UNIVERSITY OF NAIROBI

ASSESSMENT OF RECOVERY AND RECYCLING OF CFCs USED IN REFRIGERATION INDUSTRY IN KENYA

BY
GEORGE NYORI

DEPARTMENT OF MECHANICAL ENGINEERING

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B.Sc. (MECH. ENG)

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Declaration

This thesis is my original work and has not been, to the best of my knowledge, presented for a degree in this or any other university for examination, or any other purposes.

Signed.______________________________________.

George Nyori

This thesis has been submitted with my approval as university supervisor.

Signed.______________________________________.

Prof. J.F.Kanyua

Dedication

Dedicated to my dear wife Rahab Wangui and my two sons Manasses Makari and Dennis Muthua.

Acknowledgements

I am indebted to many friends and colleagues who helped, knowingly or unknowingly, during the course of this work. Special and sincere thanks goes to my supervisor Prof. J. F. Kanyua, who besides providing me with guidance, without which I would not have realised my objective, has undertaken the difficult task of scrutinising through my work making valuable suggestions.

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Summary

Ozone depletion and its after effects on the life on earth have become a matter of global concern. In 1987, at Montreal in Canada, the international community came together for taking the necessary steps to stop further damage to the stratospheric ozone layer. The man-made Chlorofluorocarbons (CFCs) were among the Ozone Depleting Substances (ODS) that were to be controlled. In the Montreal Protocol (1987) the world adopted a programme of heavy cuts in the use of CFCs. It was agreed that production (not consumption) of CFCs is to be finally phased out by the year 2000. Several meetings have been held since Montreal(1987) which have adjusted the ODS phase-out program initially proposed.

CFCs consist of Chlorine, Fluorine and Carbon and are mainly used, in Kenya, in the refrigeration industry. CFC-12, CFC-500, CFC-502 are the CFCs used as refrigerants in Kenya. Kenya's developing economy is very much depended, mainly, on the use of these CFCs. It is therefore crucial to keep major services running while preventing Kenya from becoming a dumping ground for obsolete equipment. With 10 years grace period for developing countries like Kenya, the sustenance of the existing CFC-based equipment will depend on the success of conservation programmes such as recovery and recycling, waste reduction measures and retrofit technologies.

This report therefore presents the background analysis that is intended to facilitate the launching of efficient programmes for collection, recovery and recycling, waste reduction measures and retrofit technologies. The report also presents the background analysis appropriate for legislation and institutional strengthening for the purpose of implementation of the programmes.

A comprehensive field survey auditing the usage of refrigerants in Kenya was carried out in the major towns such as Nairobi, Mombasa, Kisumu, Nakuru, Eldoret etc. The audit was used to develop a national guideline on the current level of usage of refrigerants in Kenya. The audit involved interviews through questionnaires and checklists covering extensively both primary and secondary sources of information. In the data collection exercise, 910 questionnaires were distributed to various groups. 563 of the questionnaires were received back and among them 448 had useful information. The audit exercise was therefore based on these 448 questionnaires.

The findings of the audit indicated that in 1995 the consumption(the amount used excluding the 'banked' quantity) of refrigerants were 67.7MT of CFC-12, 29.6MT of HCFC-22, 0.4MT of Ammonia, Negligible amounts of HFC-134a, CFC-502, Hydrocarbons and of liquid CO_2 . The amounts 'banked' within the refrigeration equipment were 103.1MT of CFC-12, 41.2MT of HCFC-22, 1MT of Ammonia and negligible amounts of HFC-134a, CFC-502, Hydrocarbons and of liquid CO_2 . Kenya does not manufacture any of the above chemicals, except liquid CO_2 , and therefore all are imported. There exists a lot of undocumented information pertaining to the importation of these refrigerants and appropriate legislation and institutional strengthening is needed for the success of conservation programmes.

Montreal Protocol awareness by direct and indirect users was evaluated through checklists and questionnaires. It was established that most Kenyans are 'cost' conscious and not environmental conscious. Therefore the incentive to awareness is purely motivated by business consideration and not by environmental issues.

Most servicing practises are unorthodox and these have led to a lot of refrigerant waste, of the order 41.5MT (61.3%) of CFC-12 in 1995 due to flooding within the market by many unqualified and unregistered servicing technicians and agents. Refrigeration equipment and refrigerant technologies in current end users were also studied to determine the level of technology in the country. The present legislative and institutional framework with respect to CFCs is limited and therefore the country lacks an established machinery to ensure elaborate enforcement of regulations and legislation on the use of refrigerants.

With the current level of consumption the maximum attainable CFC-12 through recovery and recycling is in the order of 21.4MT in 1995. This amounts to 49.3% of recharging demand or about 31.6% of the total demand for CFCs. Viable recovery and recycling programmes can be set up at a profit given initial financial support. This will set refrigerant 'banks' and thus avoid premature scrapping or costly retrofit of CFC-12 equipment upto the year 2010 which is the terminal year for CFC-12 usage for developing countries.

The findings of the analysis indicate that given adequate support and with appropriate legislation and institutional strengthening for implementation , viable programmes for recovery and recycling of refrigerant gases can be set up in Kenya. The analysis showed that recovery and recycling in Kenya will be economically viable at the venture level. However financial incentive by the Government of Kenya and the international community will be required to promote the implementation. In the context of the findings of the analysis, it is desirable and necessary to introduce regulatory legislative measure regarding various aspects of CFC consumption such as sales, purchasing and conservation through recovery and recycling.

In order to initiate and implement the above scheme, it is necessary to strengthen the institutional framework in Kenya. This would involve creating proper awareness about the harmful effects of ozone layer depletion and the repercussions of the Montreal Protocol to Kenyan Refrigeration Industry. The existing legislation related to licensing, control and standards for importation, local manufacture and use of chemicals and equipment is considered inadequate for implementation of the refrigerant conservation programmes. It is recommended that:

- The licensing of refrigeration contractors and service agents be restricted to trained and registered technicians.
- The retailing of CFCs be restricted to registered suppliers and contractors and service agents only.

Apart from the above legislative acts proposed herein, the Government of Kenya has already established the National Environmental Secretariat (NES) whose duties are spelt out in the Institutional Framework. The various personnel, material policies and modalities for the implementation of conservation programme and long term regulation of use of CFCs already exist and only needs to be put into practice.

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CHAPTER SIX - ECONOMICS OF COLLECTION, RECOVERY AND RECYCLING OF REFRIGERANTS

CHAPTER SEVEN - FRAMEWORK FOR IMPLEMENTATION

Notations

O_3 Ozone
MT Metric Tonne
gm gram
T_c Critical Temperature
P_c Critical Pressure
Δh_{comb}.... Heat of combustion

Abbreviations

UNEP .... United Nations Environmental Program
UV .... Ultra-violet
UV(R) .... Ultra-violet radiation
UV-A .... Long wave UV(R)
UV-B .... Medium wave UV(R)
UV-C .... Short wave UV(R)
UNIDO ....United Nations Industrial Development Organisation
p.a. ....Per annum
IIR ....International Institute of Refrigeration
IIAR ....International Institute of Ammonia Refrigeration
ASHRAE ....American Society of Heating, Refrigeration and Air-conditioning Engineers
AFEAS .... Alternative Fluorocaborns Environmental Acceptability Study
CBS ....Central Bureau of Statistics
GALCO .... 'Gaz Liquiefies et Comprimes'
NTH ....Norwegian Institute of Technology
PIR ....Paris Institute of Refrigeration
SCQMDB ....South Coast Quality Management Distribution Board
SCBR ....Swedish Council for Building Research
AEC......................Atomic Energy Commission
LFL.......................Lower Flammability Limit
GWP.....................Global Warming Potential
ODP......................Ozone Depletion Potential
ODS......................Ozone Depletion Substance
COP.......................Coefficient Of Performance
CAESA.............Climatized Auditing of Emissions of Sulphur into the Atmosphere
ICI ....International Chemical Industries.
PIR ....Paris Institute of Refrigeration
UNEP.............. United Nations Environmental Programme
UNDP ....United Nations Development Programme
IIR .... International Institute of Refrigeration
IIAR .... International Institute of Ammonia Refrigeration
MTAA .... Motor Trade Association of Australia

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CHAPTER ONE
INTRODUCTION

1.1 Ozone Layer

High in the sky, higher than more than a handful of people have ventured, lies a life-giving layer of poison. It is as far as is known, unique to our planet. If it had not developed, earth would have remained a small, unremarkable sphere, tucked away in a far corner of one among billions of galaxies - peopled by no more, at best, than the most primitive underwater lifeforms. If it were to disappear, the sun's ultraviolet light would sterilise the surface of globe, annihilating all terrestrial life.

The layer is made of ozone (O_3), a form of oxygen with three atoms instead of the normal two. The added atom turns the gas we breath into poison and any animal that inhale more than a trace of this ozone would die. Near the earth's surface, ozone is an increasingly troublesome pollutant, a constituent of photochemical smog and of the cocktail of pollutants popularly known as acid rain(UNEP 1989a). But safely up in the stratosphere , 15 to 48 km above the earth's surface as shown in Figure 1.1 below, the blue, pungent smelling gas is as important to life as oxygen is on lower altitudes.

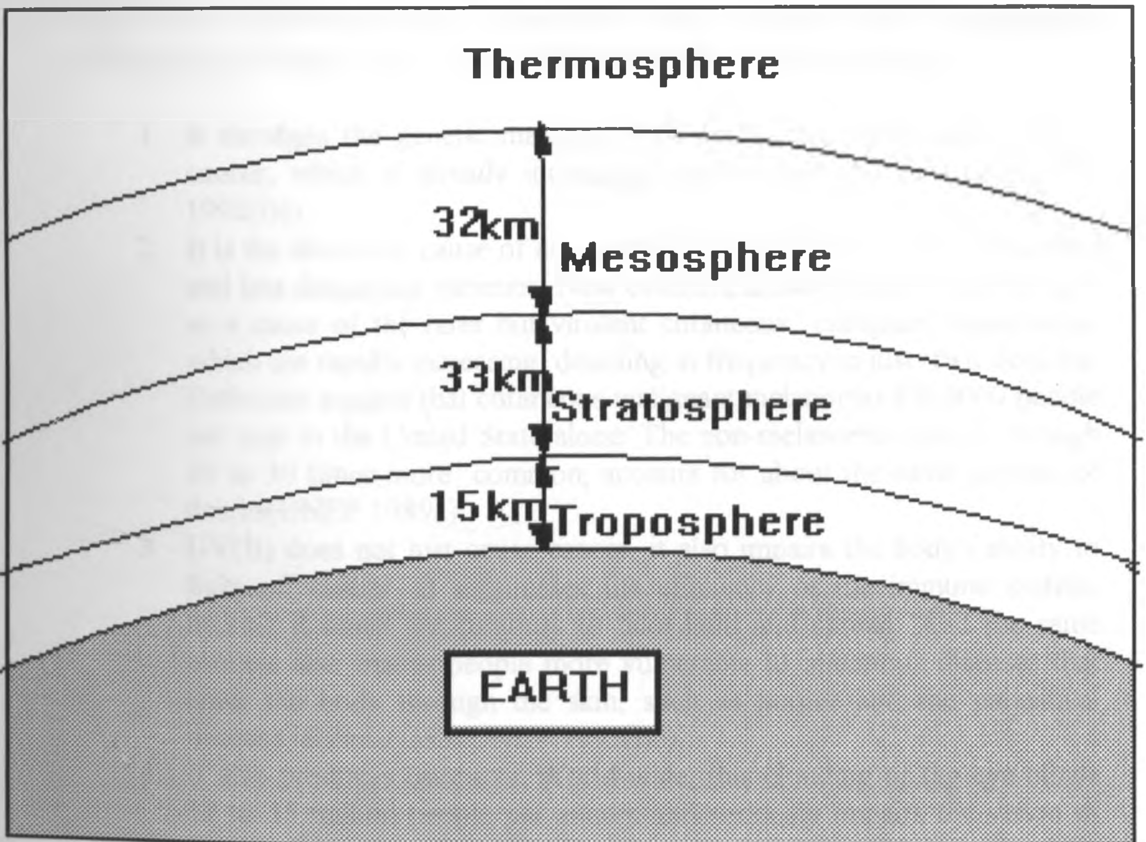


Figure 1.1: The Atmosphere
(CAESA(1962); Hymes(1962) and Donn(1970))

1.1.1 The Benefits of the Fragile Ozone Layer

Ozone forms a fragile shield, curiously insubstantial but remarkably effective. It is scattered so thinly through the 33km -deep stratosphere that if it were all collected together it would form a girdle around the earth no thicker than 10 mm. Concentrations of stratospheric ozone varies with height ; but it never makes up as much as one hundred thousandth of the atmosphere around it (CAESA, 1962).

Yet this thinnest of filters efficiently screens out almost all the harmful ultraviolet rays of the sun. The shorter the wavelength of ultraviolet radiation(UV(R)), the greater the harm it can do to life - and the better it is absorbed by the ozone layer. Relatively short wave ultraviolet radiation known as UV-C, is lethal to living things - and is almost totally screened out. Longer wavelength ultraviolet, UV-A , is relatively harmless, and is almost entirely allowed through. In the middle lies UV-B, less lethal than shorter wave radiation but still dangerous; the ozone layer absorbs most of it.

1.1.2 Health Risks

The small amount of UV-B radiation that does manage to penetrate the ozone shield causes considerable harm, providing a stern warning of the consequences of impairing the ozone layer. UV-B radiation has the following effects:-

1. It damages the genetic material DNA and is the main cause of skin cancer, which is already increasing rapidly around the world(UNEP 1992(i)c).
2. It is the dominant cause of non-melanoma skin cancers, the commonest and less dangerous varieties. New evidence is increasingly implicating it as a cause of the rarer but virulent cutaneous malignant melanomas, which are rapidly increasing, doubling in frequency in just two decades. Estimates suggest that cutaneous malignant melanomas kill 6000 people per year in the United State alone. The non-melanoma cancers, though 20 to 30 times more common, account for about the same number of deaths(UNEP 1989a).
3. UV(B) does not just cause cancer, it also impairs the body's ability to fight off cancer. It suppresses the efficiency of the immune system, making it easier for tumours to take hold and spread. And the same process also makes people more vulnerable to infectious diseases that enter the body through the skin, such as herpes and the parasitical decease leishmaniasis(UNEP 1992(i)c).
4. It also produces cataracts. World-wide, this clouding of the eye blinds 12 to 15 million people per annum and seriously impairs the vision of another 18 to 30 million people per annum(UNEP 1989a). It also help to cause or exacerbate other eye disorders.
5. Increasing UV-B radiation has also been found to reduce the quality of certain types of tomatoes, potatoes, sugar beets and Soya beans.

6. Forests appear to be vulnerable too; about a half of the species of conifer seedlings that have so far been studied have been adversely affected by UV-B(UNEP, 1989a).
7. UV-B strikes beneath the surface of the sea, causing damage to within the first 20 metres deep in clear water. It is particularly harmful to small creatures such as plankton, the larvae of fish, shrimp, crab and plants essential to the food web of the sea. Even small increases could bring about important changes in the underwater life, damaging fisheries.
8. Polymers used in buildings, paints, packaging and countless other substances are degraded and turned brittle by UV-B; (Kanyua, 1993 b and AEC 1989)

It seems clear than even the present levels of the UV radiation are limiting the growth of some plants, and will cut the productivity of agriculture and forestry if it increases. Depletion of ozone in the stratosphere could cause levels of the poisonous gas to drop just where it is not wanted. This would have it own effect on human health, and spread to damage crops, ecosystems and materials such as polymers used in building, paints and packaging material.

The earth and its inhabitants have an enormous stake in preserving the fragile ozone shield. But we have unwittingly subjected it to stealthy and sustained attack. Of all the magnitude of threat facing the global environment currently, none are greater than the changes taking place in the atmosphere of planet earth(UNEP 1989b).

1.1.3 <u>Pioneer Work on Effects of CFCs</u>

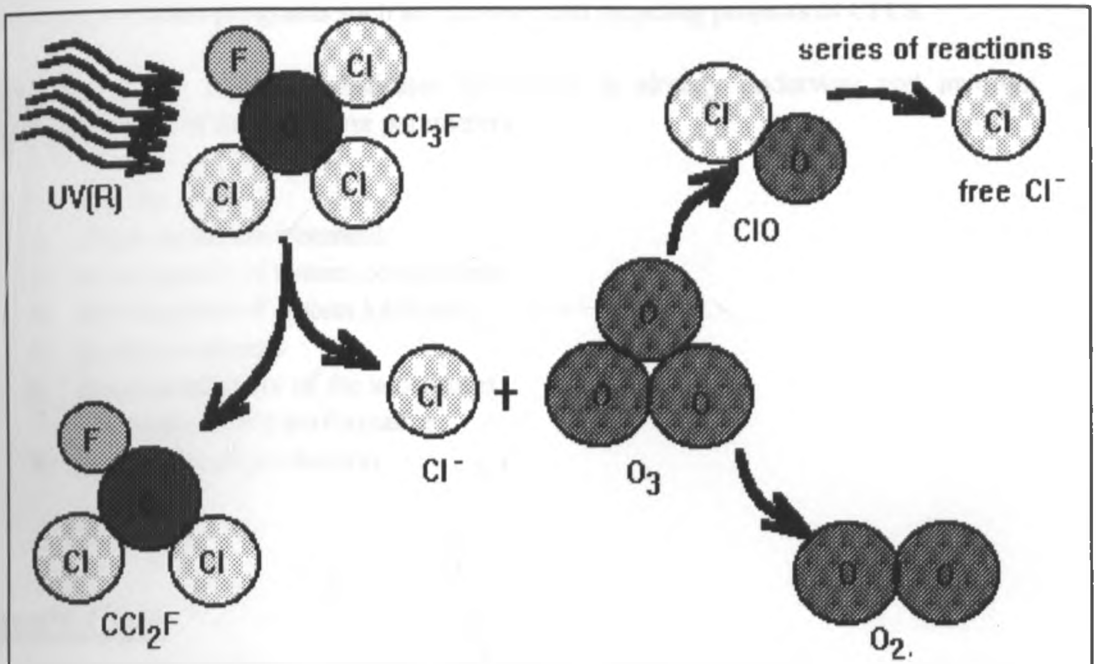
In autumn 1973 two scientists, Sherwood and Molina, at the University of California at Berkeley began investigating the effect of Chlorofluorocarbons(CFCs) on the atmosphere. Sherwood and Molina, realising that all the long-lived CFCs ever released still remain in the atmosphere, decided to investigate what happened to them. In their result they claimed that the man-made synthetic chemicals known as Chlorofluorocarbons (CFCs) were damaging the stratospheric Ozone layer which protects the earth from dangerous high levels of ultraviolet radiation from the sun(Molina and Sherwood, 1973). At the time, however , theirs was a controversial hypothesis, and for years it was debated by scientists and challenged by industry.

