THE HIGH COST OF COOL

The Economic Impact of the CFC Phaseout In the United States

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EXECUTIVE SUMMARY

Chlorofluorocarbons (CFCs) are an important class of compounds. They have an impact on the life of nearly every American. Yet, as a result of environmental fears, their production will soon be eliminated - by the year 1996. In making this decision, little consideration was given to the costs of eliminating such a widely used class of compounds over a relatively short period of time.

This study examines the probable economic cost of the CFC phaseout on the refrigeration and air conditioning sector in the United States. The estimated cost of the CFC phaseout is $44.5 to $99.4 billion over the next decade. This estimate breaks down as follows (figures in billions):

- Vehicle air conditioners — $28.0 - $42.0
- Energy consumption — $ 0 - $32.1
- Domestic refrigeration — $ 4.0 - $ 8.0
- Commercial refrigeration — $ 3.0 - $ 5.4
- Chillers — $ 4.4 - $ 5.0
- HCFCs & HCFC Equipment — $ 5.1 - $ 6.9

Compliance with the law will impose large up-front costs on businesses and individuals. Much equipment will need to be replaced or modified (retrofitted).

After decades of fine-tuning and extensive field experience, air conditioning and refrigeration equipment using CFCs has become very reliable. In contrast, most CFC replacements are new, and manufacturers are still near the bottom of the learning curve in making the massive technological changes necessary.

Because of the accelerated phase-out, which provides a limited time frame in which to end dependence on CFCs, non-CFC systems are being rushed into use, despite many unsolved problems. In effect, a multi-billion dollar field test of experimental equipment is being conducted at consumer expense. The frequency of break downs, and the costs of repairs can be expected to increase for many applications.

The CFC phaseout may well be the single most expensive environmental measure taken to date. During the policy debate, the costs were underemphasized to the point that they never became an important factor. The impact on consumers was scarcely considered. It may be too late to reverse course on the CFC phaseout, but it can serve as a lesson for the future.

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IN THE UNITED STATES

by Ben Lieberman

INTRODUCTION

Chlorofluorocarbons (CFCs) are an important class of compounds. They are the refrigerants used in over $100 billion worth of air-conditioning and refrigeration equipment in the U.S. They have an impact on the life of nearly every American, as many people own CFC-using equipment and purchase goods and services that rely on CFCs.

CFCs have an impact on the life of nearly every American.

As a result of environmental fears, their production will soon be eliminated. A number of scientists have argued that CFCs and other compounds deplete the earth's ozone layer.[1] According to the theory, CFC molecules that escape into the atmosphere at ground level eventually rise to the upper atmosphere (stratosphere), where they are broken down by sunlight and release their chlorine atoms. The chlorine atoms then destroy ozone molecules, leading to depletion of the stratospheric ozone layer. Since the ozone layer partially shields the earth from incoming ultraviolet radiation, its depletion is predicted to lead to an increase in ultraviolet radiation reaching ground level.[2] Because increased ultraviolet radiation levels could adversely affect human health and the environment, the Congress and the international community have outlawed the production of CFCs by the end of 1995.

In making this decision, there was little consideration given to the costs of eliminating such a widely used class of compounds over a relatively short period of time. In the U.S., these costs will be between $44.5 to $99.4 billion over the next decade for refrigeration and air-conditioning alone. This amounts to approximately $445 to $994 per household. These costs should have been taken into account during the CFC phaseout decisionmaking process.

The federal government, once it chose to embark on the accelerated CFC phaseout, has tried to minimize the issue of the costs to the public. While overstating the dangers of ozone depletion in numerous reports, hearings, and press conferences, agency officials and legislators have often underemphasized the economic consequences and human impact of eliminating CFC production by 1995.[3] The few studies that estimate the costs tend to understate them, while overstating the environmental benefits of eliminating CFCs.[4] As a result, the public has accepted the CFC phaseout in near total ignorance of the impact it will have on them.

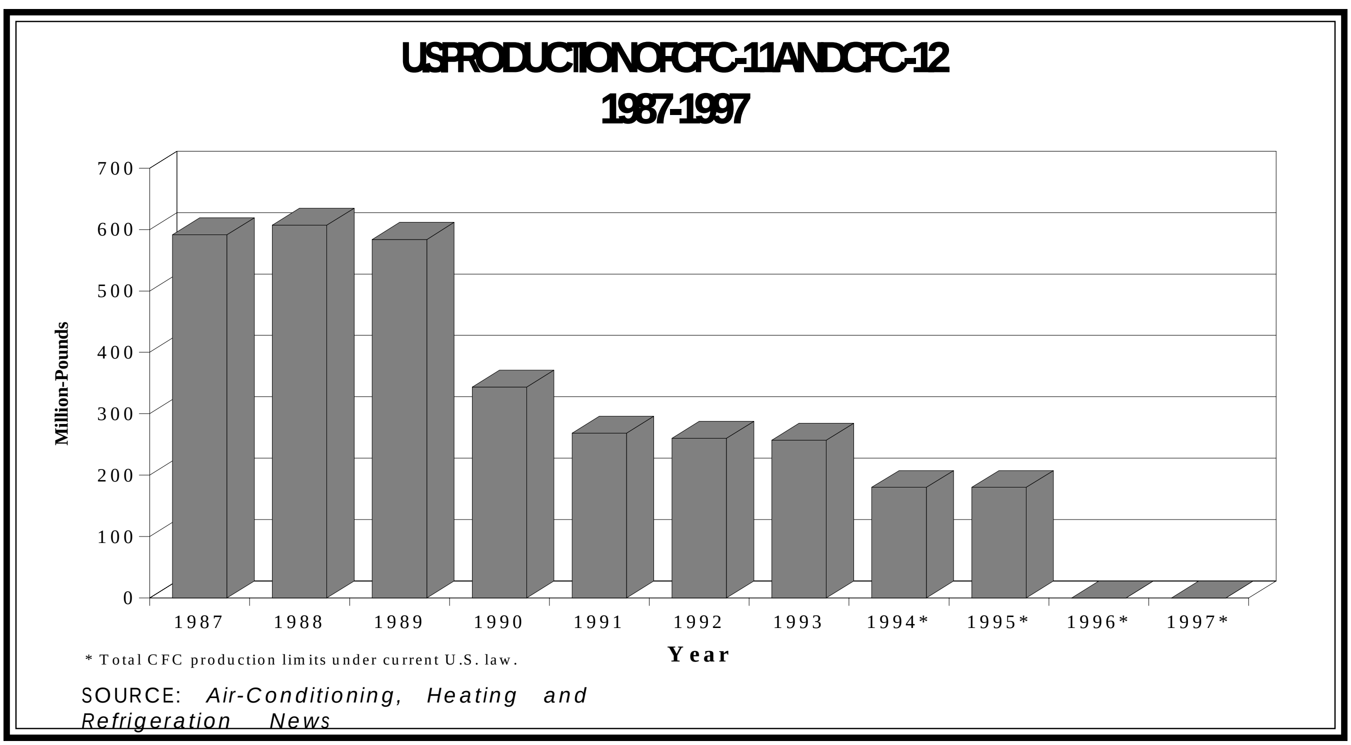
This paper will attempt to provide a realistic assessment of the costs in the U.S. of eliminating CFC production by 1995. It will be limited to the impact on refrigeration and air-conditioning[5], and will emphasize the costs that, directly or indirectly, will be imposed on American consumers over the course of the next ten years.

There was little consideration given to the costs of eliminating such a widely used class of compounds over a relatively short period of time.

