
R-22	R-22 Water & Ground Source Heat Pumps	4.1	5.1%	2.5%	57%	20
R-22	R-22 Dehumidifiers	0.2	0.5%	0%	50%	15
R-22	R-22 Packaged Terminal Units	0.7	5.1%	2.5%	57%	12
R-22	R-22 Window Units	0.6	0.6%	5%	50%	12
R-22	R-12 Tour Buses	5	10.0%	0.92%	50%	12
R-22	R-22 Transit Buses	8	44.0%	1.47%	50%	12
R-22	R-22 Trains	22	43.2%	0.91%	50%	5
	Refrigeration Equipment					
R-22	R-12 Cold Storage	0.0088	17.2%	2.5%	43%	20
R-22	R-22 Cold Storage	0.0088	20.0%	2.5%	43%	25
R-22	R-502 Cold Storage	0.0088	17.1%	2.5%	43%	25
R-402A	R-502 Cold Storage	0.0088	25.0%	2.5%	10%	25
R-502	R-502 Cold Storage	0.0088	25.0%	2.5%	10%	25
R-22	R-12 Retail Food	1,800	17.6%	1.7%	43%	15
R-22	R-22 Retail Food	93	6.4%	1.7%	43%	20
R-22	R-502 Retail Food	6.3	13.8%	1.7%	43%	20
R-402A	R-502 Retail Food	6.3	21.3%	1.7%	10%	20
R-502	R-502 Retail Food	6.3	21.3%	1.7%	10%	20
R-22	R-12 Transport	7.53	27.9%	2.5%	38%	12
R-402A	R-12 Transport	7.53	27.9%	2.5%	10%	12
R-401A	R-502 Transport	7.53	27.9%	2.5%	10%	12
R-502	R-502 Transport	7.53	27.9%	2.5%	10%	12
R-22	R-11 Industrial Process Refrigeration	952	12.0%	2.5%	51%	25
R-22	R-12 Industrial Process Refrigeration	992	5.4%	2.5%	51%	25
R-401A	R-12 Industrial Process Refrigeration	850	5.4%	2.5%	51%	25
R-22	R-22 Industrial Process Refrigeration	9,100	12.3%	2.5%	51%	25

Source: VM IO File_6-30-06_ALL
[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. 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.

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

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.

For example, the centrifugal chiller new-equipment market that originally used R-11 first transitioned from R-11 to R-22. Then, between 2000 and 2010, 70 percent of the R-22 new-equipment market is assumed to transition to R-134a and the remaining 30 percent to R-407C.

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

1	2	3	4	5
R-22 Equipment Type and Original ODS Refrigerant	Substitute	Start Date	End Date	Market Penetration of Substitute[a]
CFC-11 Centrifugal Chillers	HFC-134a	2000	2010	70%
	R-407C	2000	2010	30%
CFC-12 Centrifugal Chillers	HFC-134a	2000	2010	70%
	R-407C	2000	2010	30%
R-500 Chillers	HFC-134a	2000	2010	70%
	R-407C	2000	2010	30%
HCFC-22 Chillers	HFC-134a	2000	2009	7%
		2009	2010	63%
	R-407C	2000	2009	3%
		2009	2010	27%
HCFC-22 Residential Unitary AC	R-407C	2010	2010	10%
	R-410A	2000	2005	5%
		2000	2006	5%
		2006	2006	20%
		2007	2010	20%
		2010	2010	40%
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	8%
		2009	2010	81%
HCFC-22 Water & Ground Source Heat Pumps	R-407C	2006	2009	1%
		2009	2010	5%
	R-410A	2001	2006	4%
		2006	2009	9%
		2009	2010	81%
HCFC-22 Dehumidifiers	HFC-134a	1997	1997	89%
	R-410A	2007	2010	11%