CFCs consist of chlorine, fluorine and carbon. They are used in many fields such as:

- coolants for refrigeration and air-conditioning equipment,
- propellants for aerosol sprays (personal care products, insecticides etc.),
- agents for production of plastic foams,
- cleaning agents for electrical and metal parts,
- Organic Rankine cycles

(ASHRAE 1989, Kanyua 1993a ,UNEP 1992(i)a)

Scientist are now in agreement that CFCs; due to their inherent chemical stability, do not break down in the troposphere but survive long enough to enter the stratosphere where they are broken down by the action of ultraviolet light. One breakdown product, Chlorine, acting as a catalyst, reacts with the stratospheric Ozone (O_3), to produce molecular Oxygen (O_2) thus reducing Ozone concentration as illustrated in Figure 1.2 below:



When gases containing Chlorine, such as CFCs, are broken down in the atmosphere each Chlorine atom sets off a reaction that may destroy hundreds of thousands of ozone molecules.

Figure 1.2: Effect of CFCs on the Ozone layer. (UNEP 1992(i)b)

Although the stratospheric ozone layer contains only a minute proportion of ozone, it is the earth's only defence against harmful forms of solar radiation. It is estimated that if emissions of CFCs continue to grow as in the past, the ozone layer will be depleted by about 20% within the lifespan of today's(1996) children. Just half this loss in the protective shield would cause three and half million extra deaths from skin cancer and ten million extra cataracts in the world yearly(ASHRAE 1989).

1.2 Montreal Protocol

Ozone depletion and its effects on the life on earth has become a matter of global concern. With the signing of the Montreal Protocol(UNEP 1987), the International community agreed on the necessary steps to stop the damage to the stratospheric ozone layer. In the Montreal Protocol the world adopted a program of heavy cuts in the use of CFCs such that productions were to be frozen at 1986 levels and ultimately reduced by 50% by 1988. It was agreed that production (but not the consumption) is to be finally phased out by the year 2000. Kenya is a signatory to this protocol.

Several meetings have been held since Montreal (1987) which have adjusted the ozone depleting substances (ODS) phase-out program initially proposed(see lists on the references). Also, several industrialised countries have proposed unilateral and co-ordinated advancement of the phase-out program. The effect of this on Kenya and other developing countries will be that it will be necessary to accelerate their phase-out programs and also take measures to guarantee continued supply of CFCs for the user. This will be achieved by refrigerant conservation programs such as recovery and recycling projects of CFCs.

Identification of the suitable substitutes for CFCs is already underway and involves testing/investigation of the following parameters:-

1. toxicity
2. effect on the environment
3. development of system components
4. development of system lubricants
5. product-redesign
6. future availability of the substitutes
7. thermodynamics performance
8. economics of production

1.3 Kenya's Case

Kenya's developing economy is very much dependent on the use of CFCs in agriculture, tourism industries etc. It is therefore crucial to keep major services running while preventing Kenya from becoming a dumping ground for obsolete equipment. In the refrigeration industry; the sustenance of the existing systems will depend strongly on the success and the ability to:

1. collect, recover and recycle the existing CFCs
2. retrofit the existing equipment with the available alternative refrigerant
3. install new equipment and new refrigerants

Therefore reclaimed and recycled refrigerants may be used to service equipment as retrofitting exercise is being experimented on.

With 10 years grace period for phasing out CFCs in developing countries (UNEP 1992(ii)), the recoverable quantity of CFCs up to the year 2010; which is the terminal year for complete phasing out of CFCs as per the Montreal Protocol; can be recycled for reuse and so keep the refrigeration industry running as transition to the new refrigerants and equipment are being experimented on.

For a country like Kenya where the general public, firms and institutions are "cost" conscious and not "environment" conscious, the incentive to phase-out of CFCs will depend on cost of the substitutes and the new systems(Kanyua 1993c). It should be noted that HFC-134a is commercially available as a drop in substitute for CFC-12. It is also noted that in Kenya there is a high level of wastage of CFCs used as refrigerants due to the following reasons:-

1. employment of untrained technicians
2. poor quality charging systems
3. laxity in management
4. damage to refrigerators due to damage of evaporators with sharp objects
5. compressor failure caused by voltage fluctuations
6. lack of an established machinery to enforce elaborate regulations or legislation
7. public unawareness of the dangers of ozone depletion.
   (Kanyua 1993c)

The phase-out program of CFCs in Kenya must therefore address itself to these problems since the solutions to these problems will have a big effect on the future use of alternative refrigerants. It is therefore necessary to know how much CFCs are being used in refrigeration industry in Kenya and to formulate an efficient method of collecting ,recovering and recycling of these chemicals for re-use.

1.4 Objectives of the Present Study

The present project report aims at analysis and evaluation of CFCs listed as controlled substances under the Montreal Protocol and used in Kenya as refrigerants. The findings of the evaluation will be used to formulate an efficient system of collecting, recovering and recycling of this CFCs and waste reduction measures. Recovery and recycling of refrigerants in this case will focus mainly on systems using CFC-12 and the findings can thereafter be adopted for systems using HCFC-22 and HFC-134a and any other refrigerants introduced in the field.

Public awareness survey will be a key point since most Kenyans may fall victims of dumped new and second hand equipment and for some, an eventual closure of business since they will be overtaken by events.

The objectives of the present study are therefore as listed here below:-

1. Establish the current level of imports and consumption of refrigerants in Kenya
2. Evaluate the extent of public awareness of the Montreal Protocol
3. Analysis of the current level of refrigerant wastage and refrigerant conservation measures
4. Establish the current level of refrigeration equipment characteristics in end users
5. Establish the current level of refrigerants characteristics in end users
6. Formulation and economic and efficient collection, recovery and recycling programmes for CFCs used as refrigerants in Kenya

CHAPTER TWO
LITERATURE REVIEW

2.1 The Development of Refrigeration

The first patent for a refrigeration machine was obtained by Jacob Perkings in 1834(UNEP 1992(i)d). His machine, in common with a number of others developed during the 19th. century was based on the vapour compression cycle - on the same principle in which nearly all refrigerators operate today. These first(19th century) refrigeration machines used ethers or ammonia as the refrigerant and were powered by steam. (Rogers & Mayhew 1980a; Reynolds & Perkins 1977a; Eastop & McConkey 1963a; UNEP 1992(i); Van Wylen & Sonntang 1978a).

By the early decades of the 20th. century, electric motors were used to power refrigeration equipment. This enabled the compressor to be reduced in size and the whole system to become more versatile. By 1930 vapour compression refrigeration systems usually with ammonia as refrigerant were used for a range of commercial and industrial purposes. Domestic refrigeration systems -commonly using sulphur dioxide in iso-butane as the refrigerant - also become increasingly widely used (UNEP 1992(i)d).

At this time(1930s) all the commonly used refrigerants were either toxic, flammable or had to be operated at very high pressures. Growing public awareness of the toxicity of sulphur dioxide used in domestic refrigeration systems persuaded manufacturers to investigate Chlorofluorocarbons (CFCs) in the hope of developing a safer refrigerant. CFCs had been common since the 1880s but were not used until the early 1930s when production of dichlorodifluoromethane (CFC-12) began, and processes to develop ethane-derived CFCs (CFC-113, CFC-114 & CFC-115) were developed(UNEP 1992(i)d). These CFC fluids are non-toxic, inert and can be used over a range of pressures. These properties made them ideal refrigerants since there was flexibility in refrigeration system materials and design. CFC-based systems became increasingly reliable and efficient and have since then been used as the working fluid in vapour compression refrigeration and air conditioning systems.

2.1.1 Vapour Compression Refrigeration Cycle

In a vapour compression cycle (see Figure 2.1), the refrigerant is evaporated at low pressure, process 7-8. As the refrigerant evaporates, it absorbs energy from the surrounding air , thus lowering the air temperature and cooling the material to be refrigerated. Pressure is then increased by the compressor, process 1-2'. The refrigerant condenses in the process 3-4 and gives up the energy it had previously absorbed . The refrigerant is then throttled, process 5-6 via a capillary tube or an expansion valve and the cycle is repeated.

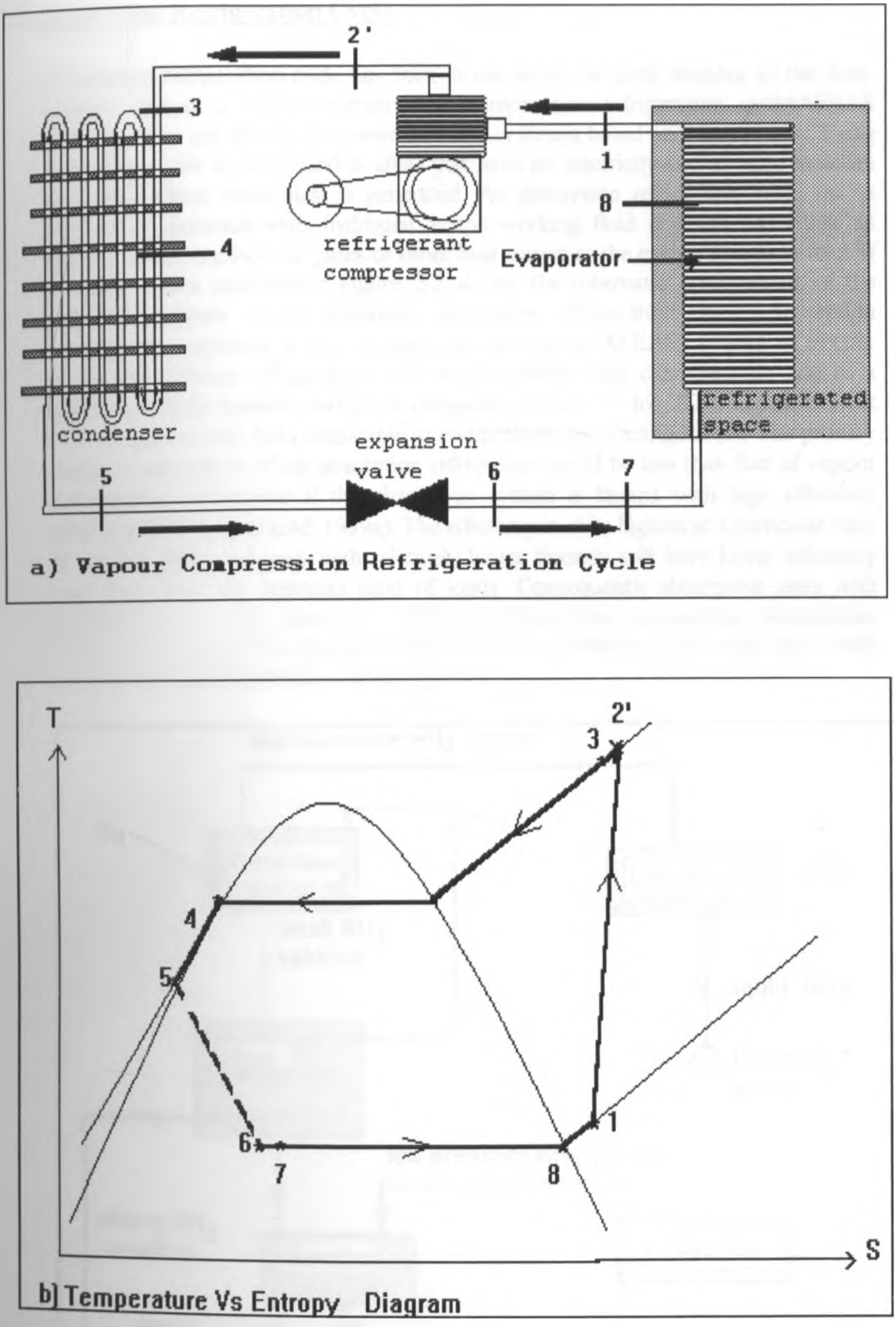


Figure 2.1 : Vapour Compression Refrigeration Cycle.

2.1.2 Absorption Refrigeration Cycle

Absorption refrigeration cycle has been in use since the early decades of the 20th. century and is a viable alternative to compression refrigeration cycle(AFEAS ;1991a).There are already consumer products in Kenya based on this principle. These refrigerators are mostly found in areas that have no electricity and in large factories especially where waste heat is generated. An absorption refrigerator relies on a mixture of ammonia-water-hydrogen as the working fluid and can use either an electric heater, combustion gases or other heat source as the energy source instead of a motor driven compressor Figure 2.2 shows the schematic arrangement of the essential elements of an ammonia- absorption refrigeration cycle. Absorption refrigeration consumes $1^{3}/_{4}$ to 2 times the site energy(AFEAS; 1984a) as electric driven compression refrigeration with similar cabinet load characteristics and as a result electrically heated absorption refrigerators have 75 to 100% higher indirect CO_2 emissions than that comparable to compression cycle refrigerators. The primary energy consumption of the absorption refrigerator could be less than that of vapour compression refrigerator if the absorption system is heated with high efficiency natural gas burners(AFEAS 1989a). The efficiency is at its highest at a particular ratio of cooling loads and units with relatively larger freezers will have lower efficiency than those with the optimum ratio of loads. Consequently absorption units with smaller freezers could have lower CO_2 emissions than comparable compression refrigeration if very high burner efficiency can be achieved. However this is still under investigation.(AFEAS 1989a)

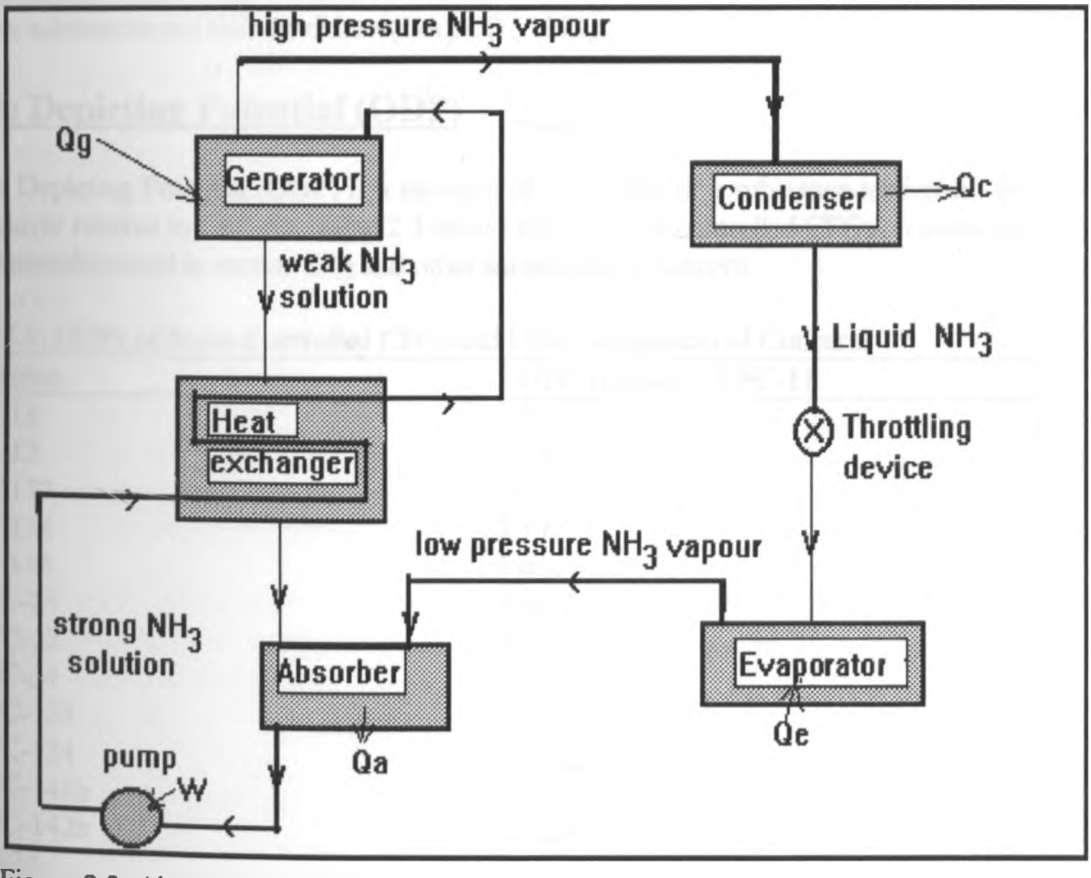


Figure 2.2: Absorption Refrigeration Cycle

2.2 Properties of Refrigerants

Practically all the existing refrigeration systems utilise the vapour compression cycle because of its simplicity and acceptable efficiency. The cycle operates on the CFCs and because of their success and their acceptable properties up to recent times, the future refrigerants will be based on the existing CFCs but with much reduced ozone depleting potential (ODP) defined in Section 2.3.

The desirable properties of a refrigerant are:

- Chemical and thermal stability
- Non-flammable
- Low toxicity
- Compatibility with other materials
- Low cost (industrial production and selling price)
- Favourable thermodynamic and transport properties
- Immiscibility with lubricants

Thermodynamics and transport properties of a refrigerant determine the refrigeration capacity, compressor work input, size of the components and hence the energy efficiency, capital and running costs of the refrigeration plant. These properties have therefore been used to screen the potential replacements for CFCs as refrigerants. Because of the success of the CFC refrigerants, most efforts to develop replacement refrigerants have focused on hydrogen-containing compounds which are otherwise similar to CFCs. These compounds include HFCs, 134a, 152a, 125 and 23 and HCFCs 123, 22, 141b, 142b and 124. Mixtures of these substances are also candidates(GALCO ; 1992).

2.3 Ozone Depleting Potential (ODP)

Ozone Depleting Potential (ODP) is a measure of the ability of a substance to deplete the ozone layer relative to CFC-11. Table 2.1 shows the ODPs of controlled CFCs , transitional substances(discussed in section 2.4) and other substances of concern.

Table 2.1: ODPs of Some Controlled CFCs and Other Substances of Concern.