THE CURRENT STATE OF THE LAW

Both international and U.S. law restrict the production of CFCs.[6] In 1987, the international community responded to fears of global ozone depletion by ratifying the Montreal Protocol on Substances That Deplete the Ozone Layer (Montreal Protocol). It was signed initially by 24 nations, including the U.S. and most major CFC producers. Today the Montreal Protocol has 123 signatories. It originally called for an eventual 50 percent reduction in global CFC production, but has since been amended to require a total phaseout, except for "essential" uses, by the end of 1995 for developed nations and 2005 for developing nations.[7]

Domestically, the Congress included provisions to the Clean Air Act Amendments of 1990, which set production limits on CFCs, culminating in a total phaseout by the year 2000. In February 1992, the phaseout was accelerated in response to a NASA press conference, where several scientists predicted a severe depletion of the ozone layer over North America during the winter.[8] The Senate unanimously passed an amendment urging president Bush to move up the phaseout



date to 1995, to which the president agreed.[9] A few months later, NASA admitted that their prediction was incorrect, but the accelerated phaseout was unaffected.[10]

In response to Congress, the EPA recently promulgated the regulation that outlines the phaseout.[11] Generally, CFC production is limited to 25 percent of 1986 production levels for 1994 and 1995, with a complete end to production on January 1, 1996.[12] Estimates of past and projected CFC production in the U. S. are displayed in the chart above. In addition, a related class of compounds called HCFCs is being phased out under a slower timetable.[13] The EPA has also imposed regulations regarding the manner in which air-conditioning and refrigeration equipment is serviced and disposed of, in an attempt to reduce the atmospheric release of existing CFCs.[14]

CFCs are rapidly becoming scarce.

AN OVERVIEW OF THE COSTS

Before analyzing the effect of the phaseout on specific end uses, it is worthwhile to take an overall view of its impact. Compliance with the law will impose large up-front costs on businesses and individuals, as much equipment will need to be replaced or modified (retrofitted). In addition, there will be increases in ongoing operational expenditures as a result of higher maintainance costs, refrigerant costs and energy consumption. This will add as much as $9.94 billion annually over the next decade to the cost of meeting America's refrigeration and air-conditioning needs. The breakdown of the costs over the next decade assessed in this paper is displayed in the table at right and the chart below.

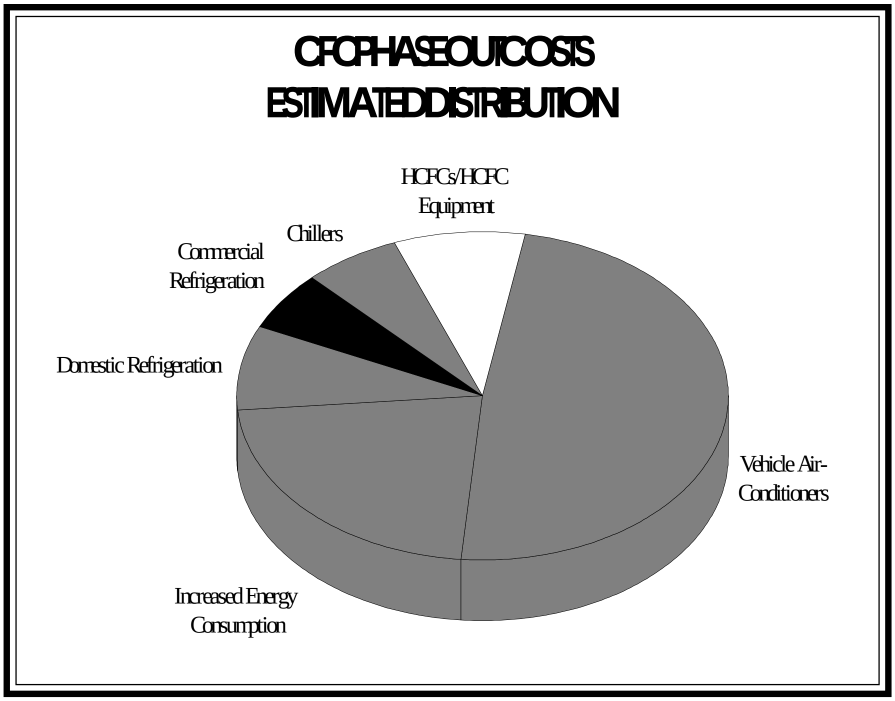
ESTIMATED CFC PHASEOUT COSTS
REFRIGERATION AND AIR-CONDITIONING
1994 through 2003
(figures in $billions)

Cost	Range
Vehicle Air-Conditioners	28.0 - 42.0
Energy Consumption	0 - 32.1
Domestic Refrigeration	4.0 - 8.0
Commercial Refrigeration	3.0 - 5.4
Chillers	4.4 - 5.0
HCFCs and HCFC Equipment	5.1 - 6.9
TOTAL	**44.5 - 99.4**

Note: The following are not included in the above analysis: refrigerated transportation, industrial refrigeration, medical and laboratory equipment, dehumidifiers, vending machines, water coolers, drinking fountains.

Equipment Costs

In the U.S., there is approximately $135 billion worth of air-conditioning and refrigeration equipment in commercial and domestic use.[15] Much of this equipment has a useful life of 10 to 25 years, needs additional refrigerant to make up for leakage over time, and is not designed to work with non-CFC refrigerants.[16] Because CFCs are rapidly becoming scarce, much equipment will have to be prematurely replaced or



retrofitted to use CFC alternatives. Billions of dollars in additional equipment and installation outlays will be required to maintain the status quo.

Even after the current base of equipment is replaced, there may be ongoing increases in equipment costs. There are some indications that the alternative systems will have a shorter useful life than their CFC-using counterparts, but it is difficult to know for certain as non-CFC equipment has only recently come into use. Although the potential costs of more frequent replacements could be high, they cannot be accurately estimated at this time and will not be included in the total accounting.

OPERATIONAL COSTS

Maintenance

After decades of fine-tuning and extensive field experience, air-conditioning and refrigeration equipment using CFCs had become very reliable. In contrast, most CFC replacements are new, and manufacturers are still near the bottom of the learning curve in making the massive technological changes necessary. Properly matching equipment with these new refrigerants will take several more years. This task is further complicated by the fact that many non-CFC refrigerants have inherent chemical and thermodynamic properties that make them difficult to manage.

In effect, a multi-billion dollar field test of experimental equipment is being conducted at consumer expense.

Under ordinary circumstances, extensive research and development would be completed by industry prior to new equipment being introduced in the market. However, because of the accelerated phaseout, which provides a limited time frame in which to end dependence on CFCs, non-CFC systems are being rushed into widespread use, despite many unsolved problems. In effect, a multi-billion dollar field test of experimental equipment is being conducted at consumer expense. The frequency of breakdowns, and the costs of repairs can be expected to increase for many applications.

Further, the rapid introduction of numerous new refrigerants has thrown the refrigeration and air-conditioning service industry into a state of confusion. In the last few years, no less than 10 new refrigerants have come into use, and more are on the way.[17] Some have unique equipment requirements and servicing needs, which are currently being discovered through trial and error.[18] Further, because some of the new refrigerants are chemically incompatible with others, service equipment that comes in contact with one refrigerant (for example recovery devices or gauges) may cause contamination if later used on a system with a different refrigerant. Unless servicemen own and maintain several sets of dedicated equipment, refrigerant cross-contamination will become a serious problem.

The situation is so complex that even skilled servicemen admit that they are often not certain as to the proper procedure. Costly mistakes made during installation, routine maintenance, and repairs will be common for many years, imposing significant costs on equipment owners.

Costly mistakes made during installation, routine maintenance, and repairs will be common for many years.