1	2	3	4	5
R-22 Equipment Type and Original ODS Refrigerant	Substitute	Start Date	End Date	Market Penetration of Substitute[a]
HCFC-22 Packaged Terminal Units	R-407C	2000	2006	5%
		2006	2009	2%
		2009	2010	23%
	R-410A	2000	2006	5%
		2006	2009	5%
		2009	2010	40%
	HFC-134a	2000	2009	2%
		2009	2010	18%
HCFC-22 Window Units	R-407C	2003	2009	3%
		2009	2010	35%
	R-410A	2003	2009	7%
		2009	2010	55%
CFC-12 Tour Buses	HFC-134a	2006	2008	100%
HCFC-22 Transit Buses	HFC-134a	1995	2009	100%
HCFC-22 Trains	Unknown	2002	2009	100%
CFC-12 Cold Storage	R-404A	1996	2010	75%
	R-507A	1996	2010	25%
HCFC-22 Cold Storage	R-404A	1996	2009	7%
		2009	2010	68%
	R-507A	1996	2009	2%
		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	HFC-134a	1995	2010	100%
CFC-12 Industrial Process Refrigeration	HFC-134a	1995	2010	15%
	R-404A	1995	2010	50%
	R-410A	1999	2010	20%
	R-507A	1995	2010	15%
HCFC-22 Industrial Process Refrigeration	HFC-134a	1995	2009	1%
		2009	2010	14%
	R-404A	1995	2009	5%
		2009	2010	45%
	R-410A	1999	2009	2%
		2009	2010	18%
	R-507A	1995	2009	1%
		2009	2010	14%
CFC-12 Retail Food	R-404A	1995	2000	17%
		2000	2005	32%
		2005	2010	18%
	R-507A	1995	2000	7%
		2000	2005	14%
		2005	2010	12%

1	2	3	4	5
R-22 Equipment Type and Original ODS Refrigerant	Substitute	Start Date	End Date	Market Penetration of Substitute[a]
HCFC-22 Retail Food	R-404A	1995	2000	17%
		2000	2005	32%
		2005	2010	18%
	R-507A	1995	2000	7%
		2000	2005	14%
		2005	2010	12%
R-502 Retail Food	R-404A	2000	2010	75%
	R-507A	2000	2010	25%
CFC-12 Transport	HFC-134a	1995	1999	100%
R-502 Transport[b]	HFC-134a	1993	1995	55%
	R-404A	1993	1995	45%

Source: VM IO File_6-30-06_ALL
[a]The market penetration of the substitute represents the percent of the R-22 new-equipment market that is replaced by the substitute refrigerant.
[b]The R-502 transport refrigeration market transitions directly to HFC-134a and R-404A. There is no interim transition to R-22.

A.2 Supplemental Analysis: Pre-charged Imports

Through discussions with industry representatives, it was determined that the anticipated trends in imports of equipment precharged with R-22 needed to be taken into account in the analysis. EPA's Vintaging Model assumes that no new R-22 equipment enters the market after 2010. To create a scenario that reflects the fact that R-22 equipment may in fact be imported post 2010, EPA's Vintaging Model inputs of four end-uses—window units, dehumidifiers, packaged terminal units, and residential unitary ACs—were altered to run a scenario that reflects the assumptions listed in Table A-3 below.

Table A-3: Assumptions for the Import Analysis[a]

End-use	Transition Modification
Window Units	100% of the market remains R-22 through 2030 (i.e., no transitions away from R-22)
Dehumidifiers	
Packaged Terminal Units	10% of the market continues using R-22 through 2030 while the remaining 90% of the market transitions to non-ozone depleting alternatives as described in Table A-2
Residential Unitary AC	

[a]These end-uses and transition modifications were chosen based on industry contacts, which indicated that currently almost all window units and dehumidifiers sold in the U.S. are imported and that a smaller percentage of residential unitary AC systems and packaged terminal units are imported (ARI 2005; AHAM 2005).

A.3 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 more detailed projections for future servicing needs and is organized as follows:

- Section B.1 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.
- Section B.2 provides estimates of the quantities of R-123 and R-124 needed to service AC and refrigeration equipment by end-use.

Estimates are provided for AC and refrigeration equipment by end-use from 2005 to 2020 in five year increments. 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 pure 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).