Substance	ODP relative to CFC-11
CFC-11	1.0
CFC-12	1.0
CFC-113	0.8
CFC-114	1.0
CFC-115	0.6
HCFC-21	0.04
HCFC-22	0.055
HCFC-31	0.02
HCFC-123	0.02
HCFC-124	0.022
HCFC-141b	0.11
HCFC-142b	0.065
HFC-24	0
HFC-32	0
HFC-134a	0

2.4 Transitional Substances

The Montreal Protocol(1987) introduced the concept of transitional substances, such as hydrochlorofluorocarbons (HCFCs) which have quite low ODPs compared to CFCs. These chemicals will be necessary for some applications, in the medium term, to enable a rapid phase out of the controlled substances to take place. These transitional substances are not controlled under the Protocol, but parties must report data on their production and trade. However guidelines to facilitate first their adoption are necessary and subsequently their timely substitution by non-ozone depleting and more environmentally suitable alternative substances and technologies. The guidelines cover:-

1. The limitation of transitional substances to those applications where non-Ozone-depleting and environmentally suitable alternative substances or technologies are not available and where controlled or transitional substances are currently used.
2. Their selection to be according to ozone depletion and other environmental, safety and economical considerations.
3. The maximisation of emission control system, recovery and recycling and their eventual collection and destruction.

The regulation also provided for a regular review of the use of transitional substances rest high quantities are used, with a view to their replacement by non-ozone depleting and more environmentally suitable alternatives as the scientific evidence requires, said at the time to be no later than 2040 and, if possible, no later than 2020.

2.5 How Refrigeration Nomenclature Works

Refrigerant numbers provide the information needed to deduce the chemical structure of the refrigerant as is illustrated in Figure 2.3 and the nomenclature works as follows :-

1. The digit on the far right provides information on the number of fluorine atoms in one molecule.
2. The digit second from right indicates the number of hydrogen atoms plus one in one molecule.
3. The digit on the left indicates the number of carbon atoms minus one (omitted if 0) in one molecule.
4. The vacant valences are filled with chlorine atoms and so indicates the number of chlorine atoms in one molecule.

The international organisation for standardisation has also developed a convention for describing the structure of refrigerants using the letter 'R' or 'refrigerant' followed by two to four numbers as illustrated in Table 2.2.

2.6 Collection, Recovery and Recycling of Refrigerants

The objective of collection, recovery and recycling of CFCs is to reduce emission of CFCs into the atmosphere and at the same time reduce the amount of new CFCs required for servicing CFC-operated systems.

A recovery and recycling program would involve the following three basic procedures as illustrated in Figure 2.4.

1. Collection
2. Recovery
3. Recycling

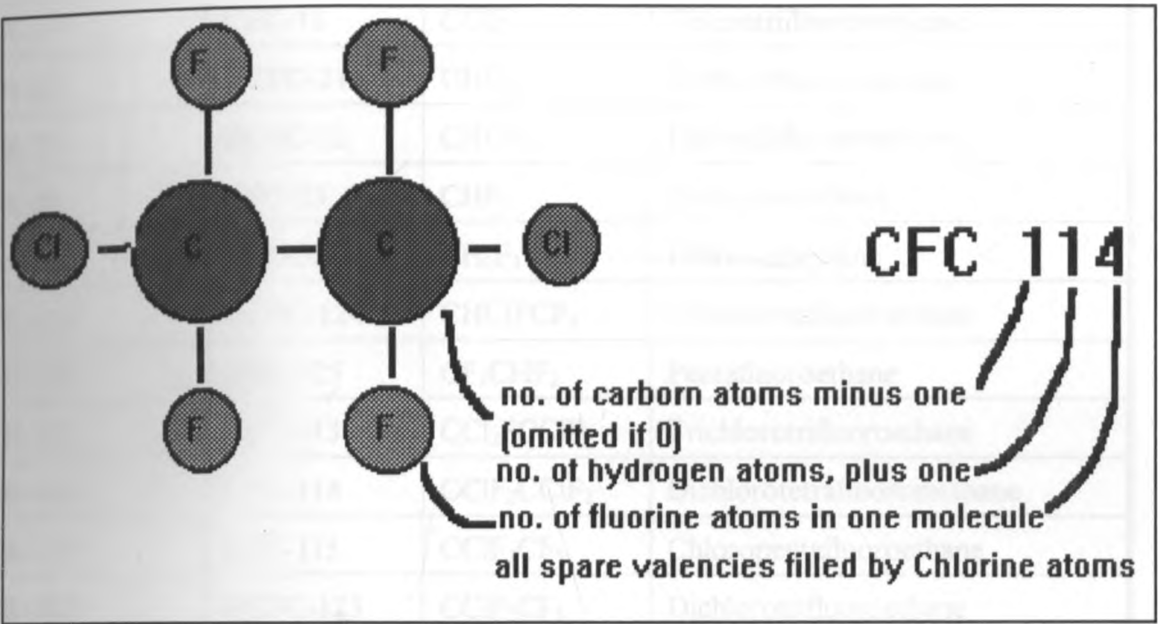


Figure 2.3: Refrigerants Nomenclature(UNEP 1992(i)d)

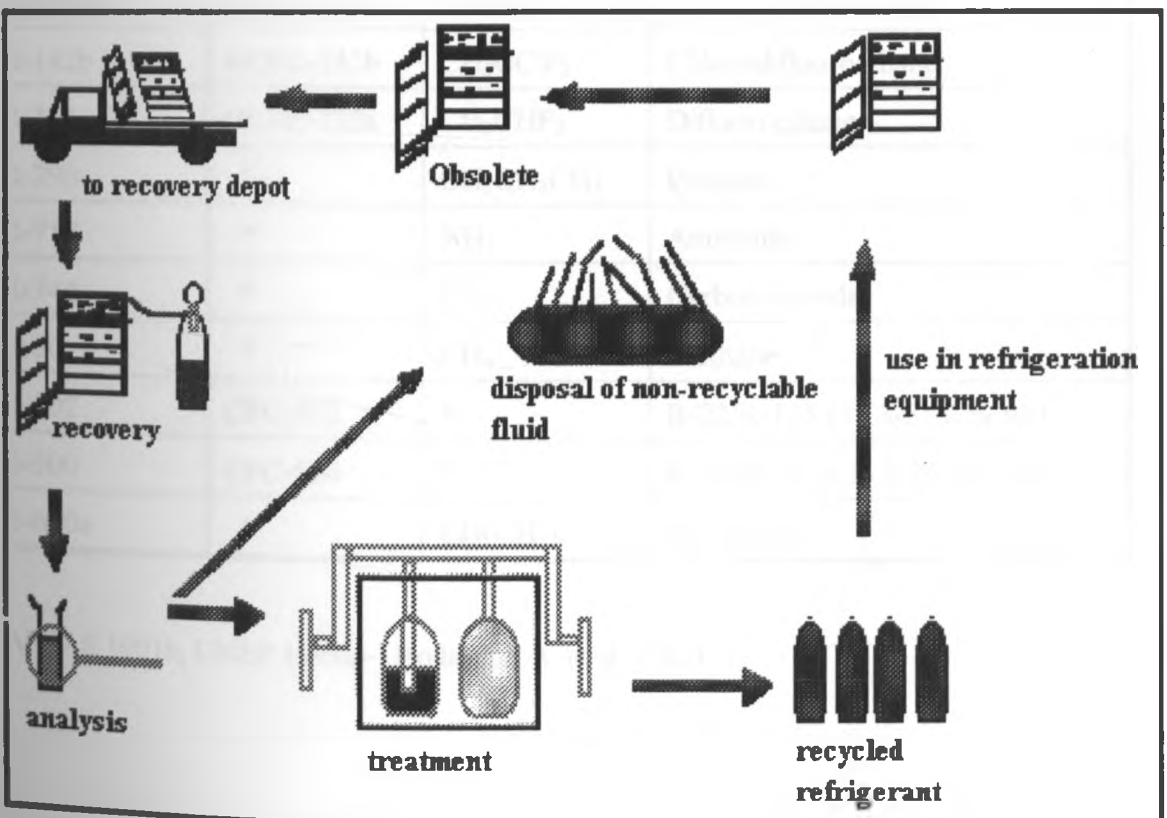


Figure 2.4 :Steps in the Collection, Recovery and Recycling of Refrigerants(UNEP 1992(i)g)

Table 2.2- Refrigerant Nomenclature

Refrigerant number.	Acronym	Chemical formulae	Name
R-11	CFC-11	CCl_3F	Trichlorofluoromethane
R-12	CFC-12	CCl_2F_2	Dichlorodifluoromethane
R-13	CFC-13	$CClF_3$	Chlorotrifluoromethane
R-21	HCFC-21	$CHCl_2F$	Dichlorofluoromethane
R-22	HCFC-22	$CHClF_2$	Chlorodifluoromethane
R-23	HFC-23	CHF_3	Trifluoromethane
R-32	HFC-32	CH_2F_2	Difluoromethane
R-124	HCFC-124	$CHClFCF_3$	Chlorotetrafluoroethane
R-125	HFC-125	CF_3CHF_2	Pentafluoroethane
R-113	CFC-113	CCl_2FCClF_2	Trichlorotrifluoroethane
R-114	CFC-114	$CClF_2CClF_2$	Dichlorotetrafluoromethane
R-115	CFC-115	$CClF_2CF_3$	Chloropentafluoroethane
R-123	HCFC-123	$CClF_2CF_3$	Dichlorotrifluoroethane
R-134a	HFC-134a	CF_3CH_2F	Tetrafluoroethane
R-141b	HCFC-141a	CCl_2FCH_3	Dichlorofluoroethane
R-142b	HCFC-142b	CH_3CClF_2	Chlorodifluoroethane
R-152a	HCFC-152a	CH_3CHF_2	Difluoroethane
R-290	*	$CH_3CH_2CH_3$	Propane
R-717	*	NH_3	Ammonia
R-744	*	CO_2	Carbon dioxide
R-50	*	CH_4	Methane
R-502	CFC-502	*	R-22/R-115 (48.8/51.2 % wt)
R-500	CFC-500	*	R-12/R-152a(73.8/26.2% wt)
R-600a	*	$CH(CH_3)_3$	Iso-butane

(AFEAS 1991b, UNEP 1993a, Holland, F.A. et al 1982)

When proper equipment and procedure are used for recovery ,reclaim and recycle of refrigerants the net recovery should be between 80% and 90% of the initial charge value(Kanyua 1993b). The recovery rates varies depending on the initial charge, type of system, the contamination of the recovered refrigerant, the treatment etc. In the case of Kenya a recovery rate of 80% can be assumed since this is a new activity in Kenya .

The refrigerant collection, recovery and recycle program is aimed at:

1. Reduction of emission of refrigerants into the atmosphere
2. Making available existing refrigerants for use in existing systems.
3. Reduction of quantities and costs associated with importation of new refrigerants.
4. Making possible the use of existing CFC -operated systems for their full life-spans.
5. Reduction in servicing costs.

2.7 Use of Refrigeration in Kenya

The consumption of CFCs in Kenya has been reported by UNEP Consultants(UNEP 1990(i)), UNIDO consultant (UNIDO 1992) and University of Nairobi (Kanyua 1993). However the data collected and used by these reports was so little to really give a national guideline of national consumption. This project aims therefore at first updating the data on CFCs used as refrigerants in refrigeration and air-conditioning sectors in. The data on use of CFCs in Kenya are presented in Chapter Three.

The major problems causing wastage of refrigerants in Kenya according to the above three reports have been identified as:

- lack of quality control
- servicing and installation by untrained technicians
- lack of appropriate charging systems
- damage to refrigeration systems by users
- damage to stationary refrigeration systems due to vibrations induced by unbalanced installation.
- damage to refrigeration systems by voltage fluctuations.
- damage to transport and mobile refrigeration and air conditioning unit due to poor roads
- lack of awareness of environmental matters
- lack of professional and government bodies to set standards

CHAPTER THREE
REFRIGERANT AUDIT

3.1 Summary of Audit

3.1.1 General Introduction.

In the refrigeration and air conditioning industry CFCs are used as refrigerants , and in the blowing of foam used as insulation surrounding the refrigeration units. The controlled CFCs which are used in the refrigeration and air conditioning sector in Kenya are CFC-11, CFC-12, CFC-500 and CFC-502. Other refrigerants currently in use are HCFC-22, Ammonia , Liquid CO_2 , HFC-134a and hydrocarbons such as propane and butane.

In this chapter we focus on CFCs used as refrigerants in Kenya. A comprehensive field survey was carried out in Nairobi, Mombasa, Kisumu, Nakuru ,Eldoret and Malindi to serve as basis for the assessment of the present and past levels of consumption of CFCs and other refrigerants in various refrigeration sub-sectors. The refrigeration sub-sectors looked into and their constituents are as tabulated in Table 3.1.

Table 3.1 : Refrigeration and Air-conditioning Sub-sectors and Their Constituents

Sub-sector	Constituents
Domestic refrigeration	stationary but moveable refrigeration units used mainly for domestic purposes
Commercial and retail refrigeration	stationary moveable and immovable refrigeration units used mainly for commercial purposes by retailers of food products
Cold storage and cold rooms	stationary immovable refrigeration facilities used for cold storage
Comfort air conditioning	immovable air-conditioning units used for comfort purposes within a building
Transport refrigeration	in-built refrigeration facilities used for transportation of perishable goods
Mobile air conditioning	in-built air-conditioning facilities for climatization of passenger cars
Industrial refrigeration	stationary and immovable refrigeration facilities in industrial processing plants

3.1.2 Data Collection

The entire requirements of CFCs for Kenya are derived from importation. In the present study the consumption of CFCs was worked out on the basis of import as well as the utilisation/demand for CFCs for each sub-sector. The import and utilisation was estimated through a comprehensive national survey. The survey covered interviews through questionnaires and checklists covering the following groups:-

1) Primary sources such as
- importers/distributors of CFCs
- end users such as manufacturers and assemblers of refrigerators
- retailers of domestic refrigerators
- retailers of refrigeration equipment
- servicing agents
- refrigeration and air conditioning contractors

2) Secondary sources such as
- industrial experts
- associations
- government departments.

The findings of the survey are represented per sub-sector. Each of the refrigeration product sub-sector is described under the following headings:

- Product definition
- Market for the refrigeration product
- CFCs consumption and 'bank'

In the data collection exercise, 910 questionnaires were distributed to various groups. 563 of the questionnaires were received back and among them 448 had useful information. The audit exercise is therefore based on these 448 questionnaires . Among the questionnaires received back their distribution among the various groups are as shown in Table 3.2.

Table 3.2: Questionnaires and Checklists Received Distribution Profile

Group	Number of questionnaires
Manufacturers/assemblers	6
Registered servicing agents	93
Unregistered servicing agents	27
Commercial contractors	15
Importers of CFCs	6
Government official	21
Retailers of domestic refrigerators	38
Domestic refrigeration users	109
Air-conditioning users	41
Other refrigeration users	85
Associations and industrial experts	7
Total	448

A list of the organisation/persons requested to and provided data is given in Appendix C.

3.2 Supply of Refrigerants

The entire requirements of refrigerants in Kenya are met through imports mainly from Europe. However, in recent years imports from Middle East (legal and illegal) have been important due to significant price differences. It should be noted also that there has been imports from India and China which are not party to the Montreal Protocol. In recent months there has been, though quite small, imports of finished goods and CFCs from South Africa.

3.2.1 Supply and Physical distribution

Refrigerants are imported in Kenya by three types of organisations. The share of imports in 1995 is given in Table 3.8

a) Subsidiaries/ associates of foreign manufacturers of CFCs.
There are 3 main such companies accounting for 67% of CFC imports. The three companies and their principals are:

1) Twiga Chemical Industries Limited - ICI, UK
2) Hoechst East Africa Limited - Hoechst, Germany
3) British Oxygen Company (BOC)- Du Pont, Germany

All these companies are located in Nairobi. Two of them (BOC & Twiga Chemicals) have their refilling facility (station in which refrigerants are put into cylinders under pressure) in Mombasa while Hoechst's facility is in Nairobi.

b) Importers who are also users
The three major companies in this category are

1)Refrigeration Contractors Limited - Nairobi
2)Premier Refrigeration and Engineering Works - Nakuru
3)Integrated Cooling Equipment - Mombasa

These companies imports CFCs directly and account for 16% CFCs imports.

- Refrigeration Contractors Limited imports CFCs from Galco Limited (Belgium) and also from Middle East for their consumption as well as for supplying to other smaller users.

- Premier Refrigeration limited imports from ICI (UK)and from Galco limited (Belgium) for their own consumption as well as for their group companies

- Integrated Cooling Equipment have been importing from India and China but of late have turned to the middle east (Dubai). However there is a lot of undocumented information of the actual quantity imported by this company.

Some companies such as Nairobi Afrigas, Sanyo Armco and Ramco import their requirements directly along with the other refrigeration components. Therefore refrigerants comes along with the other components.

c) Retailers of Refrigeration equipment

Refrigerant gases also find their way into Kenya through imports of refrigerated equipment. Some refrigeration equipment retailers import CFCs from Europe, Middle east and U.S.A. along with other refrigeration equipment spare parts.

It should also be noted that there are also a number of illegal imports of finished products and chemicals through the neighbouring countries like Somali and Ethiopia. which are undocumented hence difficult to quantify.

3.2.2 Distribution Channel

The main importers receive their shipments at Mombasa and the CFCs and other refrigerant gases are transferred from 1MT containers into smaller cylinders in importers refilling facilities. The cylinders are distributed through a network of dealers/agents as well as own outlets covering the major towns in Kenya. BOC has 23 agents in the country to whom the filled cylinders are supplied by BOC and at the same time empty cylinders are collected back. The supplies by BOC are in 50kg to 70kg cylinders.

Smaller users of CFCs and other refrigerant gases procure their requirements in disposable cylinders , of 13.6kg and 26.2kg.

Some retailers also buy these refrigerants (mainly CFC-12 and HCFC-22) and sell in smaller quantities to smaller users. In such cases the smaller users carry empty cylinders to these outlets and purchase these refrigerants in quantities of 1kg. to 5kg at a time.

3.2.3 Level of imports

The level of imports of CFCs and other refrigerant gases in Kenya in Metric Tonnes is summarised in Table 3.3., while the share of imports of refrigerants in 1995 by individual importers is given in Table 3.4.