Also, refrigerant recovery rules, requiring servicemen to take measures to prevent refrigerant leakage during servicing, and rules requiring leak detection and repair, are time consuming and require expensive equipment, adding to the costs of repairs and maintainance.[19]

Air-conditioning and refrigeration servicing has become more costly.[20] Some servicemen estimate that they will be charging clients about 25 percent more than they had previously. However, the total increase in maintenance costs cannot be determined at this time, as most of these costs are incurred after equipment has been in use for a few years, and non-CFC equipment has only recently made inroads into the American market. Because of the uncertainties, these costs will not be included in the total accounting, except in those cases where it is specifically noted.

Refrigerant Use

Before the phaseout took effect, the market price of the most common types of CFC refrigerants, CFC-11 and CFC-12, was less than $1.00 per pound wholesale. Today, as a result of production limits and excise taxes, they cost approximately $8.00 to $10.00 per pound at the wholesale level, and up to twice that for some retail users.[21] This amount is expected to rise considerably in the months and years ahead. In 1994 and 1995, the quantity of CFCs allowed to be produced is about 180 million pounds annually, but based on recent years, considerably more than that will be needed.[22] After January 1, 1996, when all production ends, cost increases will further accelerate due to limited supplies.[23] Predictably, a black market in CFCs is developing.[24]

A black market in CFCs is developing.

Refrigerant recovery and subsequent recycling or reclamation, though required by law, is not likely to make up for the shortfall. There are limitations on how much refrigerant can be recovered and reused.[25] Also, compliance has not been widespread, particularly among those servicing equipment with a small refrigerant charge.[26]

The leading replacement refrigerants are also expensive. Unlike CFCs, the patents on which have long since expired, many of these new compounds are still under proprietary protection.[27] Others are more expensive to produce. The most common replacement, hydrofluorocarbon-134a (HFC-134a), costs at least $7.00 per pound.[28] In addition, some replacement refrigerants require expensive lubricants and additives in order to function properly. Cheaper alternatives, such as ammonia and hydrocarbons, have limitations—flammability, toxicity, regulatory barriers—that will take several years to overcome, and are not likely to be widely used in the U.S. in the near future.

Before the stringent production restrictions were in effect, the U.S. produced and consumed approximately 650 to 700 million pounds of CFCs annually, at least 300 million of which were used as refrigerants.[29] Conservatively estimating a $5.00 per pound increase in the current cost of CFCs and alternatives over the pre-phaseout cost of CFCs, an additional $1.5 billion per year will be spent on refrigerants. Most of these costs are included in the costs of new equipment and retrofits, and are not separately discussed.

Energy Use

Air-conditioning and refrigeration are energy intensive, consuming about 28 percent of the nation's electricity.[30] CFCs are currently used in many of these applications. Their replacement has raised concerns about the impact on energy consumption.

In nearly every case, the phase-out of CFCs will result in higher costs and decreased performance.

As refrigerants, CFCs are relatively energy efficient. Their thermodynamic properties—thermal conductivity, latent heat of vaporization, boiling point—are nearly ideal, for a variety of applications. In contrast, many of the leading replacements, such as HFC-134a, are not as well suited, and a loss in energy efficiency (relative to comparable CFC-using equipment) is unavoidable.[31] In addition to thermodynamic efficiencies, there may be other problems with non-CFC systems that will lead to greater energy use.[32]

One hypothetical estimate of the annual increase in overall electricity use resulting from a CFC phaseout gives the range of 13 to 94 billion kWh/yr, or (assuming $ 0.06 per KWh) $0.78 to $5.64 billion dollars.[33] The middle of this rangeamounts to an additional energy cost of$3.21 billion per year.

Other recent studies by the EPA, DOE and the alternatives industry found little or no energy penalty.[34] They compared the efficiencies of new alternative systems utilizing optimized engineering design with the old and inferiorly equipped CFC systems they are replacing. Relative efficiencies of comparable CFC and non-CFC systems were not considered.[35] The energy efficiency gains in new equipment are due to technological advances largely unrelated to the refrigerant chosen, although the CFC phaseout may have provided the impetus for immediate implementation of these costly improvements. In effect, the efficiency gap between new non-CFC and old CFC systems is being narrowed, and in some cases eliminated, but at the expense of higher equipment costs.

Nonetheless, the gap between comparable CFC and non-CFC systems persists. However, the extent of this gap is difficult to determine, as the energy efficiency of new non-CFC equipment is currently being improved, and the efficiency of comparable CFC systems can only be speculated, as CFCs are no longer being used in stste of the art equipment. In addition, the CFC phaseout has accelerated the retirement rates for old, inefficient systems. For these reasons, it is hard to estimate what energy consumption would have been without the CFC phaseout, and what it will be with the phaseout.

For the purposes of this study, the assumed range of increased annual energy expenditures is $0 to $3.21 billion, or $0 to $32.1 billion over the next decade. The low end of this range assumes that energy use for air-conditioning and refrigeration will be no different than if there there been no CFC phaseout. The high end, which represents the middle of the range discussed previously, estimates a penalty of about 2 percent of total energy consumption.

THE IMPACT ON SPECIFIC END USES

The higher initial and ongoing costs discussed above will affect most kinds of refrigeration and air-conditioning applications. In nearly every case, the phaseout of CFCs will result in higher costs and decreased performance. The most heavily affected applications will each be discussed separately.

Vehicle Air-Conditioners

Americans own approximately 140 million automobiles and trucks that use CFCs in their air-conditioners.[36] Unless willing to do without air-conditioning, these owners are faced with two choices—continue using CFCs, or retrofit their system to use an alternative refrigerant. Either choice entails increased costs.

Approximately 20 million cars and trucks are brought in for air-conditioner servicing each year.

<u>Continue Using CFCs:</u>

Generally, vehicle air-conditioners run without problems for the first few years, and then need servicing once every two or three years thereafter. The most common problem is refrigerant leakage. Approximately 20 million cars and trucks are brought in for air-conditioner servicing each year.[37]

The accelerated phaseout already has increased the cost of servicing. Servicemen are required to comply with refrigerant recovery rules in order to reduce the amount of refrigerant that escapes during servicing.[38] This takes as much as a half hour and requires equipment costing about $1,000. As a result, labor costs for air-conditioner servicing have gone up.

The cost of the refrigerant, CFC-12, has also increased from under $1.00 per pound to as much as $10.00 wholesale and about twice that retail. A vehicle may need up to three pounds to be fully operational. The cost is expected to rise further, particularly in 1996 when all production ends.

It is now illegal to sell small cans of CFC-12 to the public, which were used to recharge vehicle air-conditioners.[39] Considering that 60 to 80 million pounds of refrigerant were sold in these cans, it is reasonble to assume that millions of people recharged their own vehicle air-conditioners, at minimal cost.[40] They are no longer able to do so. Now they are forced to take their vehicles to an EPA-certified mechanic or dealer whenever their air-conditioner needs servicing, and pay the market price for refrigerant and labor.

As a result, recharging an air-conditioner low on refrigerant, which cost between $20 and $40 as recently as 1991 (and just a few dollars for do-it-yourselfers), currently averages approximately $100.[41] This figure will increase, possibly doubling by 1996, if CFC-12 costs continue their present trends. Performing repairs on a system, such as fixing a leak, averages $265, a 20 percent increase over the 1991 average.[42] This amount is also likely to increase with time. Also, the number of vehicle owners being persuaded by servicemen to spend considerably more to repair leaks rather than "top off" (adding lost refrigerant without repairing the leak) will increase, in order to avoid the possibility of further CFC-12 losses in the future.[43] In Florida and parts of California, leak repair is required by state law.