B.1 R-22 Equipment and Servicing Demand by End-Use

Table B-1 presents the number of units of equipment using R-22 that are estimated to be in use in 2005, 2010, 2015, and 2020. These estimates were developed based on EPA's Vintaging Model, which takes into account recent input from industry representatives (EPA 2006a). 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

Equipment Type	2005	2010	2015	2020
Window Units	67,784,600	74,178,600	41,559,400	4,102,600
Packaged Terminal Units	2,606,600	2,478,800	1,355,100	123,100
Residential Unitary AC	51,821,200	46,884,600	29,197,700	10,709,100
Small Commercial Unitary AC	18,582,000	17,097,500	10,666,800	4,291,400
Large Commercial Unitary AC	1,910,100	1,849,900	1,208,600	505,200
Chillers	11,700	10,100	9,400	6,800
Dehumidifiers	11,666,700	3,517,600	1,448,400	0
Water & Ground Source Heat Pumps	1,390,100	1,392,000	1,058,200	680,900
Other Mobile AC	94,600	46,600	14,100	0
Total AC	155,867,600	147,455,700	86,517,700	20,419,100
Cold Storage[a]	253,881,300	231,153,800	132,924,500	61,119,300
Retail Food	2,261,700	2,195,400	1,553,500	763,000
Refrigerated Transport	10,700	0	0	0
Industrial Process Refrigeration	7,800	8,700	7,500	5,600
Total Refrigeration[b]	2,280,200	2,204,100	1,561,000	768,600
Total	158,147,800	149,659,800	88,078,700	21,187,700

[a]For this table, units of Cold Storage are presented in cubic feet of storage.
[b]Totals do not include Cold Storage

Table B-2 presents the metric tons of R-22 estimated to be needed to service AC and refrigeration equipment in 2005, 2010, 2015, and 2020.

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

Equipment Type	2005	2010	2015	2020
Window Units	200	300	100	<50
Packaged Terminal Units	100	100	<50	<50
Residential Unitary AC	20,900	20,700	13,500	6,100
Small Commercial Unitary AC	15,400	14,100	8,800	3,500
Large Commercial Unitary AC	2,900	2,800	1,800	800
Chillers	3,100	3,000	2,400	1,600
Dehumidifiers	<50	<50	<50	0
Water & Ground Source Heat Pumps	300	300	200	100
Other Mobile AC	300	100	<50	0
Total AC	43,200	41,400	26,800	12,100
Cold Storage	1,000	1,000	800	600
Retail Food	23,800	17,300	8,500	2,600
Refrigerated Transport	100	0	0	0
Industrial Process Refrigeration	8,200	8,900	7,100	5,300
Total Refrigeration	33,100	27,200	16,400	8,500
Total	76,300	68,600	43,200	20,600

Although the equipment-specific servicing estimates can not be broken down into recovered versus new refrigerant, the overall servicing demand is expected to be met in part by the use of recovered refrigerant. By 2010, it is projected that between five and 27 percent of all equipment can be serviced with recovered refrigerant. The use of recovered R-22 (as a percent of overall servicing demand) is projected to increase to between 10 and 52 percent by 2015, and 21 and 100 percent by 2020. Servicing demand is assumed to be increasingly satisfied by recovered (as opposed to virgin) refrigerant, as an increasing number of old equipment units gets retired, and their installed refrigerant becomes available for reuse.

B.2 Other HCFC Refrigerants Projected by End-Use

Table B-3 presents the estimated servicing demand, in metric tons, of R-123 and R-124 in 2005, 2010, 2015, and 2020, as broken down by equipment type.

Table B-3: Other HCFC Servicing Demand (Metric Tons)

Refrigerant and Equipment Type	2005	2010	2015	2020
R-123				
Chillers	500	400	300	200
Industrial Process Refrigeration	<50	100	100	100
Total	500	500	400	300
R-124				
Transport	<50	0	0	0
Industrial Process Refrigeration	<50	<50	<50	<50
Total	<50	<50	<50	<50

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