Table 3.3: Level of Imports of Refrigerant Gases in Kenya (MT)

Type	1989	1991	1993	1995
CFC-12	200.00	83.00	41.00	55.00
HCFC-22	50.00	56.00	70.00	80.00
CFC-502	N.A	5.00	<0.50	0.11
CFC-500	N.A	N.A	<0.50	0.15
Ammonia	N.A	200.00	190.00	200.00
HFC-134a	N.A	N.A	N.A	0.13
Propane	N.A	N.A	N.A	<0.50
Butane	N.A	N.A	N.A	<0.50
Liquid CO_2	N.A	N.A	N.A	<0.50

N.A. = Not Available

source:

1989 - UNEP 1990(i)
1991 - UNIDO 1992
1993 - Kanyua 1993
1995 - Present field survey

Table 3.4: Share of Imports of Refrigerant CFC-12 in 1995

Firm		Quantity (MT)	Percentage
Twiga Chemicals		12.10	22%
British Oxygen Company		18.15	33%
Hoechst E.A		6.60	12%
Refrigeration contractors		5.50	10%
Premier Refrigeration		2.20	4%
Integrated Cooling Equipment		1.10	2%
Others	Legally	8.25	15%
	Illegally	1.10	2%
TOTAL		55.00	100%

Figure 3.1a indicated that 67.67MT were consumed in 1995. However from Table 3.4 the imported quantity of CFC-12 is 55MT. This indicate clearly that some figures of imports are undocumented and level of illegal import of CFC-12 is higher than the 2% shown.

3.2.4 Current Prices of Refrigerants (1995) in Kenya

The current retail selling prices of the refrigerant gases in Kenya is as shown in Table 3.5 below.

Table 3.5 : Retail Selling Prices of Refrigerants in Kenya (1995)

Refrigerant	Retail price Ksh/kg	Value Added Tax %
CFC-12	130 - 220	5
HCFC-22	200	5
CFC-500	750	5
CFC-502	750	5
Ammonia	400	5
HFC-134a	1600	5
Propane	500	5
Butane	500	5
Liquid CO_2	650	5

NB: CFC-12 is sold in containers of various sizes ranging from 13.6kg to 65kg. Hence the prices per kg show a wide variation

source: Importers/ dealers

Overview of the User Industry

3.3.1 Domestic Refrigeration

a) Product Definition

The domestic refrigeration sub-sector is concerned with three different types of product:

- one door refrigerators, which can contain a very small freezer compartment
- Two door fridge/freezers
- Freezers, either upright or chest

However due to stringent measures by European countries, there are already HFC-134a based refrigerators in Kenya that have been imported from Europe. There are also in existence ammonia-based absorption refrigerators in Kenya and mostly used in areas where there is no electricity.

b) Domestic Refrigeration Market

The Kenyan market for domestic refrigeration is dominated by Nairobi and Mombasa which accounts for 61% of the total sales (see Table 3.6). Information from the major retailers of domestic refrigerators indicate that in 1995 the approximate sales from the major towns in Kenya is as shown in Table 3.6. Imported domestic refrigerators were in the order of 10,000 units in 1995 while locally assembled were of the order of 20,000 units.

In Kenya refrigerators are assembled by a small number of small sized production plants estimated to be about 6 in 1995 and whose production levels are as indicated in Table 3.7.

Table 3.6: Domestic Refrigeration Market Profile (1995)

Town	Quantity	Percentage
Nairobi	11,000	35
Mombasa	8,500	26
Kisumu	4,000	16
Nakuru	2,700	10
Eldoret	1,800	8
Others	2,000	5
TOTAL	30,000	100

Table 3.7: Domestic Refrigeration Production in Kenya (1995)

Company	Town	Quantity
Premier Refrigeration	Nakuru	6,000
Sanyo Armco	Nairobi	5500
Kamco	Nairobi	1,500
Integrated Cooling Equipment	Mombasa	2,000
Nairobi Afrigas	Nairobi	4,500
Abdulrasal Mulla	Malindi	500
TOTAL		20,000

It is assumed that nearly all upper middle and upper income earner's households have some form of refrigeration units, which are generally replaced after 5 to 8 years of use, although technically they have a product life of 15 to 20 years.

Unit sales have grown steadily with a 8% increase over the period from 1989 to 1995 as shown in Table 3.8 below. They have now reached a total of 30,000 with import accounting for 33% and locally assembled accounting for 67%.

Table 3.8: Total Unit Sales of Domestic Refrigerator and Freezers

Year	1989	1991	1992	1995
Unit sales	10,000	20,000	20,000	30,000

source:

1989 - UNEP 1990(i)
1991 - UNIDO 1992
1992 - Kanyua 1993
1995 - Present field survey

However the local market is attempting to stimulate demand. This is being done by offering new equipment with added features. These features include:-

- Integrated units for fitted kitchens which present a total colour co-ordinated image of the kitchen . This range from 3 cuft to 5 cuft.
- Zoned fridge/freezers, which have three or four different compartments, each of which is maintained at different temperatures, ranging from 'ladder' to 'deep freezer' temperatures.
- Frost free fridges which remove the need for de-frosting
- 'environmentally friendly' fridges which contain HFC-134a as refrigerant. However these fridges are 10% less efficient than their CFC-12 predecessors.

c) Consumption and 'Bank'

Domestic refrigeration appliance use hermetically sealed units which are reliable and leak proof.

The refrigerant charging norm per unit ranges between 75gm. to 250gm. depending upon the size of refrigerator as shown in Table 3.9.

Table 3.9: Unit charging norm (CFC-12)

Cold Space Capacity (cuft)	4	5	6	8	10	12	15	20	25	30
R or F	R	F	R	R	F	R/F	F	F	F	F
Charging norm (gm)	75	100	90	110	150	180	180	210	230	250

R-Refrigerator F - Freezer F/R - Freezer and fridge combined

The most popular size is the 8cuft (single door).

In 1995 Kenyan manufacturers/assemblers of domestic refrigerators and freezers produced about 20,000 units. On average each unit contains 120gm of CFC-12. This means that the ideal consumption of CFC-12 by manufacturers/assemblers of domestic refrigerators was approximately

20,000 x 120 gm = 2.4 MT

However due to the low level of production resulting in high losses in handling and rejection/reworking it is estimated that twice this amount is used i.e.

2.4 x 2 = 4.8 MT

Besides the use of CFC-12 in manufacture of new units, CFC-12 is also used during the servicing of the stock of refrigerators and freezers. Domestic and commercial refrigerators/chillers/freezers are serviced by a large number of servicing agents located mainly in the larger towns. The total number of servicing agents within this field are as tabulated in Table 3.10.

Table 3.10 :Distribution of Registered Servicing Agents by Geographical Location (1995).

TOWN	Nairobi	Mombasa	Kisumu	Nakuru	Eldoret	Others	TOTAL
Number	50	45	15	10	6	14	140

However there are other smaller unregistered agents estimated to be about 60 nation-wide. The total number of servicing agents can therefore be estimated at 200.

Information obtained from the registered servicing agents indicate that over the product life, on the average 2 times the original CFC charge is used for servicing due to leakage and compressor failure. However due to servicing by unqualified technicians and use of CFC-12 for flushing and leak testing, use of improper facilities and general laxity in the industry, 4.8 times the original charge is used over the product lifespan.

Assuming that the average lifespan of equipment to be 12 years, this implies that on average, each unit requires

(120gm x 4.8) / 12 = 48gm (40% of the initial charge) per annum

Data from the present survey indicate that 5% of the households in Kenya have refrigerators and 0.25% have freezers. Given that there were about 5 million households in Kenya in 1995(CBS 1995), the number of refrigerators and freezers in households is currently about:

5,000,000 x 0.05= 250,000 refrigerators
5,000,000 x 0.0025=12,500 freezers

These figures underestimate the number of units because they ignores households with more than one of either unit and excludes those owned by non-domestic users. Thus it is estimated that the number of refrigerators and freezers owned by non-domestic users in Kenya to be about 10,000 and the number of refrigerators and freezers in excess due to households with more than one of either unit to be about 3000. The total number of domestic refrigerators and freezers is estimated at :-

(250,000 + 12,500 + 10,000 + 3,000) = 275,500

It is further estimated that there are about 440 domestic refrigerator absorption type, Ammonia -based, and about 60 HFC-134a based

The 'bank' of CFC-12 in domestic refrigerators and freezers by 1995 was therefore estimated as:

275,000 x 120gm. = 33 MT

The additional consumption of CFC-12 in 1995 as a result of servicing demand is equal to 40% of the estimated 'bank'. This additional consumption of CFC-12 is about:

33 MT x 0.40 = 13.3 MT

This implies that the total consumption of CFC-12 by domestic refrigeration sub-sector in 1995 was

4.8MT(charging) + 13.3MT (servicing) = 18.1 MT

<u>Other refrigerants</u>

<u>Ammonia</u>

The average charging norm is about 240gm. Bank of ammonia in domestic refrigerators and freezers by 1995 was estimated as

440 x 240gm. = 0.11 MT

Consumption of ammonia as a result of servicing is low as very few agents actually deal with ammonia. However about 20 ammonia refrigerators were reported to have been serviced in 1995. Consumption by servicing agents is therefore estimated as

20 x 240gm. = 4800gm.

However 3 times this amount is actually used due to poor servicing habits. Amount of ammonia consumed in 1995 was therefore estimated as

4800gm x 3 = 14.4 kg

HFC-134a

Average charging norm is about 150gm. HFC-134a banked in refrigerators and freezers by 1995 was estimated as

60 x 150gm. = 9 kg

Currently there are no reported repairs of HFC-134a based refrigerators and freezers. Consumption by servicing agents is therefore zero.

3.3.2 Commercial and Retail Refrigeration

a) Product Definition

Commercial & retail refrigeration is used to store and display food and drink items in supermarkets, smaller shops, restaurants, bars and butcheries etc. The food or drink can either be stored frozen or chilled. These displays include:-

- Food display counters
- Cold buffets
- Bottle coolers
- Ice makers
- Water chillers
- Display chillers
- Ice cream cabinets

Retail and commercial refrigeration uses different refrigerants which are suited to different storage temperature ranges as shown in Table 3.11.

Table 3.11: Refrigeration Temperature Range for Retail and Commercial Refrigeration

Refrigerant	Temperature range(refrigerated space)
CFC-12	-15°C to +15°C
CFC-502	down to -45°C
HCFC-22	-35°C to +15°C
HFC-134a	-5°C to +6°C

b) Market for Commercial and Retail Refrigeration

Estimates on historic sales of commercial and retail refrigeration in Kenya shows that there were about 25,228 units(present study) in Kenya in 1995.

A total of 2000 units were introduced in the market in 1995(present study). Out of these total imports accounted for 750 units and 1,250 units were assembled locally.

Kenyan market for commercial and retail refrigeration has the following characteristics:-

- A growing demand for retail refrigeration
- An increased manufacturing/assembling activity
- Increased level of imports.

The demand for commercial and retail refrigeration and its servicing and maintenance is expected to grow strongly over the next 7 years. This is as a result of the growth in catering business, departmental stores, the horticultural industry , small scale producers of milk and milk products, Coca Cola bottling companies demand and decontrol of major sectors of economy.

c) Consumption and Bank

The distribution of retail and commercial refrigeration units, in Kenya in 1995 ,on the refrigerant basis was as follows:-

- units using CFC-12 are about 25,000 with an average charge of 250gm per unit.
- units using HCFC-22 are about 200 with an average charge of 500gm per unit
- units using CFC-502 are about 8 with an average charge of 450gm.
- units using HFC-134a are about 20 with average charge of 210gm per unit

The supply of refrigerants to the commercial and retail refrigeration market, is through the following three channels:-

1. Some large retail chain users e.g. Uchumi Supermarkets, purchases their own refrigerants and only hire contractors/servicing agents to charge the refrigerant into the cooling system whenever needed.

2. Other retailers use contractors/servicing agents to both supply the equipment and charge the refrigerant.

3. Other users such as Coca Cola have their own technicians and buy refrigerants directly from major importers

Over 50% of the consumption of CFCs is used when servicing existing equipment to replace CFC lost through leakage and compressor failure during operation of the system. The Consumption of CFCs in 1995 is shown in Figure 3.3

Estimates of the CFC-12 'bank' contained within commercial and retail refrigeration units is estimated as :

25,000 X 250gm = 6.25 MT

CFC-12 for New charge

1,250 x 250gm = 312.5 kg

However twice this amount is used due to poor working methods, therefore CFC-12 for new charge

312.5kg x 2 = 625kg = 0.63 MT

The technical product life of retail refrigeration is 12-15 years, however, large department stores replace their refrigeration equipment after 5-8 years. These equipment, if is free-stand is likely to be sold to smaller retail outlets. These smaller outlets will retain this equipment for a further 5-7 years. The overall product life of such equipment is, therefore, equivalent to the technical life of the product i.e. 12-15 years.

About 25% CFC-12 based units of the population require total recharging every year due to compressor failure or leakage, while 49% of the population require topping up once or twice a year to the extent of 50% of the original charge. The total average charge being 250g.

CFC-12 for servicing is estimated as:

0.25 x 25,000 x 250gm =1562.5 kg = 1.57 MT

due to poor servicing facility about twice this amount is used i.e.

1562.5 kg x 2 = 3125 kg = 3.13 MT

CFC-12 for topping up is estimated as :

0.49 x 25,000 x 0.5 x 250gm = 1.53 MT

However twice this amount is used due to poor servicing facility and techniques i.e.:

1.53 MT X 2 = 3.06 MT

Therefore in 1995 CFC-12 consumption by the retail and commercial refrigeration sub-sector was estimated as:

0.63 MT(charging) + 3.13.MT(recharging) + 3.06 MT(Topping up) = 6.82 MT

<u>Similarly for HCFC-22.</u>

About 24% HCFC-22 based units of the population require total recharging every year due to compressor failure or leakage, while 50% of the population require topping up once or twice a year to the extent of 50% of the original charge.

amount 'banked'	200 X 500gm. = 0.1 MT
servicing	0.24 x 200 X 500gm X 2 = 48 kg
Topping up	0.5 X 200 x 500gm X 0.5 X 2 = 50 kg

Total consumption of HCFC-22 = 0.05 + 0.05 = <u>0.10 MT</u>

<u>for CFC-502.</u>

About 25% CFC-12 based units of the population require total recharging every year due to compressor failure or leakage, while 50% of the population require topping up once or twice a year to the extent of 50% of the original charge.

amount 'Banked'	8 X 450gm = 3.6kg
amount used for Servicing	0.24 X 8 X 450 x 2 = 1.7kg
amount used for Topping up	0.5 X 8 X 450 X 2 X 0.5 = 1.8kg

Total consumption 1.7 + 1.8 = <u>3.5 kg</u>

<u>For HFC-134a</u>
'Banked 20 X 210gm =4.2 kg
HFC-134a based units have just been introduce and there is no reported case of servicing.

3.3 Cold Storage and Cold Rooms

a) <u>Product Definition</u>

This sub-sector covers facilities used for cold storage (20°C to -25°C) in the following industries:

- Fish and meat processing industry
- Fruit juice industries
- Hotels
- Horticultural crops industry
- Fisheries and Butcheries
- Mortuaries
- Dairy

CFC-12 and HCFC-22 are the only refrigerants used in all the products.

b) <u>Market for Cold Storage and Cold Rooms</u>

The rapid expansion of the tourism industry, horticultural crops industry and the liberalisation of the milk, fish and meat industries has resulted in a high growth rate, estimated to be about 10% per annum from 1990 to 1995 although this growth rate may be adversely affected by recent downturn of the Kenyan economy.

The major contracting companies engaged in fabrication and installation of cold room insulation and equipment are:

1. Hall Equatorial
2. Daikin Kenya
3. Refrigeration Contractors
4. Remco Ltd.
5. Refrigeration Centre
6. Kooltech
7. Gilfillian refrigeration
8. Frametree refrigeration
9. African marine & malad engineering
10. Frigitech

The above contractors also serve all the other refrigeration and air-conditioning sub-sectors. There are several other smaller contracting companies. Practically all major and small companies are based in Nairobi and Mombasa.

c) Consumption and Bank

There are about 10,000 cold rooms(present study) of various physical and refrigerating capacities and working temperature. The cold rooms operating at very low temperatures (-25°C to -40°C) are very few. Approximately 2,000 of the units are 14 or more years old and so will be written off in case of breakdown.

About 650 CFC-12 based units were installed in the country in 1995 while HCFC-22 based units were 550. About 60% of all units in the country are operated on CFC-12 while the other 40% are operated on HCFC-22.

Most private firms are very cost conscious and therefore avoid frequent recharging and topping up of the refrigeration systems

Charging, recharging and topping up is done on site by technicians hired by contracting companies or by technicians employed by the firm owning the cold room(s). The average charging norm is about 6 kg of CFC-12 per unit and 8kg of HCFC-22 per unit. However, the actual quantity used per charging or recharging operation is about 3 times this due to high losses/wastage caused by use of untrained technicians and laxity in charging methods. About 6% of the population requires recharging every year. Also, about 25% of all units require annual topping up to the tune of 35% of the initial charge.

The quantities of CFC-12 and HCFC-22 involved in 1995 is as follows:

CFC-12 bank:	10,000 x 0.60 x 6 kg	= 36 MT
CFC-12 used for New Charge:	650 x 6 x 3 kg	= 11.7 MT
CFC-12 used for Recharging:	10,000 x 0.60 x 0.06 x 6 x 3 kg	= 6.48 MT
CFC-12 Required for Topping up:	10,000 x 0.60 x 0.25 x 0.35 x 6 x 3 kg	= 9.45MT
Total consumption of CFC-12 =	27.63 MT	

HCFC-22 bank:	10,000 x 0.40 x 8 kg	= 32 MT
HCFC-22 used for New Charge:	550 x 8 x 3 kg	= 13.2 MT

HCFC-22 used for Recharging:	10,000 x 0.40 x 0.06 x 8 x 3 kg = 5.76 MT
HCFC-22 Required for Topping up:	10,000 x 0.40 x 0.25 x 0.25 x 8 x 3 = 8.4 MT
Total consumption of HCFC-22 =	27.36 MT

3.3.4. Comfort Air Conditioning

a) Product Definition

The comfort air condition is concerned with three different types of product:-

- Central air-conditioning plants or commercial unitary systems
- Window mounted units or unitary room air-conditioners
- Split units (both duct free and ducted system)

Central air-conditioning plants are employed in 5-star hotels (about 30 units) and in some high class office buildings (about 20-30 units) and hospitals(about 15 units).

Window-mounted units are used in offices(about 10,000), hotels(about 5,000), hospitals(about 3,000).

Split units are used in hospitals(about 2,000), hotels(about 4,000), office(about 3,000) and some factories(about 2,000) and residential buildings(about 925).