Retrofit:

CFC-using air-conditioners can be modified to use an alternative refrigerant, HFC-134a. However, this is an expensive changeover, requiring the replacement of several components, including the hoses, safety valve, O-ring seals, drier, and possibly the condenser, as well as a thorough flushing of the system to remove all traces of CFC-12 and mineral oil, which act as contaminants in the presence of HFC-134a. The estimated average cost of a retrofit is $433.[44] Also, there are unanswered questions as to the performance and reliablity of retrofits.[45] It is unlikely that many consumers will choose the retrofit option, unless CFC-12 becomes prohibitively expensive or totally unavailable.

The auto industry has spent several hundred million dollars to redesign vehicle air-conditioning systems.

Total Costs For Existing Vehicles:

Assuming the 140 million CFC-using vehicles need an average of two more air-conditioner repairs or recharges before they are retired over the course of the next ten years, and each servicing averages $100 to $150 more than a comparable pre-phaseout servicing, the increased cost will be $28 to $42 billion over the next decade.[46] The total will be even higher if difficulties in obtaining CFC-12 force a large number of people to retrofit their vehicles. The option of simply not repairing an inoperative CFC-12 air-conditioner is also costly, as it will reduce the resale value of a vehicle by several hundred dollars.[47]

New Vehicles:

New car and truck air-conditioners are now designed to use HFC-134a. Introduced in a few models in 1992 and 1993, HFC-134a air-conditioners will predominate in 1994 models. The auto industry has spent several hundred million dollars to redesign vehicle air-conditioning systems and retool assembly lines to accommodate the changes. Eventually, these costs will be passed on to consumers in one form or another.

It is unlikely that HFC-134a systems will be as reliable as CFC-12 systems.[48] High failure rates after several years in use may be common. Unlike CFC-using systems, which (excepting minor repairs and occasional recharges) often lasted as long as the vehicle, a number of HFC-134a air-conditioners will probably need a major repair during the vehicle's useful life. If so, owning and maintaining a new HFC-134a air-conditioner for the life of the vehicle will cost several hundred dollars more than a comparable pre-phaseout CFC system. Any additional costs will become apparent only after the new HFC-134a air-conditioners have been subjected to a few years of use.[49] Because these costs are speculative, they are not included in the total accounting for this paper.

Domestic Refigerators

There are about 150 million refrigerators in domestic use in the U.S.

There are about 150 million refrigerators in domestic use in the U.S.[50] Nearly every household has at least one. They are reasonably priced and extremely reliable, often providing 15 or more years of trouble-free service. Until recently, nearly all used CFC-12 as their refrigerant. The phaseout will have relatively little effect on these refrigerators, as less than 5 percent ever require servicing due to refrigerant leakage.

However, refrigerator manufacturers are already preparing for the phase-out. As a result of CFC-12 shortages and price increases, several refrigerator manufacturers have begun to make the transition to non-CFC refrigerators, well ahead of the January 1, 1996 phaseout date. By that time, all newly manufactured refrigerators will be CFC-free.

As with vehicle air-conditioners, the alternative refrigerant of choice for new domestic refrigerators is HFC-134a.[51] Although it is too early to determine the price of these new refrigerators, at least one introductory model is priced $100 higher than a comparable CFC refrigerator, most of which range from $500 to $1,500, depending on the brand name and features.[52] Assuming a $50 to $100 increase per refrigerator, the nearly 10 million domestic refrigerators (and stand-alone freezers) sold each year will cost an additional $0.5 to $1.0 billion.[53]

Assuming HFC-134a refrigerators predominate beginning in 1996, the cost over the next decade will be $4.0 to $8.0 billion.

HFC-134a refrigerators may use more energy than an equivalent CFC system.[54] Like vehicle air-conditioners, HFC-134a refrigerators are unlikely to be as reliable and long-lasting as their CFC-using counterparts.[55] Expensive repairs may be common, some necessitating replacement, particularly after about 8 years of use. Because the first HFC-134a refrigerators are only a few years old, there is no direct evidence regarding their long-term reliability.[56] If they prove less durable than CFC refrigerators, the cost of additional repairs and premature replacements could be significant. This potential cost is not included in the total accounting.

HFC-134a refrigerators are unlikely to be as reliable and long-lasting as their CFC-using counterparts.

Chillers

There are at least 80,000 chillers operating in the United States.[57] Chillers, so called because they chill water which is used to cool air, are the most efficient means to air-condition large buildings. They also provide the cooling in certain industrial applications. About 65,000 are low-pressure chillers that use CFC-11, and most of the rest are high-pressure chillers that operate with CFC-12, HCFC-22, or R-500 (a mixture that includes CFC-12).[58] These systems are expensive to purchase and install and are expected to last more than 20 years. Most contain a thousand or more pounds of refrigerant, and often have high leak rates.[59] Thus, the future of this equipment has been significantly affected by the phaseout.

Thus far, less than 10 percent of chillers have been replaced or retrofited to use non-CFC refrigerants.[60] Most will still be reliant on CFCs when production comes to an end in 1996.[61]

Chiller owners are faced with several choices, and must make them in a short period of time and with limited information. Basically, they can continue to use CFCs, retrofit existing equipment to use an alternative refrigerant, or replace their system with a totally new non-CFC chiller. Each choice entails significant additional costs. Which option is appropriate in each case depends on the type and condition of the chiller, and the characteristics of the building it is located in. It also depends on the future availability of CFCs and the rate of non-CFC technological breakthroughs. At this point, the number of chiller owners that will choose each option and the total cost can only be estimated. The three options will be discussed in turn.

There is no legal requirement that CFC equipment be retired, only that CFC production cease.

Continue Using CFCs:

There is no legal requirement that CFC equipment be retired, only that CFC production cease. Existing CFC chillers can be used beyond the phaseout date, provided that sufficient refrigerant is available. However, with CFC production to end in 1995, the only way of assuring the long-term operation of CFC chillers is to minimize the amount of additional refrigerant needed. This requires refrigerant containment, i.e. taking steps to reduce refrigerant leakage, and recovering (rather than venting) refrigerant during maintenance and servicing (both of which are also regulatory requirements). It also necessitates storing extra CFCs for future use.[62] This option is particlarly attractive for CFC-11 chillers in good working order, where leakage can be reduced to a minimum.[63] Assuming that about half (30,000 to 35,000) of the CFC-11 chiller owners choose this option over the next decade, and the average cost is approximately $20,000 to $30,000 parts and labor,[64] the total cost over the next decade will be $0.6 to $1.05 billion dollars.

Retrofit:

For about 15,000 to 20,000 existing chillers, retrofitting to use alternative refrigerants is an economically sound decision. Perhaps 10,000 to15,000 CFC-11 chiller owners, anxious to end their reliance on CFCs, will choose to retrofit to HCFC-123. Retrofitting will also be chosen by the owners of many relatively new CFC-12 and R-500 chillers, because difficulties in reducing leakage makes continued reliance on CFCs risky, and total replacement would be wasteful. They can be retrofit to use HFC-134a. In either case, a retrofit entails extensive modifications to a chiller.[65] Retrofit costs range from $10,000 to well over

$100,000.[66] Assuming an average retrofit cost of $50,000, the total cost of retrofitting chillers will be $0.75 to $1.00 billion over the next ten years.