The above figures were estimated from the present field study

All window-mounted and split units use hermetically sealed compressors and soldered/welded refrigerant pipes and connections. All central air-conditioning plants are operated on open compressors. CFC-12 and HCFC-22 are the refrigerants used in this sub-sector.

b) Market for Comfort Air-conditioning

The growth rate for this sub-sector is quite high (about 50% p.a. in 1995). The actual growth rate is difficult to estimate because of the many small contractors involved in installation of the smaller units and the nature of importation of the smaller units (illegal entry and lack of data from Customs Department etc.). However Mombasa takes the biggest share ; with virtually all offices, hotels, retail shops and most higher market residential houses air conditioned. This is because of the hot weather condition at the coast.

c) Consumption and Bank

There are about 30,000 air-conditioning plants in total in Kenya in 1995. About 25% of these are operated on CFC-12 while 75% are operated on HCFC-22. The average charge for CFC-12 is about 250gm while the average charge for HCFC-22 is about 300gm. About 10% of CFC-12 operated plants require servicing each year.

Information provided by contractors indicates that there are about 6 centrifugal compressor chiller units operating on CFC-12, each having 500 kg of CFC-12. These chillers were installed in the period 1975-1985 and will therefore require CFC-12 for servicing for the next 10 years (assuming lifespan of 20 years). The CFC-12 for this is estimated to be 50 kg per unit per annum per unit i.e.

total per annum 50 x 6 = 300 kg = 0.3MT

CFC-12 banked	30,000 x 0.25 x 0.25 kg + 500x6 kg	= 4875 kg
CFC-12 for servicing	30,000 x 0.25 x 0.1 x 0.25 kg	= 187 kg .

For servicing due to improper servicing methods 3 times this amount is used i.e. 187kg x 3 = 561 kg

Total consumption 561 +300 = 861kg = 0.86 MT

Damage to refrigeration systems in this sub-sector is low because operators do not have access to the systems except the on/off and adjustment switches. Demand for CFC-12 for recharge is therefore low.

20% of HCFC-22 operated plants require servicing each year.

HCFC-22 banked	30,000 x 0.75 x 0.3 kg = 6750kg
HCFC-22 for servicing	30,000 x 0.75 x 0.2 x 0.3 kg = 135kg

However three times this amount is used i.e. 135 x 3 kg = 405 kg = 0.4 MT

3.3.5 Transport Refrigeration

a) Product Definition

The transport refrigeration is important as it ensures the safe delivery of fresh foodstuffs, horticulture and medical supplies to their destinations.

Transport refrigeration covers four separate product categories.

- trucks- Overland transport by refrigerated trucks and truck mounted refrigerated containers.
- sea freight containers
- railway wagons
- ships

These categories are discussed in detail in Chapter Five.

b) Market for Transport Refrigeration

There is however very little published information or industrial data estimating the size of transport refrigeration sub-sector in Kenya. However market for transport refrigeration is distributed throughout the country. Producers of perishable goods, horticulture and medical suppliers dominate this sub-sector.

c) Consumption and Bank

It is estimated that there were about 60 refrigerated trucks in use in Kenya in 1995 and all these units operate on CFC-12. The charging rate is about 6 kg per unit, with 15% per annum of the population requires recharge due to leakage, and about 30% per annum of the total population requires topping up to 35% of the initial charge. The charging procedure uses about 3 times the amount of refrigerant required due to poor charging systems and untrained technicians. The poor state of roads in Kenya contributes very highly to the leakage problems.

There are about 50 sea freight containers working on CFC-12, with an average charge of 12 kg per unit. These containers experience same leakage problems mentioned above.

There are about 40 railway wagons operated on CFC-12 with an average charge of 7 kg per unit and experiencing the same problems as the trucks above.

Shipping and container refrigeration both use almost exclusively one type of refrigerant; containers CFC-12, Shipping HCFC-22. The dominance of these refrigerants within this sub-sector is a result of the world-wide nature. Both of these transport refrigeration methods require the refrigeration system to be serviced and maintained anywhere in the world. It is therefore important to consider this section of transport refrigeration from a global perspective.

There are about 50 sea freight containers with an average of 12kg per unit. There are about 40 refrigerated ships with an average of 50kg of HCFC-22.

CFC-12 banked:

Trucks	: 60 x 6	=	360 kg
Railway	: 40 x 7	=	280 kg
Sea freight	: 50 x 12	=	600 kg
Total		=	1240 kg ≈ 1.24 MT

CFC-12 used for New Charge: Zero

CFC-12 Consumption in Recharge and Topping up:

Trucks :	(60) [0.15 + (0.30 x 0.35)] [6][3] = 275 kg
Railway wagons:	(40) [0.15 + (0.30 x 0.35)] [7] [3] = 214 kg
Sea freight Containers:	(50)[0.15 + (0.30 x 0.35)][12][3]= 459 kg
TOTAL	948 kg ≈ 0.95MT

HCFC-22 banked	40 x 50 kg = 2000kg = 2 MT
HCFC-22 for new charge	Zero

HCFC-22 consumption in recharge and topping up

40(0.15 + (0.3 x 0.35)) (50) (3) = 1.53 MT

3.3.6 Mobile Air-Conditioning

a) Product Definition

The mobile air conditioning sub-sector covers the comfort air conditioning of passenger vehicles (saloons and coaches). All mobile air-conditioners are operated on CFC-12.

b) Market for Mobile Air-conditioning

Before 1987, mobile air-conditioning was insignificant, but has started to grow due to consumer behaviour and importation/assembly of cars in which air-conditioning units are regular components. Most firms dealing with tourists and especially those in the Coast have most of their cars and coaches air conditioned.

c) Consumption and 'Bank'

There are three vehicle assembly plants in Kenya that deal with mobile air-conditioning i.e.

- General Motors (Nairobi)
- Associated Vehicle Assemblers (Mombasa)
- Kenya Vehicle Assemblers (Mombasa)

These firms assemble about 6 international makes of vehicles from completely knocked-down kits.

In 1986 it was estimated that there were about 100,000 cars in Kenya(UNEP 1989((i)). Assuming a growth rate of 10% between 1987 to 1995, this implies that there are now (1995) about 230,000 cars on the road. Of this total number of cars, only 5% of the cars introduced into the country between 1987 and 1995 (i.e. 11,500) are air-conditioned. There are about 3,000 air-conditioned cars to be which have found their way into Kenya in the same period, this making the total number of air-conditioned cars about 14,500. Among this total in 1995 about 815 air-conditioned vehicles were assembled locally.

The average charging rate is 1.5 kg per unit but due to poor charging systems, the actual quantity of CFC-12 used is about 3 kg per car per charge. It is reported by the firms servicing mobile air-conditioners that about 25% of air-conditioned cars are recharged per year mainly due to high incidence of leakage.

The current quantities of CFC-12 for the sub-sector are as follows:

CFC-12 banked in Cars: 14,500 x 1.5 = 21.75 MT
CFC-12 used for New Charging: 815 x 3 = 2445 kg
CFC-12 used for Recharging: 14,500 x 0.25 x 3 = 10875 kg

Total consumption 2445 + 10875 = 13320kg = 13.32 MT

3.3.7 Industrial Refrigeration

a) Product Definition

Industrial refrigeration covers the industrial processing plants (oil, gas, and petrochemical industries) and food processing plants (bakeries, breweries and frozen foods)

Industrial refrigeration can be split into direct and indirect refrigeration systems. Direct refrigeration systems have no intermediate system between the refrigerant and the space or material to be cooled. The advantage of such system is that they are more energy efficient than the indirect systems. However, they require a high refrigerant charge per kilowatt of power in order of 1-30 litres/kW. Indirect refrigeration systems have an intermediate system between the refrigerant and the area or material to be cooled. This intermediate system which could be brine, is cooled by the refrigerant and then goes on to cool the area or material. The advantage of these product systems is that they require a small refrigerant charge per kilowatt of power, typically 0.2-0.8 litres/kW. They are however less energy efficient than direct systems. The initial capital cost of indirect system is about 20%(AFEAS, 1989) higher than those of direct systems.

Industrial refrigeration systems have to produce temperatures ranging from -15°C to +10°C, with powers varying from several hundred kW up to mega-watts(MW). This wide range of temperature ranges require different compressor categories to be used.

Industrial refrigeration uses mainly Ammonia and HCFC-22 as refrigerants. Liquid CO_2 as well as hydrocarbons are used on some applications. The hydrocarbons are generally used in industries which are accustomed to dealing with fire hazards such as oil, gas and petrochemical industries. Ammonia continues to be used to a considerable extent in the food, ice making and brewing industries though it's use has continued to decline in preference to HCFCs which offer the advantage of being non-toxic and easy to handle.

b) Market for Industrial Refrigeration

The demand for industrial refrigeration equipment has risen steadily over the past five years with food processing plants being set up. However the industrial refrigeration market is a contractor oriented market. Contractors import refrigeration units and components and assemble them into customised systems at client's site.

c) Consumption and 'Bank'

Industrial refrigeration equipment is supplied without a refrigerant charge. The refrigeration equipment is assembled and installed at the client's site, and only then is the equipment charged with refrigerant. Most consumption occurs during use through leakage of the refrigerant during normal usage.

Industrial refrigeration has a technical product life of 15-30 years but an economic product life which is 8-20 years. The wide range of product life is due to the variety of products which fall into the industrial refrigeration category.

In this sub-sector the total capacity is about 5,000 tons of refrigeration (17,580 kW) based on HCFC-22 and ammonia which are not controlled substances at present.

In 1995 there were about 100 refrigerated industrial plants in Kenya. Out of this;

- 30 are HCFC-22 based with an average charge of 12kg per unit
- 66 are ammonia based with :-
  - 55 being direct refrigeration with an average charge of 15kg per unit.
  - 11 being cascade type with an average charge of ammonia as 3 kg per unit.
- 2 are hydrocarbon based with an average charge of 20 kg per unit
- 2 are liquid CO_2 based with an average charge of 18 kg per unit.

Charging, recharging and topping up is done on site by technicians hired by contracting companies or by technicians employed by the firm owning the refrigeration plant. However, actual quantity used per charging or recharging operation is about 3 times due to high losses/wastage caused by laxity in charging methods. About 6% of the population requires recharging every year. Also, about 25% of all units require annual topping up to the tune of 35% of the initial charge.

<u>Refrigerant banked in this sub-sector</u>

HCFC-22 30 x 12 kg = 360kg
Ammonia 55 x 15 + 11 x 3 = 858 kg
Hydrocarbons 2 x 20 = 40 kg
Liquid CO_2 2 x 18 = 36 kg

<u>Refrigerant consumption for fresh charge in 1995</u>

Zero

<u>Refrigerant consumption for recharge</u>

HCFC-22 30 x 0.06 x 12 x 3 = 64.8 kg
Ammonia 55x 0.06 x 15 x 3 + 11 x 0.06 x 3 x 3 =154 kg
Hydrocarbons 2 x 0.06 x 20 x 3 = 7.2 kg
Liquid CO_2 2 x 0.06 x 18 x 3 = 6.5kg

<u>Refrigerant for topping up</u>

HCFC-22 30 x 0.25 x 0.35 x 12 x 3 = 94.5 kg
Ammonia 55 x 0.25 x 0.35 x 15 x 3 + 11 x 0.25 x 0.35 x 3 x 3 = 225.2 kg
Hydrocarbons 2 x 0.25 x 0.35 x 20 x 3 = 10.5 kg
Liquid CO_2 2 x 0.25 x 0.35 x 18 x 3 = 9.5 kg

<u>Total consumption</u>

HCFC -22 =159.3 kg
Ammonia = 379.2kg
Hydrocarbons = 17.7 kg
Liquid CO_2 = 15.9 kg

3.4 Summary of the Utilisation of CFCs in the Refrigeration and Air-Conditioning Industries.

3.4.1 General introduction

The data presented in this Section is derived from the present study.

Refrigeration and air conditioning industry accounted for 90-95% of the total CFCs consumption in Kenya in 1995. The distribution between the product categories identified above is shown in Figure 3.1. Also shown in the Figure 3.1 is the relative quantity of CFC banked for each category.

Table 3.12 shows a summary of:

- Consumption and bank of refrigerant
- Refrigerants used within the product sector
- Average product life.

Figure 3.2 to Figure 3.7 show information on the product sub-sectors. Each figure contains the Refrigerant consumption profile by manufacturers/assemblers, contractors and servicing agents (both licensed & unlicensed)

Table 3.12 to 3.16 and Figures 3.1 to 3.7 are intended to give a summary for each product sub-sector. More detailed information and supporting arguments are contained in the rest of Chapter Three.

3.4.2 Conclusions From the Tables and Figures

1. The figures for consumption by manufacturers/assemblers for domestic refrigeration in Table 3.13 do not agree with the amount for new charge in Table 3.6. This implies that apart from the 6 manufacturers/assemblers some contractors and some of the servicing agents are engaged in Unlicensed small scale assembly.
2. For mobile air-conditioning the motor vehicle assemblers are also engaged in servicing as seen from figures in Table 3.13 and Table 3.15 i.e 4.4 - 2.4 = 1.9 MT of CFC-12 is used for servicing of their production.
3. For Retail and commercial air conditioning, the assemblers are also the main servicing agents i.e. Premier Refrigeration Limited that assemble Coca-Cola Company Limited's bottle coolers are also the main servicing agents for this product. Therefore 1.9 - 0.6 = 1.3 MT is used for servicing the products
4. Cold Storage and cold rooms is the highest consumer of CFC-12 in Kenya in 1995.
5. Most unlicensed Servicing agents mainly operate in domestic refrigeration sub-sector.
6. CFC-12 is the most used refrigerant in Kenya (69.3%) in 1995.
7. For CFC-12, about 15.4% of the consumption is used by unregistered servicing agents.
8. Level of refrigerant CFC-12 wastage is over 60% the total consumption.

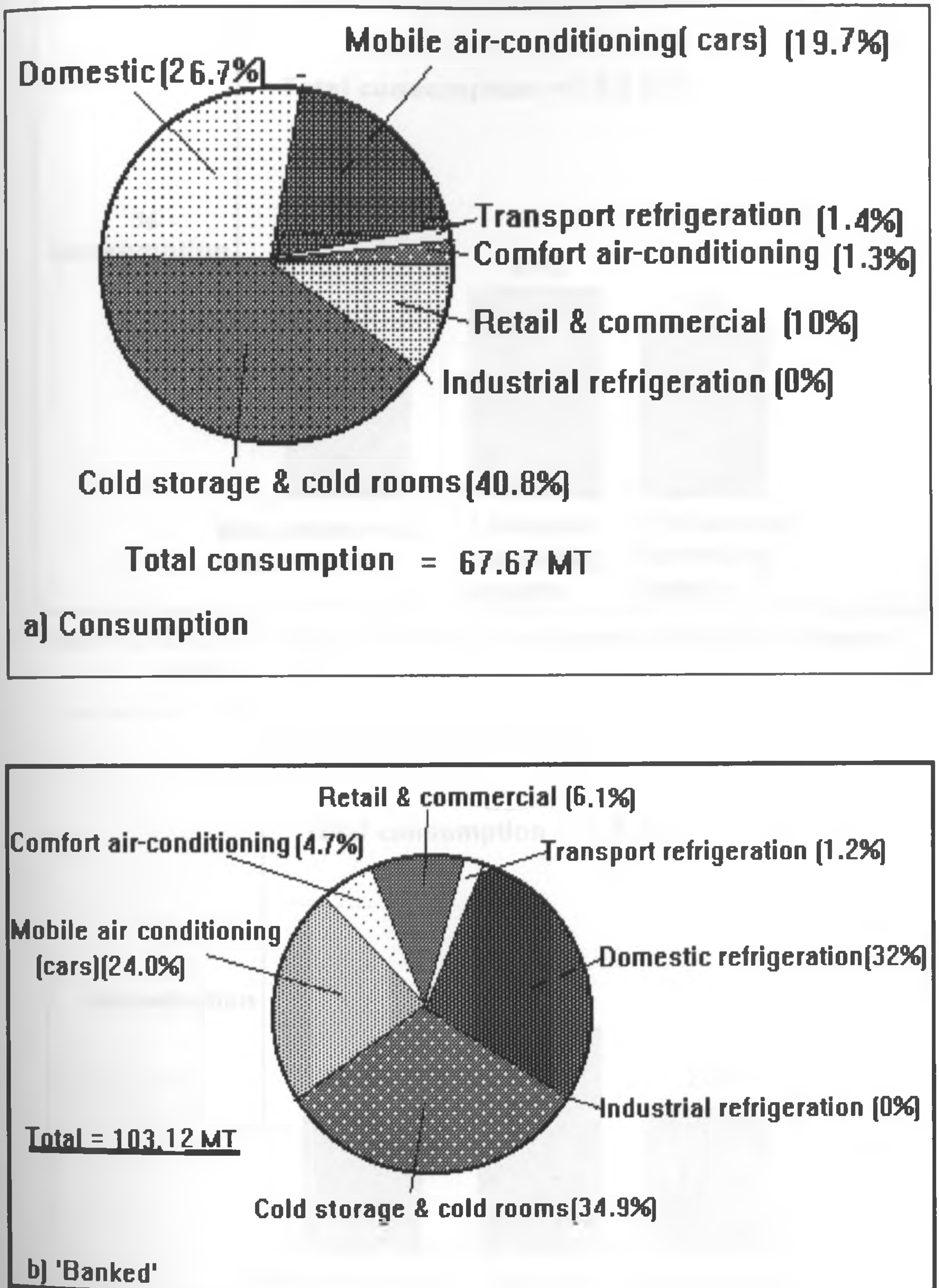


Figure 3.1: Consumption and 'Bank' of CFC-12 Used as Refrigerants in Kenya in 1995(present study).

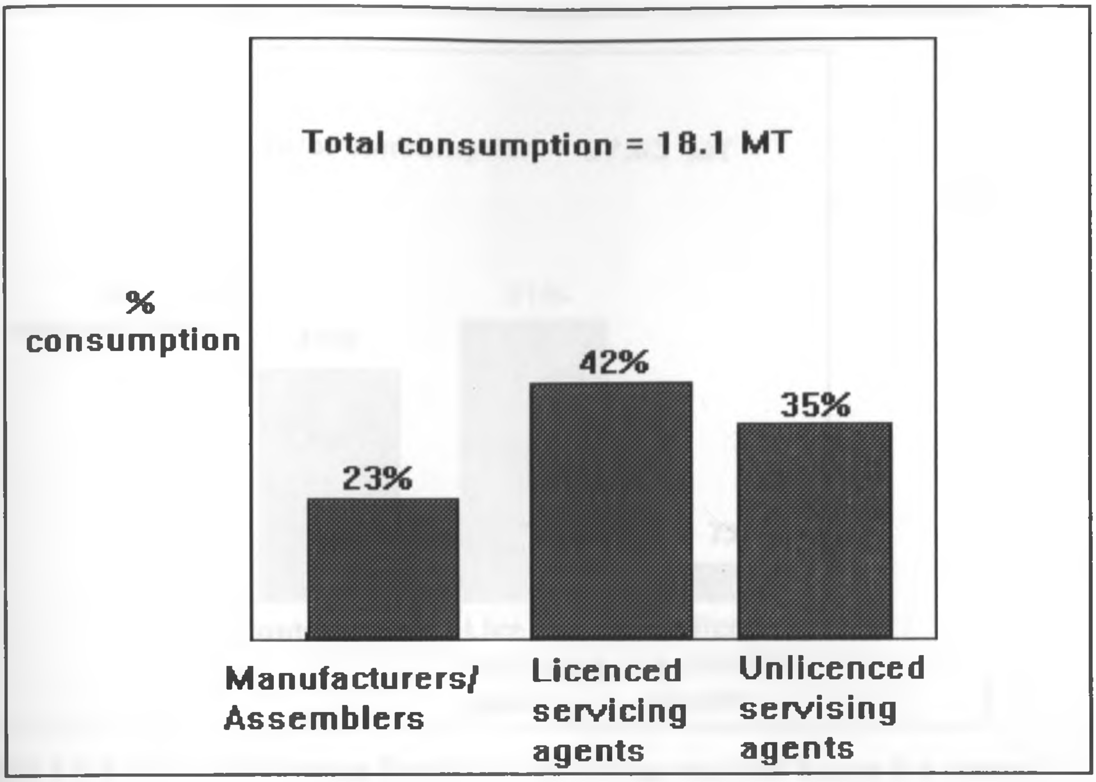


Figure 3.2 : CFC-12 Consumption Profile for the Domestic Refrigeration Sub-sector (1995)

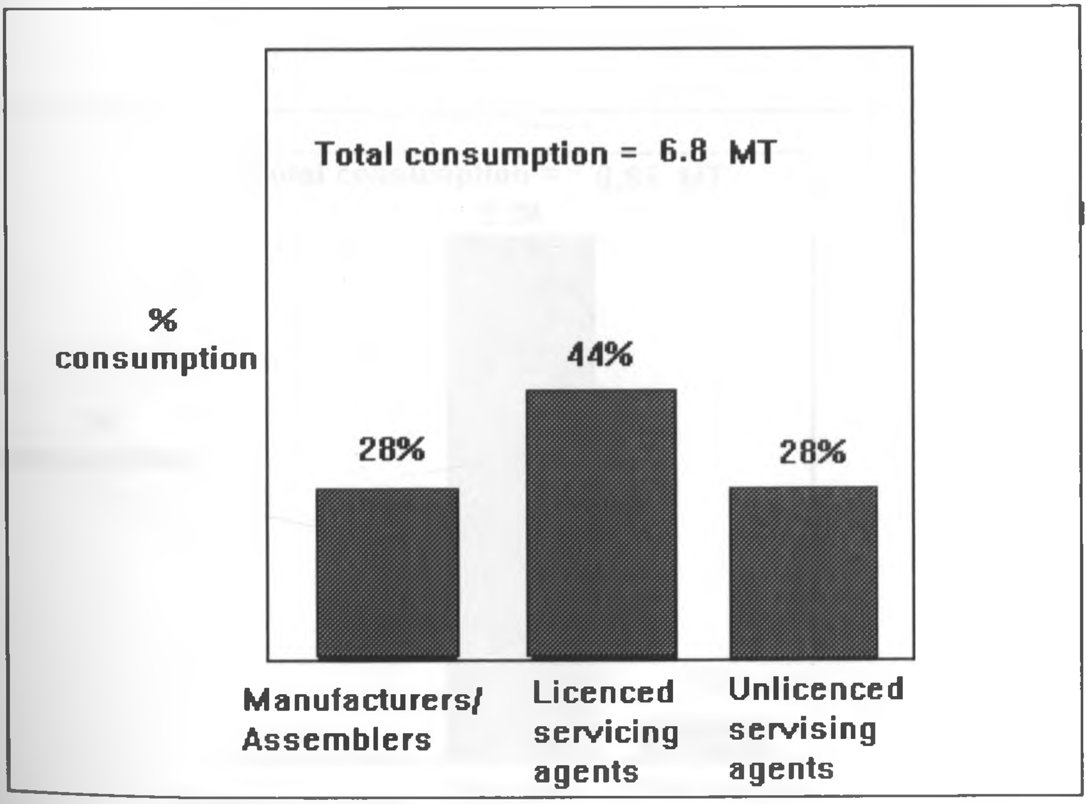


Figure 3.3 : CFC-12 Consumption Profile for the Retail and Commercial Sub-sector (1995)

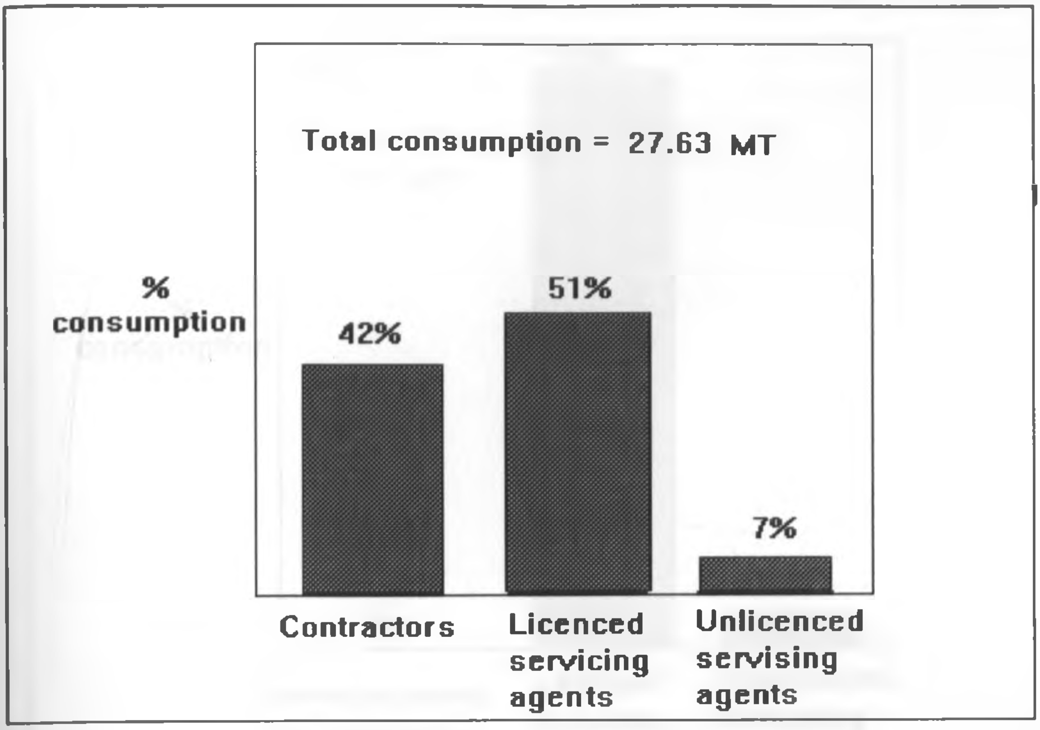


Figure 3.4: CFC-12 Consumption Profile for Cold Storage and Cold Rooms Sub- sector (1995)

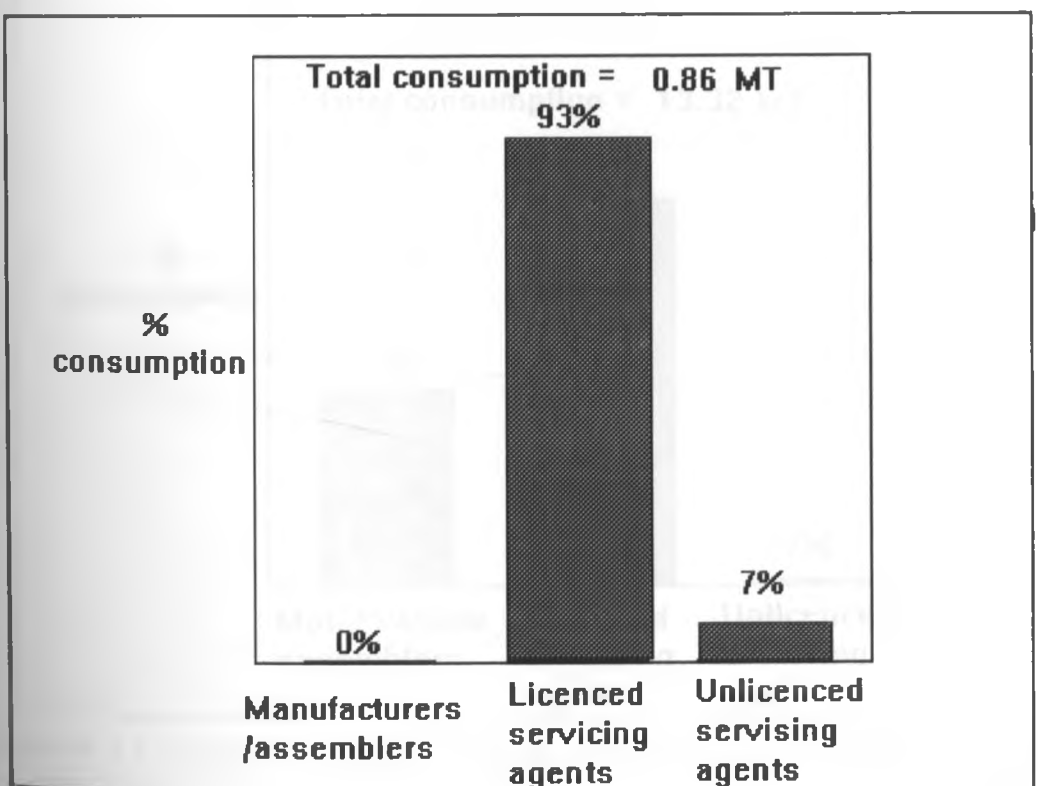


Figure 3.5 : CFC-12 Consumption Profile for Comfort Air-Conditioning Sub-sector(1995)

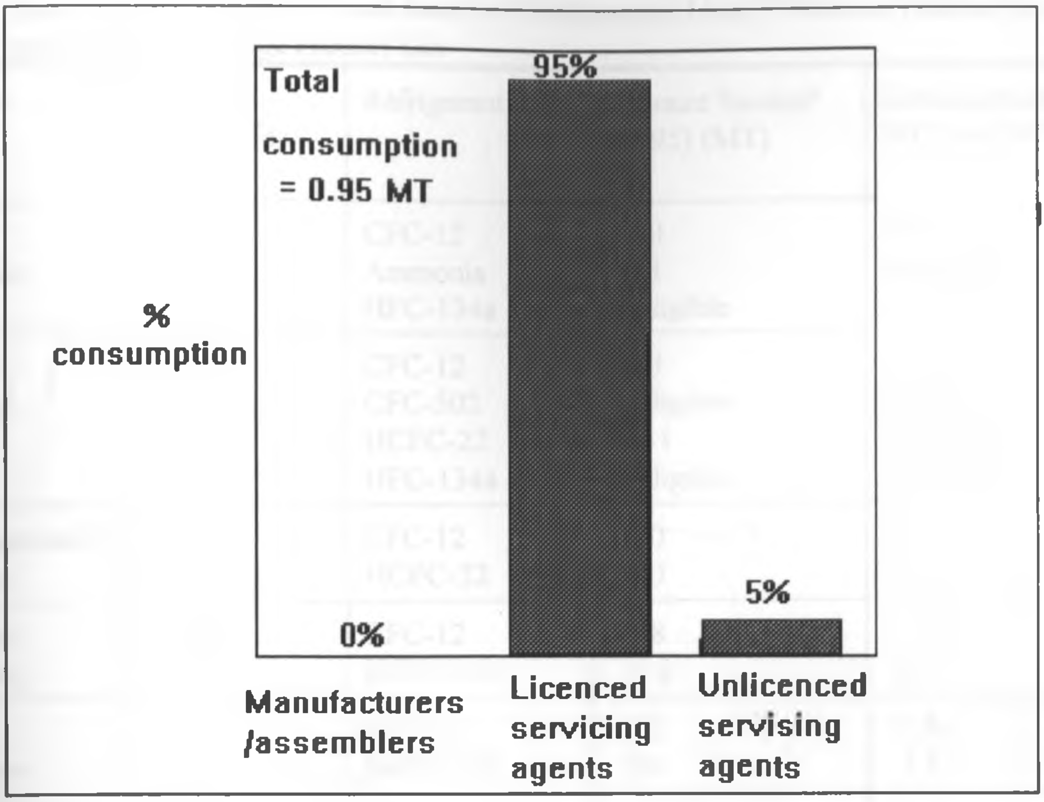


Figure 3.6 : CFC-12 Consumption Profile for Transport Refrigeration Sub-sector(1995)

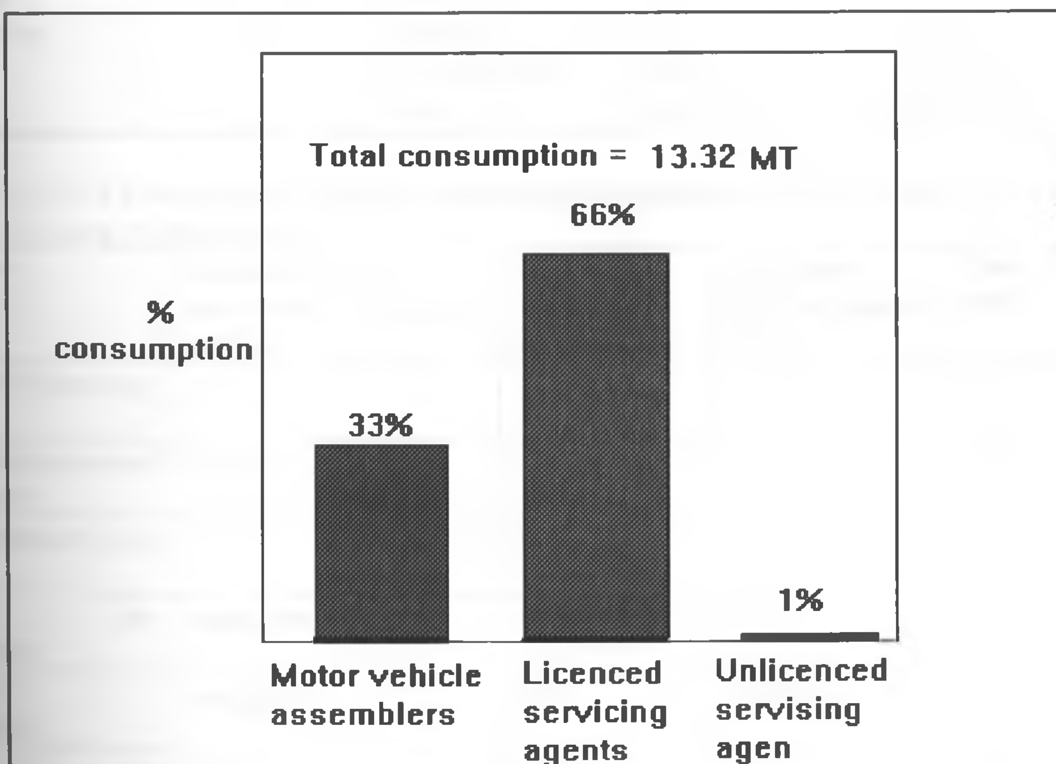


Figure 3.7 : CFC-12 Consumption Profile for Mobile Air-Conditioning Sub-sector (1995)

CFC-12 is not used in industrial refrigeration sub-sector

Table 3.12 : Summary of Consumption and 'Bank' of Refrigerants, Used Within the Product Sub-sector and the Average Product Life

sub-sector	Technical product life (years)	Refrigerant used	Amount 'banked' (1995) (MT)	Consumption (MT) in 1995
Domestic refrigeration	12 - 15	CFC-12 Ammonia HFC-134a	33.0 0.1 negligible	18.1 negligible *
Retail and commercial	12 - 15	CFC-12 CFC-502 HCFC-22 HFC-134a	6.3 negligible 0.1 negligible	6.8 negligible negligible negligible
Cold storage and cold rooms	10 - 15	CFC-12 HCFC-22	36.0 32.0	27.6 27.4
Comfort air conditioning	10 - 20	CFC-12 HCFC-22	4.8 6.8	0.9 0.4
Transport refrigeration	10 - 15	CFC-12 HCFC-22	1.2 2.0	1.0 1.5
Mobile air conditioning	8 - 12	CFC-12	21.8	13.3
Industrial refrigeration	15 - 20	HCFC-22 Ammonia Hydrocarbons Liquid CO_2	0.4 0.9 negligible negligible	0.2 0.8 negligible negligible

Table 3.13: CFC-12 Consumption Profile by Manufacturers/Assemblers, Licensed and Unlicensed Servicing Agents (1995)

Sub-sector	Manufacturers/ assemblers /contractors (MT)	Licensed servicing agents (MT)	Unlicensed servicing agents (MT)	Total (MT)
Domestic refrigeration	4.2	7.6	6.3	18.1
Retail and commercial refrigeration	1.9	3.0	1.9	6.8
Cold storage and cold rooms	11.6	14.1	1.9	27.6
Comfort air-conditioning	negligible	0.8	0.1	0.9
Transport refrigeration	negligible	0.9	negligible	0.9
Mobile air-conditioning	4.4	8.8	0.1	13.3
Industrial refrigeration	CFC-12 is not in this sub-sector			
Total (MT)	22.1	35.2	10.4	67.7
Total %	32.6	52.0	15.4	100

Table 3.14: Refrigerant Consumption in Kenya in 1995 (present study)

Refrigerant	Consumption (MT)	Consumption %
CFC-12	67.7	69.3
CFC-502	negligible	negligible
HCFC-22	29.6	30.3
Ammonia	0.4	0.4
HFC-134a	negligible	negligible
Hydrocarbons	negligible	negligible
Liquid CO_2	negligible	negligible
Total (MT)	97.7	100.0

Table 3.15: CFC-12 Consumption Profile Through New Charge, Recharging and Topping up (MT)

Sub-sector	New charge	Recharging	Topping up	Total
Domestic refrigeration	4.8	13.3	*	18.1
Retail and commercial refrigeration	0.6	3.1	3.1	6.8
Cold storage and cold rooms	11.7	6.5	9.5	27.6
Comfort air-conditioning	0.0	0.9	*	0.9
Transport refrigeration	0.0	0.6	0.4	1.0
Mobile air-conditioning	2.4	10.9	*	13.3
Industrial refrigeration	CFC-12 is not used in this sub-sector			
Total	19.6	35.2	12.9	67.7
Total %	29.4	51.6	19.0	100

* In these sub-sectors there is no topping up and equipment are just recharged fully is cases of leakage.