Premature Replacement:

Since continued reliance on CFCs or retrofitting involves significant costs and risks, some building owners may choose to purchase and install a new chiller.[67] Assuming 30,000 existing chillers will have been replaced in the next 10 years,[68] and half of these replacements are attributable to old chillers in need of replacement anyway, 15,000 replacements can be attributed to the phaseout. New chillers vary in cost depending on size, and the cost of installation depends on the features of each building. Assuming an average cost of $120,000, these chillers will add $1.8 billion to the phaseout cost.[69]

Safety Costs:

Primarily because of safety concerns surrounding some of the replacement refrigerants, new building code requirements for buildings with chillers are likely to become law.[70] The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) sets the model standards which nearly all local building codes follow.[71] Standard 34 categorizes refrigerants based on their toxicity and flammability. The most commonly used CFCs and HFC-134a are listed as A1, because they have low toxicity and low flammability. HCFC-123 is classified B1, because of higher toxicity and low flammability.[72] Standard 15 now requires that equipment rooms with a class A1-using chiller have ventilation systems, oxygen monitors, and a self-contained breathing apparatus. B1-using chillers require a refrigerant vapor detector and alarm system in addition to these requirements. The typical cost of bringing a building into compliance will be from $10,000 to $20,000.[73] Assuming an average of $15,000, the cost for all 80,000 chillers will be $1.2 billion.

There are safety concerns surrounding some of the replacement refrigerants.

Total Costs:

Within the next two years, chiller owners will have to make the transition to a market where CFCs, if available, will be very expensive. The total cost of continuing the use of CFCs, retrofitting, or replacing chillers, as well as the cost of compliance with new safety standards will be $4.4 to $5.0 billion over the next decade.

Commercial and Institutional Refrigeration

There are at least five million (and probably closer to ten million) pieces of CFC-using commercial and institutional refrigeration and freezing equipment in the U.S.[74] They are used in the 24,000 supermarkets and 228,000 smaller food stores,[75] 729,000 restaurants, bars, hotels, schools, and other places that serve food and drink,[76] and approximately 200,000 other businesses (pharmacies, liquor stores, florists etc.) that require such equipment.[77] Complying with the law will be a complex and expensive task.

These applications require equipment that provides a large volume of storage space for refrigerated or frozen items. Like chillers, these systems are expected to last a long time and occasionally leak, requiring additional CFC supplies to stay operational. Therefore, over the next decade, most of them will be retrofit to run with alternative refrigerants.[78] As with chiller owners, the majority of affected establishments have not yet done anything, thus the total costs can only be estimated at this time. It is assumed that these costs will eventually be passed on to consumers.

Supermarkets and Food Stores:

Retail refrigeration equipment falls into two general categories, medium and low temperature. Medium temperature equipment includes meat, fish, dairy, delicatessen, and produce cases, and walk-in coolers for storage. Most medium temperature systems use CFC-12. Low temperature applications include multi-deck frozen food cases, closed door freezer cases, and open chest type freezers and walk-in freezers. Most of this equipment uses a mixture called R-502, which contains CFCs. Supermarkets typically have about 30 medium and low temperature systems, while convenience stores and other small food retailers have fewer than 10, and the systems tend to be smaller than their supermarket counterparts.

A typical supermarket will cost approximately $45,000 to retrofit.

The cost of retrofitting a single system in a supermarket is approximately $1,500.[79] Thus, a typical 30-system supermarket will cost approximately $45,000 to retrofit. This amounts to $1.1 billion nationwide. Smaller food stores will probably range from $3,000 to $5,000 each, or $0.7 to $1.1 billion nationwide.

Food Service:

The 729,000 restaurants and other places that serve food or drinks typically have 10 or fewer pieces of equipment. In addition to having the same types of equipment used in food stores, they will also have ice machines and small, self-contained equipment for storing and serving food and drinks.[80] Typical retrofit costs are estimated to be in the $1,000 to $3,000 range, for a total of $0.7 to $2.2 billion.

Other Commercial Uses:

At least 200,000 other businesses use refrigeration, usually fewer than fivepieces of self-contained equipment. The retrofit cost to these businesses will probably average of $250 to $500 each, or $0.5 to $1.0 billion in total.

Total Costs:

Well over one million establishments will have to make changes in their refrigeration equipment in order to cope with the lack CFCs. The total cost for these businesses and institutions will likely be $3.0-$5.4 billion.

HCFC Equipment

In addition to CFCs, a related class of refrigerants called hydrochlorofluorocarbons (HCFCs) are also being phased out of production, but under a slower timetable. In the U.S., HCFC-22, the most commonly used HCFC, will be phased out beginning in 2010.[81] However, it is possible that the deadline will be accelerated.

HCFC-22 is used in 43 million central air-conditioners in America's homes, and in about 2 million air-conditioners in other buildings.[82] The refrigerant recovery rules also apply to HCFC-22 equipment. On average, central air-conditioners require the type of servicing necessitating recovery once every five years. Thus, in a given year, approximately 20 percent of the nation's central air systems will require refrigerant recovery. Assuming nine million of these procedures are performed on residential and other central air-conditioners annually at a typical charge of \$40 to \$60,[83] the total cost will be \$360 to \$540 million annually, or \$3.6 to \$5.4 billion over the next decade. Further, air-conditioners use about half of the 300 million pounds of HCFC-22 produced each year.[84] The price of HCFC-22 has doubled from about \$1 per pound to \$2.[85] Assuming the price remains at \$2 per pound, an additional \$150 million will be spent annually on HCFC-22 for air-conditioning, or \$1.5 billion over the next decade. Added to the refrigerant recovery costs, the increased costs associated with HCFCs will total \$5.1 to \$6.9 billion for the next ten years.

Hydrochlorofluorocarbons (HCFCs) are also being phased out of production.

In addition to central air-conditioners, HCFCs are used in some chillers, commercial refrigeration units, and other equipment. Also, a number of CFC systems are being retrofit to use HCFCs. A future supply of HCFCs will be needed to maintain these systems. If the HCFC phaseout is accelerated, as some predict, the additional cost of compliance would be great.

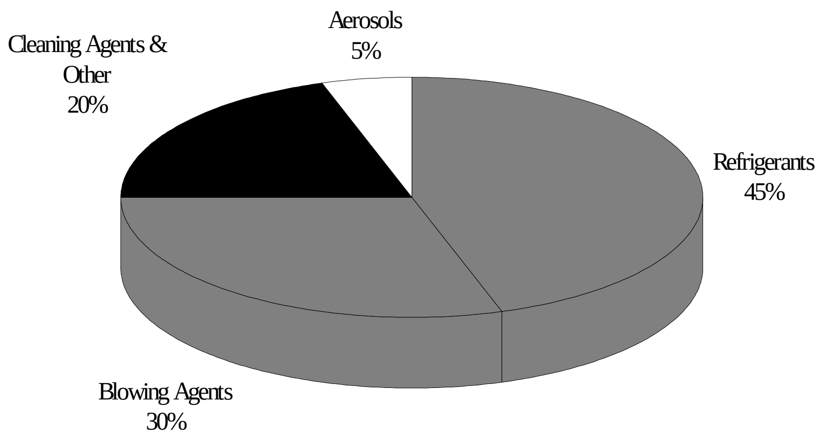
Other Equipment and Uses

In addition, other types of CFC-using air-conditioning and refrigeration equipment will also be affected, but are not separately discussed. Refrigerated transports (trucks, rail cars, ships, sea-land containers), refrigeration used in industrial processes, medical and laboratory equipment, dehumidifiers, water coolers and drinking fountains, and vending machines are not included. In aggregate, the cost of replacing or retrofitting these systems will be significant, but are left out of the total accounting for this paper.