Table 3.16: Level of Wastage of CFC-12 in 1995 (MT)

Sub-sector	Total CFC-12 used	Actual amount that goes into the equipment		Level of wastage
		New charge	Servicing and topping up	
Domestic refrigeration	18.1	2.4	3.9	11.8
Retail and commercial refrigeration	6.8	0.3	3.1	3.4
Cold storage and cold rooms	27.6	3.9	5.3	18.4
Comfort air-conditioning	0.9	0.0	0.3	0.6
Transport refrigeration.	0.9	0.0	0.3	0.6
Mobile air-conditioning	13.3	1.2	5.4	6.7
Industrial refrigeration	0.0	0.0	0.0	0.0
Total (MT)	67.7	7.8	18.3	41.5
Total %	100	11.6	27.1	61.3

3.5 Awareness of the Montreal Protocol

3.5.1 General Introduction

The Montreal Protocol awareness to manufacturers/assemblers, business retailers , servicing agents and general public in each sub-sector was analysed during the comprehensive field survey using checklists. The actual responses are summarised here with in Figure 3.8 to Figure 3.12.

It was observed however that:-

- Unawareness is very high even among the Government of Kenya officials
- Most people do not associate CFC's with ozone depletion
- Most people see ozone depletion causes and effects as restricted to western countries

3.5.2 Montreal Protocol Awareness by Manufacturers/assemblers and Servicing Agents

The considerable majority (over 80%) of manufacturers/assemblers serving the refrigeration and air conditioning sectors are aware of the Montreal Protocol. Contrary to manufacturers/assemblers, there is considerable unawareness (over 60%) among the servicing agents. However, as indicated in Figure 3.9, many do not have an in depth knowledge of the Protocol. Figure 3.8 shows the actual response to the Protocol.

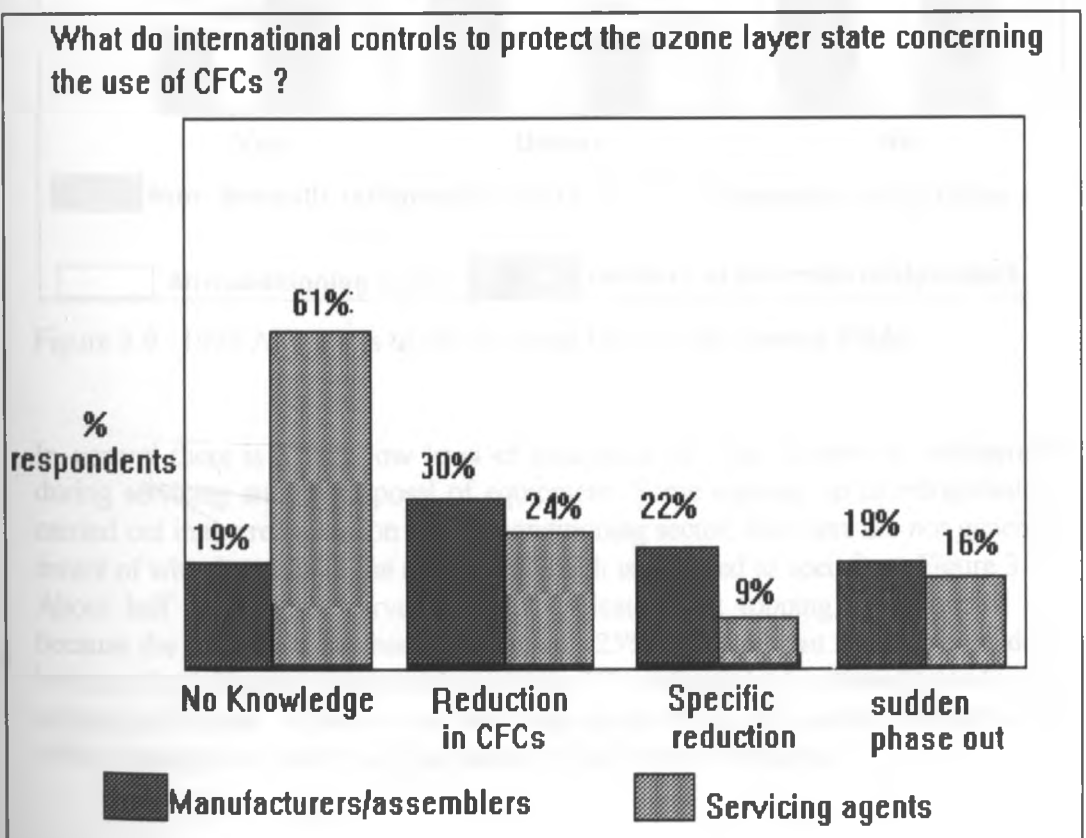


Figure 3.8 : 1995 Knowledge of the Montreal Protocol by Manufacturers/Assemblers and Servicing Agents

3.5.3 **Montreal Protocol Awareness by the General Public.**

Responses to our user checklist indicated that there is a general unawareness of controls to protect the ozone layer amongst domestic and non-domestic users of refrigeration and air conditioning equipment as illustrated in Figures 3.9. However, only five respondent out of 302 interviewed indicated knowledge of the Montreal Protocol and the actual controls.

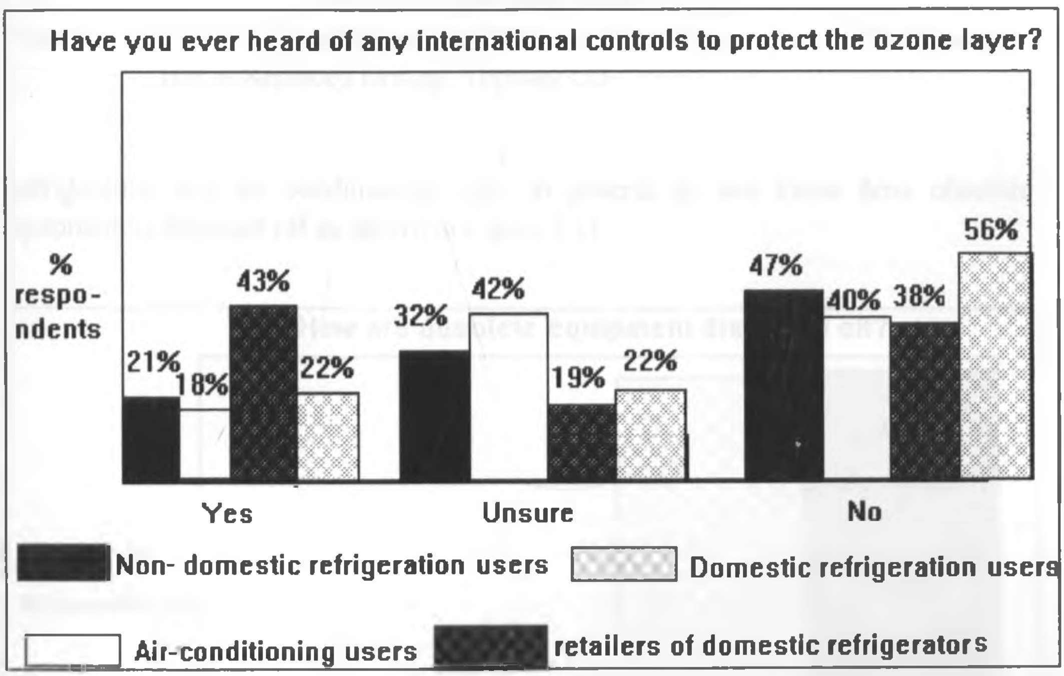


Figure 3.9 : 1995 Awareness of the Montreal Protocol by General Public.

In general there is a very low level of awareness of what happens to refrigerants during servicing and on disposal of equipment. Some topping up of refrigerants is carried out in the refrigeration and air conditioning sector, but users are not generally aware of what happens to the refrigerant which is replaced as seen from Figure 3.10. About half of our user survey sampled indicated that topping up is carried out because the refrigerant has been 'consumed'. 25% indicated that topping up is done because the refrigerant has leaked out while 25% indicated no knowledge as to why topping up is done. However only one respondent of the user survey sampled could offer an insight into what really happened to the replaced refrigerant.

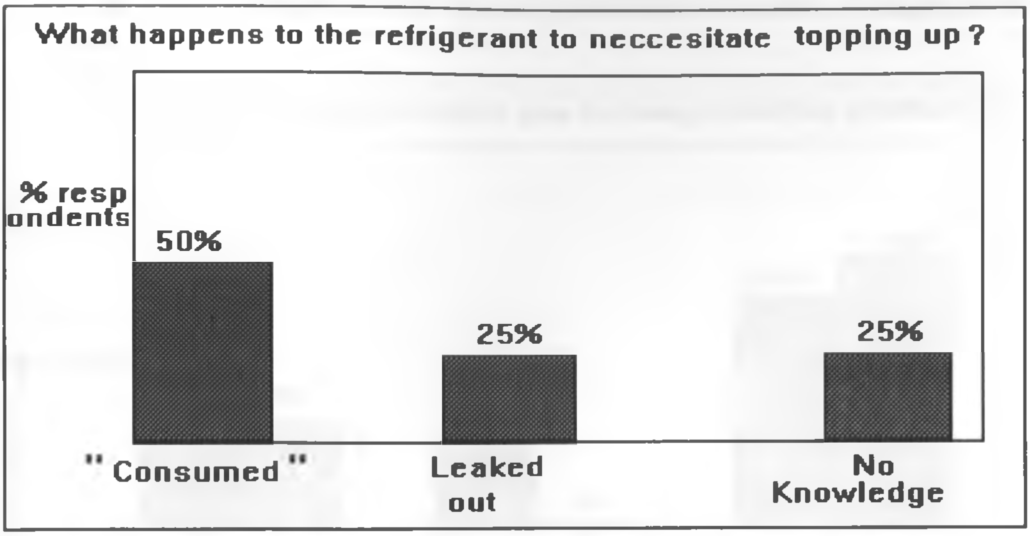


Figure 3.10: Knowledge by the General Public of What Happens to the Refrigerant that is Replaced During Topping Up.

Refrigeration and air conditioning users in general do not know how obsolete equipment is disposed off as shown in Figure 3.11.

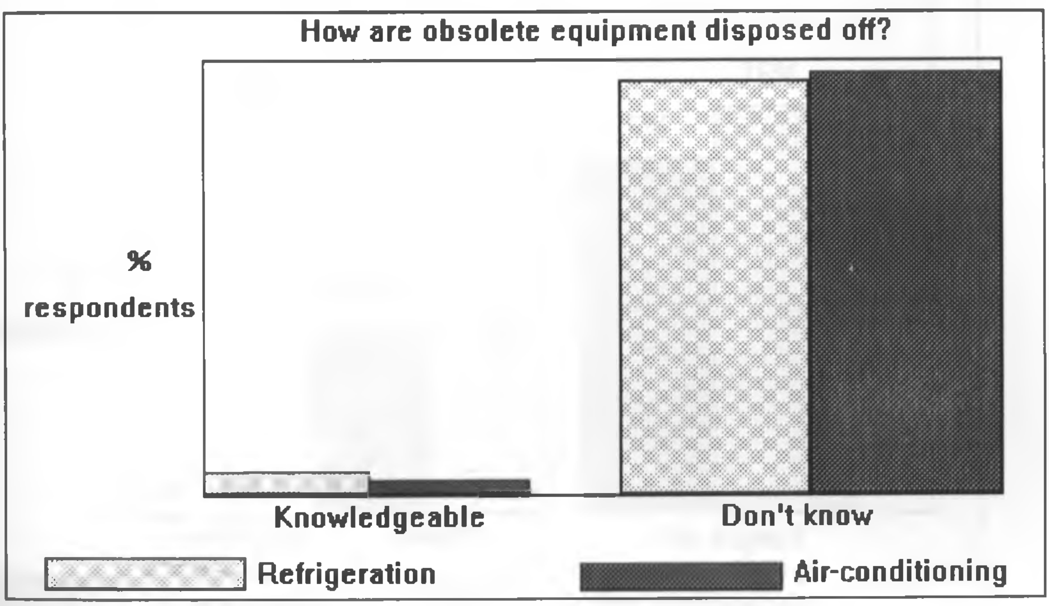


Figure 3.11 : Knowledge by the General Public on How Obsolete Equipment are Disposal Off.

3.5.4 **Effect of Montreal Protocol on Refrigeration Business**

a) **Servicing Agents**

Servicing agents operating in the refrigeration and air conditioning user sector envisage that Montreal Protocol will require a change in working practices although smaller agents (majority) tend to believe that there will be no impact. This is demonstrated by Figures 3.12a and 3.12b. However, the results from the user field survey indicate that few fears of a downturn in business amongst service agents.

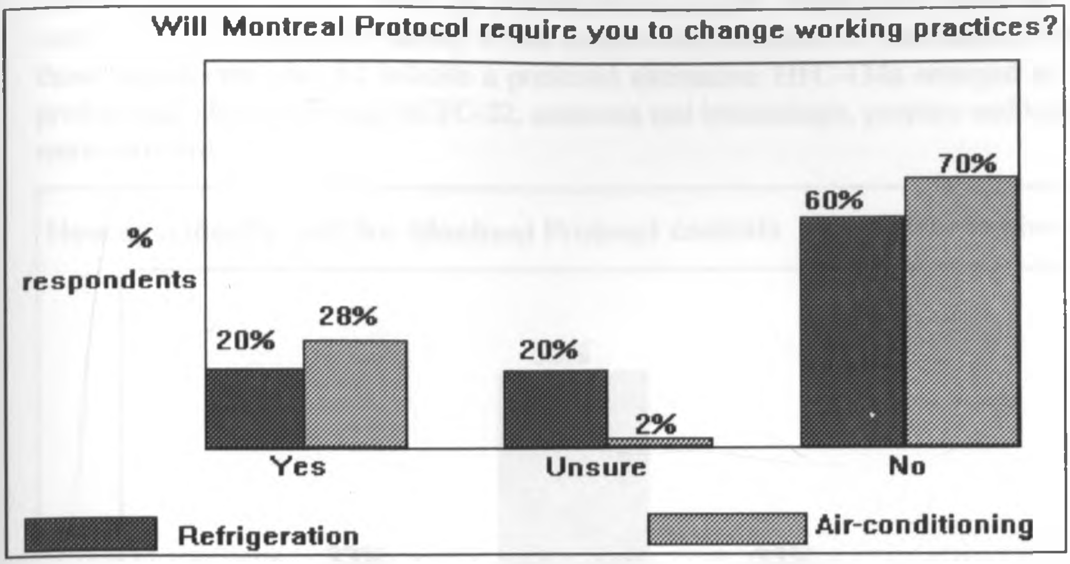


Figure 3.12 a: Effect of Montreal Protocol Controls on Business.

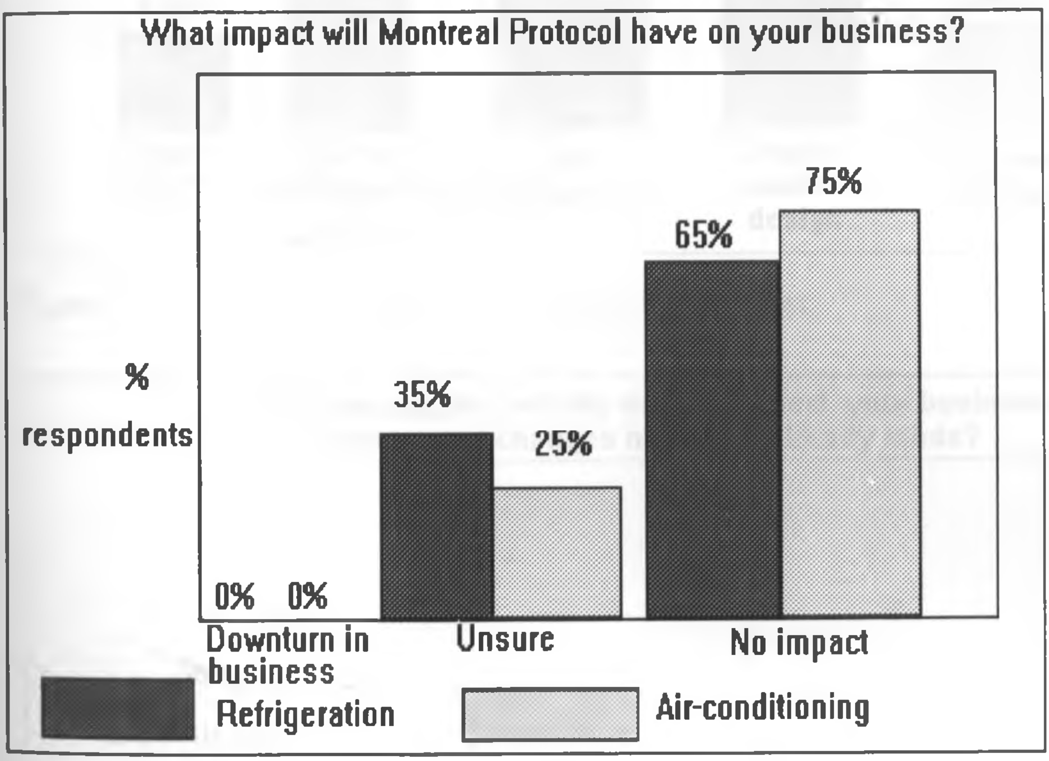


Figure 3.12 b : Effect of Montreal Protocol Controls on Business

b) **Manufacturers/assemblers**

In general there is a low level of knowledge of the details of the issues surrounding the use of CFCs amongst equipment users and there appears to be little pressure in the supply chain on manufacturers/assemblers to change products. Controls on CFCs will however, require manufacturer/assemblers to adopt alternative refrigerants and possibly also change product designs and manufacturing/assembling processes as indicated in Figure 3.12c. However changes are already beginning to be introduced as shown in

Figure 3.12d. Data from survey indicate that the implementation of change by manufacturers/assemblers are comparatively slow. This observation is supported by the manufacturers/assemblers views on alternatives to CFCs. Nearly two thirds of the respondents to our product survey in this section did not know of alternatives. From those respondents who did indicate a preferred alternative. HFC-134a emerged as the predominant choice although HCFC-22, ammonia and interestingly, propane and butane were also cited.