Finally, it must also be remembered that CFCs are also used for other applications besides refrigeration and air-conditioning. CFCs have been used as cleaning agents, solvents, and as blowing agents for foam insulation. The accompanying chart displays the distribution of CFC uses in the United States prior to the signing of the Montreal Protocol. Note that before the phaseout, refrigeration accounted for less than half of total CFC use in the United States.

CONCLUSION

DISTRIBUTION OF CFC USES PRIOR TO MONTREAL PROTOCOL



SOURCE: Alliance for a Responsible CFC Policy

The total costs of the CFC phaseout on refrigeration and air-conditioning will be an estimated $44.5 to $99.4 billion over the next decade (see table on page three).[86] These costs will ultimately be borne by consumers, and will average $445 to $994 per household. This includes direct cost increases of owning and maintaining a vehicle air-conditioner, an air-conditioned residence, and a refrigerator, as well as indirect cost increases affecting such things as food and rents in commercial buildings. However, this estimate does not include a wide-range of other costs that will be felt by consumers, including decreased convenience and efficiency.

Moreover, the phaseout has forced the reallocation of corporate research and development monies. The demand to meet the phaseout's requirements in time has meant that other, potentially more lucrative, investments have been deferred. These foregone opportunities are difficut, if not impossible, to measure, but represent additional costs imposed by the phaseout

The CFC phaseout will likely become the single most expensive environmental measure taken to date. During the policy debate, the costs were underemphasized to the point that they never became an important factor. The impact on consumers was scarcely considered. However, as consumers begin to pay for this policy they will recognize that environmental measures can be expensive undertakings. It may be too late to reverse course on the CFC phaseout, but it can serve as a lesson for the future.

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ENDNOTES

[1] See M.J. Molina and F. S. Rowland, "Stratospheric sink for chlorofluoromethanes: chlorine atom-catalysed destruction of ozone," *Nature* 249 (1974): 810-812; Executive Summary of the Ozone Trends Panel, March 15, 1988; Synthesis of the Reports of the Ozone Scientific Assessment Panel, Environmental Effects Assessment Panel, Technology and Economic Assessment Panel, Prepared by the Assessment Chairs for the Parties to the Montreal Protocol, (November 1991).

[2] Ibid.

[3] For example, during the Senate debate on the acceleration of the phaseout date from 2000 to 1995, many Senators repeated claims of increases in skin cancer, cataracts, immune system suppression, as well as crop failures and destruction of the ocean food chain that are said to be occurring as a result of an increase in ground level ultraviolet radiation caused by ozone depletion. However, direct measurements of ultraviolet radiation show no such increase. In effect, the feared consequence of ozone depletion, a significant global increase in ultraviolet radiation, is not known to be occurring. Thus, the claims of human health and environmental consequences are purely speculative. At the same time, none of the Senators seriously discussed the costs of eliminating CFCs. See *Congressional Record*, (February 6, 1992), S1128 - S1138.

[4] See ICF Incorporated, *Regulatory Impact Analysis: Compliance With Section 604 of the Clean Air Act for the Phaseout of Ozone Depleting Chemicals*, (July 1, 1992), and addendum. (The costs of eliminating CFCs are calculated at $9 billion through the year 2000, and the benefits, largely the millions of additional cases of skin cancer assumed to be averted by the phaseout, are calculated to exceed costs by as much as $31 trillion).

[5] In addition to their role as refrigerants, CFCs, HCFCs and related compounds slated for phaseout have literally hundreds of uses in agriculture, manufacturing, medicine, insulation, and fire suppression. In a number of these applications, alternative compounds are either more expensive or less effective than the compounds they are replacing. A detailed discussion of these costs is beyond the scope of this study.

[6] With limited exceptions, the law restricts CFC production and consumption (production plus imports minus exports) regardless of the end use. Specific restrictions on each end use could have afforded the opportunity to tailor the law to quickly proscribe CFC use in applications where CFC replacements are effective and economical (such as solvents and cleaning agents), while allowing more time in applications where rapid CFC elimination poses a substantial hardship (as in several refrigeration and air-conditioning uses). However, an across the board phaseout was chosen, partly for political reasons. See Dan McInnis, "Ozone Layers and Oligopoly Profits," in Greve and Smith, eds., *Environmental Politics: Public Costs, Private Rewards*, (New York: Praeger, 1992), p. 145.

[7] Essential uses are narrowly defined to include uses that are necessary for health and safety reasons or are critical to the functioning of society. In addition, it must be shown that there are no available substitutes that are acceptable.

[8] NASA News, Scientists Say Arctic "Ozone Hole" Increasingly Likely (February 3, 1992).

[9] *Congressional Record*, (February 6, 1992), S1128-S1138.

[10] NASA News, NASA Spacecraft Finds Large Arctic Ozone Depletion Averted (April 30, 1992).

[11] 58 *Federal Register* 65018 - 65082.

[12] DuPont, the largest CFC producer, had voluntarily agreed to cease production one year earlier than required. However, the EPA, fearing shortages, persuaded them to continue production until the phaseout deadline.

[13] 58 *Federal Register* 65025 - 65028.

[14] Clean Air Act Amendments of 1990, Sections 608 and 609; 58 *Federal Register* 28660 - 28734.

[15] Congressional Research Service, "CFC Phaseout: Future Problem for Air Conditioning Equipment?" (April 1, 1993), p. 4.

[16] Ibid.

[17] Had the phaseout been slower, industry could have settled on the best replacement refrigerant for each application. Such standardization would have reduced the costs and complexities of moving away from CFCs. But with so little time to act, and the replacement technologies still in the early stages, a large number of competing refrigerants have been introduced into the market, many of which will become obsolete in the next few years, as the best refrigerants emerge from the pack. The same is true for the many oils, filter driers and other components now on the market.

[18] For example, choosing the correct filter drier for an air-conditioning or refrigeration system used to be an easy task. Now, with numerous combinations of refrigerants, oils, and additives, it is difficult to know which type of filter drier will perform satisfactorily. The incorrect choice can cause damage to a system by failing to properly remove enough moisture, or by filtering out oil additives.

[19]Clean Air Act Amendments of 1990, Sections 608 and 609; 58 *Federal Register* 28660 - 28734.

[20] See "The Alternative Solution," *Refrigeration Service Contracting*, (November 1993), pp. 20-26.

[21] Informal survey of three wholesalers in the Washington, D.C. area, March, 1994; Omnibus Budget Reconciliation Act of 1989, and subsequent revisions. (The tax is $4.35 per pound in 1994, rising to $5.35 in 1995.)

[22] "Refrigerant Shortfall Challenges Chiller Owners," *Air Conditioning, Heating and Refrigeration News* (March 22, 1993), pp. 2-3.

[23] Congressional Research Service, "CFC Phaseout: Future Problem for Air Conditioning Equipment?" (April 1, 1993), pp. 9-11.

[24] "Imported CFC-12 Bypasses Tax, Sells For Less, Say Producers," *Air-Conditioning, Heating and Refrigeration News* (May 16, 1994), pp. 1-2.

[25] For example, in automobile air-conditioners, some or all of the refrigerant has already leaked out before a vehicle is brought in for servicing, and little or none is left to be recovered. In cases of repairs of hermetic compressor motor burnouts, the refrigerant may be too contaminated to be reused. Also, if two or more recovered refrigerants are commingled, the entire mixture may be unusable.

[26] See "Recovery-Recycling Unit Sales Still Soft", *Air Conditioning, Heating and Refrigeration News* (July 19, 1993), pp. 20-22; "ACCA Members Cite Poor Quality, Lack of Good 'Used' Refrigerant", *Air Conditioning, Heating and Refrigeration News* (September 6, 1993); "Recovered Refrigerant: Where is it?" *Air Conditioning, Heating and Refrigeration News* (May 16, 1994), pp. 3-4.

[27] McInnis, p. 148.

[28] Informal survey of three wholesalers in the Washington, D.C. area, March 1994.

[29]Chemical Manufacturers Association, *Production, Sales, and Calculated Release of CFC-11 and CFC-12 Through 1988*; McInnis, p. 138; 1993 Statistical Panorama, *Air Conditioning, Heating and Refrigeration News*, (March 29, 1993), at 24.

[30] "CFCs: The Challenge of Doing Without", *Electric Power Research Institute Journal*, vol. 14, no. 6 (1989), p. 6.

[31] James M. Calm, *Charactersitc Efficiencies and Costs For Air-Conditioning Equipment With Selected Refrigerant Alternatives* (Virginia: Air-Conditioning and Refrigeration Institute, 1991).

[32] For example, air-cooled condensers on some retrofitted CFC-12 and R-502 condensing units are slightly undersized, and during periods of hot weather will lead to higher discharge pressures and greater energy use. Also, systems using non-CFC refrigerant blends require a fairly critical charge of refrigerant to maintain peak efficiency. Thus, even a small leak will significantly increase energy consumption, as compared to CFC systems where leakage had a smaller impact on efficiency. Further, refrigerant cross-contamination may reduce energy efficiency, particularly in commercial refrigeration systems.

[33] "CFCs: The Challenge of Doing Without," *Electric Power Research Institute Journal*, vol. 14, no. 6 (1989), p. 10.

[34] EPA, *Moving to Alternative Refrigerants*, November 1993; *Alternative Fluorocarbons Environmental Acceptability Study* and the U.S. Department of Energy, *Energy and Global Warming Impacts of CFC Alternative Technologies* (December 1991).

[35]Ibid.

[36] American Automobile Manufacturers Association of the United States, *Motor Vehicle Facts and Figures*, annual; Montreal Protocol, Report of the Refrigeration, Air-Conditioning and Heat Pumps Technical Options Committee, (December 1991), Figure 10.1; 1993 Statistical Panorama, *Air Conditioning, Heating and Refrigeration News* (March 29, 1993), p. 7.

[37] Ward Atkinson, Sun Test Engineering.

[38] Clean Air Act Amendments of 1990, Section 609.

[39]Ibid.

[40] Atkinson

[41] 1993 Mobile Air-Conditioning Society, *Field Service Data Book*.

[42] Ibid.

[43] Many vehicle air-conditioning systems develop slow leaks, which cause the gradual loss of refrigerant. Leakage frequently occurs through high and low side Schrader valves, by diffusion through aging and hardened hoses, and through the compressor shaft seal. These minor leaks rarely damage the system, provided the pressure in the system remains above atmospheric, and merely necessitate the addition of a pound or two of refrigerant. However, now that a CFC recharge costs more, and future supplies are uncertain, some people may choose to have the leak repaired, although such a job will probably cost $250 or more. Many servicemen, for obvious reasons, are encouraging customers to repair leaks rather than top off a system. Others, as a matter of policy, refuse to top off

systems unless leaks are repaired. Some are telling customers that federal law requires leak repairs, which is not the case.

[44] Montreal Protocol, Report of the Refrigeration, Air-Conditioning and Heat Pumps Technical Options Committee, (December 1991), p.173. (Some 1992 and 1993 CFC air-conditioners were designed to be easily retrofit to HFC-134a, and the cost will be lower. For older cars, depending on the model and year, the retrofit costs range from $250 to $800.)

[45] HFC-134a and the polyalkylene glycol (PAG) oil used with it cannot operate properly in a system which previously used CFC-12 and mineral oil unless virtually all of the original refrigerant and lubricant is removed from the system. Mineral oil is not miscible with HFC-134a and any any left behind will reduce heat transfer and interfere with fluid flow. Residual CFC-12 will combine with HFC-134a to form an azeotrope, generating higher internal pressures. It can be expected that some retrofits will fail because the system was not thoroughly flushed. Further, HFC-134a operates at a much higher discharge pressure, which will place a life-shortening strain on the system, particularly when stalled in traffic on hot days.

[46] The low end of this range assumes that future servicing costs will be only slightly higher than current costs, while the high end assumes significant cost increases, particularly after 1995.

[47]Putnam, Hayes & Bartlett, Inc., *Report for the U.S. Department of Energy, Assessment of the Impacts Associated with a Total CFC Phaseout* (July 10, 1989), p. 11.

[48] The higher discharge pressures of HFC-134a will likely cause an increase in compressor failures. See "Race Against Time", *Design News* (October 1, 1990), pp. 132-136. Further, the polyalkylene glycol (PAG) oil used as a lubricant is extremely hygroscopic (water attracting). See Tecumseh Products Company, Guidelines For Utilization of R134a. Thus, ambient moisture may be drawn into a system during servicing or after a collision or other major leak, which can lead to system failure. Also, HFC-134a, unlike CFC-12, does not form wear-reducing metal chlorides. See ARI Tech Update, *Lubrication is The Key Issue in CFC Phaseout* (August 1993). And, as with all new technologies that have not been thoroughly tested, there will likely be unforseen problems that develop after a few years of actual use.

[49] Several automotive engineers with major auto makers privately admit that they expect an increase in the number of vehicle air-conditioners needing a major repair to stay in operation, particularly after about five years of use.

[50]Congressional Research Service, *CFC Phaseout: Future Problem for Air Conditioning Equipment?* (April 1, 1993), p. 5.

[51] The fact that HFC-134a is the most widely used replacement refrigerant, despite its many drawbacks, is a consequence of the acceleration of the phaseout date from the year 2000 to the end of 1995. Given the lead times needed by manufacturers, many industries had to make hasty decisions as to which replacement to use. A number of other refrigerants are more promising than HFC-134a but need a few more years of research and development before being ready for use. On the other hand, HFC-134a was one of the first replacements developed and mass produced and was chosen largely because it was the best refrigerant available on such short notice. And, once an industry commits to a particular refrigerant, it is very expensive to switch to another. As a result, HFC-134a will likely see widespread use for many years, even in applications for which it is not ideally suited.

[52] "A Greener Way to Keep Food Cool," *Washington Post*, Home Section (April 14, 1994), p. 5; "Refrigerators For A Wiser World", *Consumer Reports* (February 1994), pp. 80-86.

[53] "1994 Statistical Panorama," *Air Conditioning, Heating and Refrigeration News* (April 11, 1994), p. 32.

[54] Montreal Protocol, *Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee* (December 1991), p. 80. HFC-134a is primarily a medium temperature refrigerant, and is not well suited for American refrigerators with a large freezer section, which operate at a coil temperature of about -10^{o} F. At this low temperature, HFC-134a may exhibit reduced capacity versus CFC-12. See Dupont, *Retrofit Guidelines for SUVA 134a in Stationary Equipment*. Some comparisons obfuscate the relative efficiencies by comparing an advanced design HFC-134a model with a basic CFC-12 model, or by using theoretical rather than actual efficiencies. See EPA, *Multiple Pathways to Super-Efficient Refrigerators*. Note that there may also be a slight decline in efficiency resulting from CFC-blown foam insulation used in refrigerator walls and doors being replaced by substitute foams.

[55] The polyol ester (POE) oil chosen to be used in HFC-134a refrigerators is 100 times more hygroscopic than the mineral oil used with CFC-12. If, for example, the system experiences a leak during moving or is left open for more than 15 minutes during servicing, enough moisture can enter to cause chemical reactions that may damage the compressor or block the capillary tubes, the latter requiring replacement of the entire hermetic system. In addition to moisture problems, HFC-134a and POE oils have a low tolerance for other contaminants, (such as residual chlorine in servicing equipment that was also used to repair a CFC system). As a result, HFC-134a refrigerators will suffer more frequent breakdowns, some of which cannot be repaired. See Whirlpool Corp., *HFC-134a Refrigerant Service Procedures.*

[56] The experience with CFC-12 refrigerators when they were new may be repeated with the new HFC-134a units. The first models worked well initially, but suffered unexpected problems after several years of use. For example, the oil originally chosen broke down, causing capillary tube blockage, and a new oil with additives had to be developed. Also, the insulation protecting the motor windings was weakened by unexpected reactions between the refrigerant, oil, and trace impurities, and had to be replaced with a new type of insulating material. These and other technical problems were totally unanticipated when the systems were initially designed and tested. They revealed themselves only after years of field experience. The same is likely to occur with the new HFC-134a systems.

[57] 1993 Survey, Air-Conditioning and Refrigeration Institute.

[58] "1993 Statistical Panorama," *Air Conditioning, Heating and Refrigeration News*, March 29, 1993, pp. 6-7.

[59] Alternative Fluorocarbons Environmental Acceptability Study and the U.S. Department of Energy, *Energy and Global Warming Impacts of CFC Alternative Technologies* (December, 1991) ch.6 and App. E.

[60] "Slow Conversion to Non-CFCs Worries Chiller Manufacturers," *Air Conditioning, Heating and Refrigeration News* (April 12, 1993), p. 3.

[61] Ibid.

[62] Specifically, refrigerant containment first requires a thorough inspection of the system for leaks, and replacement of any gaskets or connections that show signs of deterioration. Then, a high efficiency purge unit is installed, which allows the system to be periodically purged of air without refrigerant also escaping. Isolation valves are installed at the oil sump to reduce refrigerant leakage during oil changes. Pressurizing devices, which reduce leakage when the chiller is not in use, and safety relief valves which prevent total loss of charge in an emergency may also be necessary. Older chillers may require eddy current testing of the condenser tubes in order to detect any weaknesses in them. CFC monitoring devices may be installed to aid in early leak detection. Since some leakage will still occur, an extra supply of refrigerant needs to be obtained, and placed in a tank or drum suitable for long term storage. Refrigerant recovery devices will also be necessary for use during servicing.

[63] CFC-11 chillers operate at sub-atmospheric pressures, thus not much refrigerant leaks out. On the other hand, CFC-12, CFC-22 and R-500 operate at pressures above atmospheric, and a line break, for example, could cause the entire refrigerant charge to escape.

[64] Informal survey of three chiller contractors, March 1994. (Actual cost is dependent on the size, age, and condition of the chiller and building.)

[65] A retrofit of a high-pressure chiller involves modifications of the gear drive and impeller (in order to reduce the loss in capacity), and careful system flushing of the old refrigerant and oil. Finally, a charge of HFC-134a and compatible ester-based lubricant is added. Low-pressure chiller retrofits to HCFC-123 require modifications of the motor and impeller, as well as replacement of motor windings, 0-rings, gaskets, and seals. In both cases, refrigerant recovery equipment will have to be procured.

[66] Retrofit costs average $50 - $70 per ton, and chillers that are candidates for retrofit are in the 200 - 3000 ton range. The term ton refers to the amount of cooling required to freeze one ton of water in a day, or 12,000 Btu/hour, and is the common unit for measuring cooling capacity. See EPA, *Moving to Alternative Refrigerants*, *Ten Case Histories*, (November 1993); "One Company's Strategy", *Engineered Systems*, (September 1993).

[67] Chiller owners who continue to use CFCs run the risk of needing additional CFCs at some future date and not being able to obtain it. Also, retrofits to HCFC-123 and HFC-134, considering the initial cost, expected useful life, and operating costs, may not be as attractive as a total replacement in some cases. In addition to new systems using HCFC-123 or HFC134a, HCFC-22 chillers using screw compressors are gaining market share because of their efficiency and versatility.

[68] An Air-Conditioning and Refrigeration Institute survey of chiller manufacturers estimates that 22,000 CFC chillers will have been replaced by non-CFC chillers by the year 1996.

[69] "One Company's Strategy," *Engineered Systems* (September 1993). (Estimated cost of chiller replacement is $275 - $375 per ton.)

[70] Strictly speaking, these new requirements are not a direct consequence of the CFC phaseout, and in fact are applicable to chillers that use CFCs. However, their promulgation occurred as a result of concerns over the toxicity of replacement refrigerants, particularly HCFC-123.

[71] See "Taking The Fear Factor Out of Refrigerants," *Engineered Systems* (January 1994), pp. 42-47.(Most local building codes have not yet made these revisions, but are expected to make them within the next two years.)

[72]Ibid.

[73] Informal survey of three chiller contractors, March, 1994.

[74] Statement of the Air-Conditioning and Refrigeration Institute on Depletion of the Stratospheric Ozone Layer, January 25, 1990. (This is a very rough estimate, and is likely too low, given the number of establishments using such equipment. Other estimates are lower, but exclude many categories of equipment.)

[75] *Statistical Abstract of the United States 1993*, "Retail Foodstores-Number and Sales, by Type: 1980 to 1991," p. 777.

[76] *Statistical Abstract of the United States*, "Commercial and Institutional Groups-Food and Drink Sales: 1980 to 1993," p. 779.

[77] *Statistical Abstract of the United States*, "Retail Trade Establishments-Number, Sales, Payroll, and Employees, by Kind of Business: 1987," p.775.

[78] Some of this equipment, particularly the smaller systems, will practice containment and continue using CFCs for as long as supplies are available. Nonetheless, it is assumed that most existing systems will be retrofit within the next ten years.

[79] "Allied Signal's AZ-50 Alternate Refrigerant Well-Received By Texas Supermarket Chain", *Air Conditioning, Heating and Refrigeration News* (January 24, 1994), p. 76. A retrofit of a commercial refrigeration system involves removing the original CFC charge, replacing the filter drier, recharging the system with a new refrigerant and compatible oil (medium temperature refrigerant replacements include MP-33, MP-39, MP-66, and HFC-134a, while low temperature replacements include AZ-50, HP-62, HP-80, HP-81, HFC-125, and HCFC-22), and a check of the system for proper performance. A supermarket will require about 300 hours of labor, while a convenience store may require 30 hours or less.

[80] Thus far, very few self-contained systems have been retrofit. It is expected that their owners will continue to use CFCs until they are no longer available, and then retrofit or replace the equipment. Retrofit costs will probably be in the $200-$300 range.

[81] 58 *Federal Register* 60158. (Another HCFC, HCFC-123, is being used in many new and retrofit chillers, and is discussed in that section. Its production will be frozen in 2015 and eliminated in 2030.)

[82] U.S. Bureau of the Census, *Current Housing Reports*; Energy Information Administration, *Commercial Building Characteristics*: 1989, Table 86. (There are also about 50 million window air-conditioners, which are not significantly impacted by the phaseout. Large buildings are cooled by chillers, and are discussed separately.)

[83] Informal survey of 5 residential air-conditioning servicemen in the Washington, D.C. area, March 1994.

[84] "1994 Statistical Panorama," *Air-Conditioning, Heating and Refrigeration News* (April 11, 1994), pp. 25-26.

[85] Informal survey of three wholesalers in the Washington, D.C. area, March 1994. (The other half of HCFC-22 production is used chillers and commercial equipment and is discussed separately.)

[86] Had the phaseout not been accelerated from 2000 to 1995, the cost would have been about one quarter of this amount.