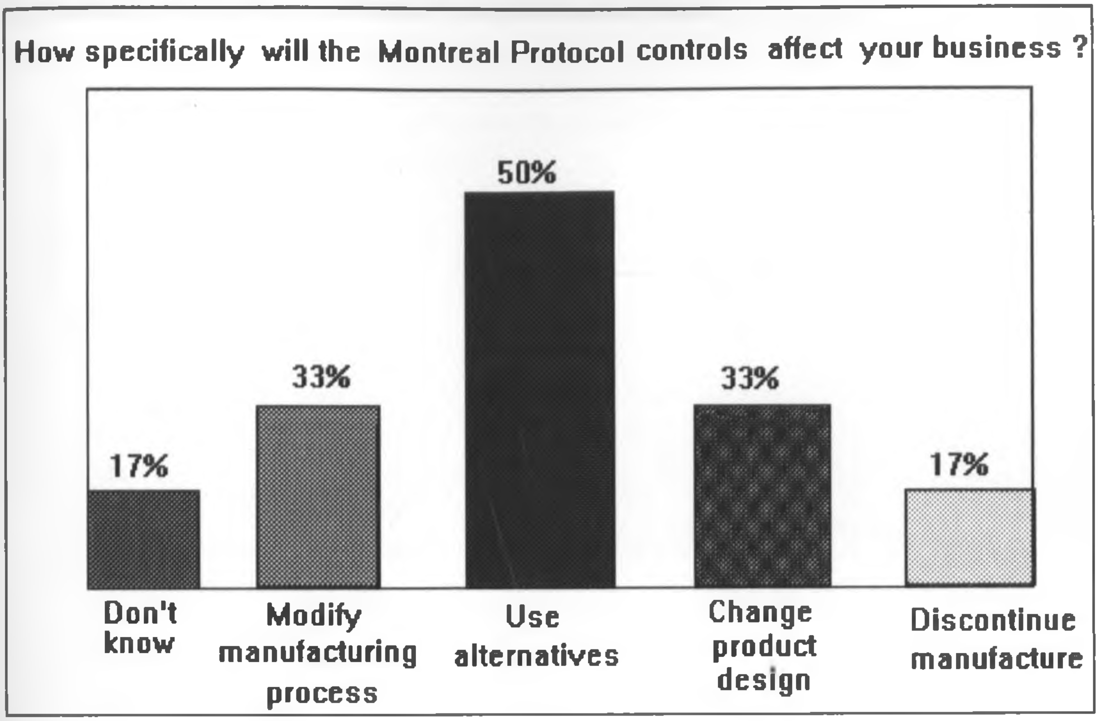


Figure 3.12 c : Effect of Montreal Protocol Controls on Business

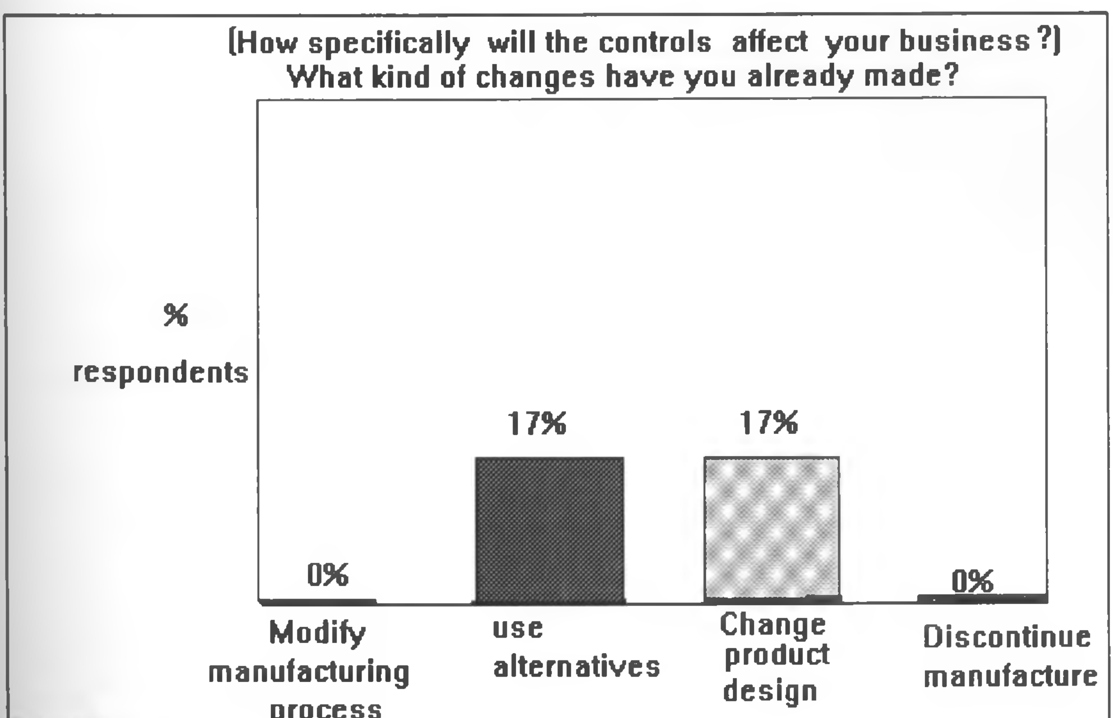


Figure 3.12 d : Effect of Montreal Protocol Controls on Business

c) **Contractors**

Information obtained from major refrigeration contractors in Nairobi and Mombasa indicates that the majority of them are aware of the changes taking place in the refrigeration industry and they have already initiated familiarisation and training, and cost implication analysis with their principals in North America, Europe and Asia. However, it should be noted that the change from CFC-12 to other refrigerants is purely motivated by business considerations and not by environmental issues.

CHAPTER FOUR

REFRIGERANTS AND TECHNOLOGIES IN CURRENT END USER

4.1 General Introduction

The present Chapter presents an overview of the characteristics and use of CFC and non-CFC substances used in refrigeration and air conditioning industry in Kenya. The following CFCs and non-CFCs refrigerants are discussed in details:-

- CFC-12(R-12)
- CFC-500(R-500)
- CFC-502(R-502)
- HCFC-22(R-22)
- HFC-134a(R-134a)
- Ammonia(R-717)
- Hydrocarbons

Various tables showing the most important characteristics and properties of these refrigerants are presented herein and include :-

- Physical and thermodynamic properties,
- Relative refrigerating capacity,
- Relative theoretical coefficient of performance (COP) at different operating conditions,
- Relative price and availability.
- Ozone depleting potential(ODP), global warming potential(GWP), toxicity and flammability

4.1.1 Refrigerant Properties

Table 4.1 provides summary information on different properties for current refrigerants in use in Kenya(1995). Detailed information is contained in the subsequent sections.

4.1 2 Relative Price of Refrigerants(1995)

To give an overview of the cost level for some refrigerants, both controlled substances and acceptable available alternatives, Table 4.1 summarises the prices relative to CFC-12. The cost values might change over time due to several factors such as:

- Increased production volumes
- Lower production cost for HFCs
- Reduced availability of CFCs

Table 4.1: Thermodynamic and Environmental Properties of CFC and non-CFC Refrigerants

Refrigerant	MTW	NBP (^0C)	T_c (^0C)	P_C (bar)	TLV (ppm)	LFL (%)	Δh_{comb} MJ/kg	ODP	GWP 100 years	Relative q_{vol} ($-30^0C/40^0C$)	COP ($-30^0C/40^0C$)	$t_{discharge}$ ($-30^0C/40^0C$)	$t_{Condensing}$ at 25 bar	Relative prices of refrigerants
CFC-12	120.91	-29.8	111.8	41.1	1000	none	-0.8	1.0	7,100	1.00	1.00	77	84.2	1.0
CFC-500	99.30	-33.8	105.5	44.3	1000	none	-	0.7	5,400	0.70	*	*	75.5	3.0 - 6.0
CFC-502	111.65	-46.6	82.2	40.8	1000	none	-	0.3	4,300	0.62	0.88	73	58.1	3.0 - 6.0
HCFC-22	86.47	-40.8	96.2	49.9	1000	none	2.2	0.055	1,600	0.59	1.00	108	61.4	1.0 - 1.5
HFC-134a	102.03	-26.1	101.1	40.6	1000	none	4.2	0	1,200	1.14	0.96	70	77.6	8.0 - 12.0
Ammonia	17.03	-33.3	132.3	113.3	25	15.0	22.5	0	0	0.58	1.02	96	58.2	1.8 - 3.0
Propane	44.10	-42.1	96.8	42.6	s.a	2.1	50.3	0	3	0.70	0.96	70	68.1	3.0 - 5.0
Iso-butane	58.13	-11.7	135.0	36.7	s.a	1.8	*	0	*	*	*	*	108	3.0 - 5.0
Butane	58.13	-0.4	152.1	38.0	s.a	1.5	*	0	*	*	*	*	124	3.0 - 5.0
CO_2	44.01	subl.	31.1	73.7	5000	none	-	0	1	*	*	*	*	0.1

MTW -Molar mass (k/g/kmol)
NBP - Normal boiling point (^0C)
T_c - Critical Temperature
P_c - Critical pressure
TLV - Threshold Limit Value (ppm by volume)
LFL - Lower Flammability Limit (% by volume in dry ambient air)
Δh_{comb}- Heat of combustion (MJ/kg).
ODP- Ozone depletion potential. ODP values are relative to CFC-11 (=1.0)
Price of CFC-12 (1995) Kshs/kg = 130 - 220

GWP- Global Warming Potential. GWP are relative to CO_2 and are given for 100 years integration time horizon.
sa - Simple asphyxiate
q_{vol} - Volumetric refrigerating capacity
COP - Relative theoretical coefficient of performance .Theoretical COP relative to CFC-12 (=1.0).
Relative value greater than 1.0 means better COP (in other words possibly higher energy efficiency and lower operating costs) than an identical application with CFC-12 as refrigerant.
$t_{discharge}$ - theoretical compressor discharge temperature
* - Data not available

4.2 Performance of CFC-Refrigerants

The following CFC refrigerants used in Kenya are discussed:

- CFC-12
- CFC-500
- CFC-502

Each of the above is discussed under :-
- Current application
- Characteristic properties

4.2.1 Performance of CFC-12 (R-12)

a) Current Applications of CFC-12

CFC-12(CCl_2F_2) accounted for roughly 69.3% of the total consumption of refrigerants in Kenya (Table 3.14). Current applications and sub-sectors with CFC-12 as refrigerant are presented in Table 4.2. Estimated share of CFC-12 in each sub-sector is given as a percent of the total refrigerant consumption.

Physical and thermodynamic data for CFC-12 is shown in Table 4.1

b) Characteristic Properties of CFC-12

CFC-12 is characterised by the following properties:
- Odourless, non-flammable and non-toxic. However, when CFC-12 is exposed to open fire it will decompose into toxic and irritating gases.
- Compatible with most metals, alloys and sealing materials (at low moisture levels).
- Fully miscible in mineral oil at all operating temperatures (high solubility).
- Low compressor discharge temperature compared to HCFC-22 and ammonia(Table 4.2). At evaporation and condensing temperature $-30^0C/+40^0C$, one-stage compression and reasonable compressor efficiency, the discharge temperature is about 77^0C for CFC-12, 108^0C for HCFC-22 and 96^0C for ammonia.
- Volumetric refrigerating capacity (kJ/m^3) is approximately 60% of that of HCFC-22 or ammonia, thereby demanding correspondingly larger compressors for larger mass flow rates required for same refrigeration effect.
- High molar mass makes CFC-12 suitable for centrifugal compressors. The disadvantage is relatively high pressure drop across valves in reciprocating compressors.

Table 4.2: Current Application of and Sub-sectors using CFC-12 as Refrigerant (1995)

area of application	% out of all refrigerants	remarks
Domestic Refrigeration	≈100%	The vast majority of refrigerators and freezers in the domestic sub-sector use CFC-12 as refrigerant.
Commercial and Retail Refrigeration	99%	Used both for medium and high-temperature refrigeration (above -15°C).
Cold Storage and Cold Rooms	50%	Used for both medium and high-temperature refrigeration (above -15°C).
Industrial Refrigeration	0%	CFC-12 is not used in industrial refrigeration sub-sector
Comfort air Conditioning	68%	Used in low refrigerating capacity air conditioners.
Transport Refrigeration	38%	Used in 1. Marine air conditioning and provision rooms for refrigeration in ships, 2. Main refrigerant in refrigerated containers, 3. Main refrigerant in refrigeration units on railcars, 4. Road transport refrigeration
Mobile air Conditioning	100%	Air conditioning in buses and coaches and saloon cars.

source : field survey

4.2.2 Performance of CFC-500 (R-500)

a) Current Application of CFC-500

CFC-500 is a non-flammable azeotropic mixture of 73.8% CFC-12 and 26.2% HFC-152a by weight(Table 2.2). In Kenya CFC-500 is used to a very small extent, though undocumented, in low temperature application (below -30°C), mainly due to slightly better COP and 10-15% higher volumetric refrigerant capacity compared to CFC-12.

Physical and thermodynamic data for R-500 is shown in Table 4.1

4.2.3 Performance of CFC-502(R-502)

a) Current Applications

CFC-502 is an azeotropic mixture of 48% HCFC-22 and 51.2% CFC-115 by weight. Current applications with R-502 as refrigerant are listed in Table 4.3

Table 4.3 Current Applications of R-502 as a Refrigerant.

AREA OF APPLICATION	% out of all refrigerants	REMARKS
Commercial Refrigeration	0.05%	Used at evaporator temperatures down to -45°C and in some medium-temperature systems(-15°C to 0°C)

source : Field study

Some physical and thermodynamic data for R-502 are listed in Table 4.1.

b) **Characteristic Properties of CFC-502**

CFC - 502 is characterised by the following properties .

- Colourless, almost odourless, non-flammable and non-toxic.
- Normal boiling point is 5.8°C lower than HCFC-22. R-502 is therefore primarily used at low evaporating temperatures down to -45°C.
- Large volumetric refrigerating capacity (kJ/m^3) at low temperatures compared to CFC-12, with the result that a relatively moderate compressor capacity is needed.
- lower COP than HCFC-22 and CFC-12.
- Lower discharge temperature than CFC-12, which may positively affect the compressor reliability. At evaporating/condensing temperatures -30°C/+40°C, one stage compression and a reasonable compressor efficiency, the discharge temperature is about 73°C with R-502, 77°C with CFC-12 and 108°C with HCFC-22 as refrigerant.
- Solubility in mineral oil is less than that of CFC-12 and HCFC-22 (low solubility).

4.3 Performance of Halogenated Refrigerants

Both HCFC and CFC refrigerants contain chlorine, but due to lower atmospheric chemical stability, HCFCs have much lower ODP, typically 2-5% that of CFC-12(Table 4.1). Moreover, the GWP factor is typically 20% that of CFC-12. Due to the agreements at the Copenhagen Meeting in 1992, the HCFCs are now controlled by Montreal Protocol. A 90% reduction of HCFCs is to be achieved before the year 2020, and a total phase out by the year 2030 (UNEP 1994a). HFCs are chlorine free and have ODP of zero. HFC-134a is currently a drop-in substitute for CFC-12. The following refrigerants are discussed in the present section:-

- HCFC-22 (R-22)
- HFC-134a (R-134a)

4.3.1 Performance of HCFC-22 (R-22)

a) **Current Applications of HCFC-22**

HCFC-22 ($CHClF_2$), in terms of mass, accounts for roughly 30% of the total consumption of refrigerants in Kenya in 1995(Table 3.14) . Current applications and sub-sectors using HCFC-22 as refrigerant are listed in Table 4.4. The estimated share of HCFC-22 in each sub-sector is given as a percentage of the total refrigerant consumption by the sub-sector.

Table 4.4: Current Applications of and Sub-sectors using with HCFC-22 as a Refrigerant(1995).

area of application	**% out of all refrigerants**	**remarks**
Domestic Refrigeration	0%	HCFC-22 is not used in this sub-sector
Commercial and retail refrigeration	1.4%	Used at evaporator temperatures down to -37°C
Comfort Air Conditioning	32%	Used mostly in units with cooling capacity from 2 kW to 420kW.
Cold Storage and Cold rooms	50%	Used at evapcrator temperatures down to -37°C
Transport Refrigeration	62%	Used in 1. Marine air conditioning 2. Provision room refrigeration in ships. 3. Central cargo refrigeration plants. 4. Fish freezers and fishing boat refrigerated storage. 5. Refrigerated railcars. 6. Trailer units within road transport refrigeration.
Mobile Air Conditioning	0%	HCFC-22 is not used in this sub-sector
Industrial Refrigeration	28%	HCFC-22 and ammonia, are the most frequently used refrigerant in industrial refrigeration sub-sector.

Some physical and Thermodynamic data for HCFC-22 are listed in Table 4.1.

b) **<u>Characteristic Properties of HCFC-22</u>**

HCFC-22 is characterised by the following properties:

- Colourless, almost odourless, non-flammable and non-toxic. However, when HCFC-22 is exposed to open fire it will decompose into toxic and irritating gases.
- Compatible to most metals, alloys and sealing material (as CFC-12). When retrofitting from CFCs it is necessary to change to recommended O-rings and other gasket materials, thus avoiding swelling and refrigerant leakage(see Chapter Six).
- Not fully miscible in mineral lubricating oil at all operating temperatures (medium solubility).

- Higher system pressure than for CFC-12. At 40°C condensing temperature HCFC-22 and CFC-12 have saturation pressures of 15.5 bar and 9.6 bar, respectively (Prestcold, 1994).
- Volumetric refrigeration capacity (kJ/m^3) is approximately the same as with ammonia and 40% higher than that of CFCs-12. Therefore, a moderate compressor capacity is needed.
- Medium molar mass makes HCFC-22 suitable for centrifugal compressors.

4.3.2 Performance of HFC-134a (R-134a)

a) General Aspects and Current Application of HFC-134a

HFC-134a (CF_3CH_2F) is quite similar to CFC-12 regarding thermodynamic and physical properties, and the phase-out of CFC-12 in applications operated at medium and high evaporating temperatures (above -15°C)is strongly related to the availability of and experience with this refrigerant. These applications include mobile air conditioning and refrigerating equipment, some stationary air conditioning equipment (air and water cooled) and domestic appliances and heat pumps. However, the application of HFC-134a is not a realistic option in low applications (below -20°C), because of its relatively poor energy efficiency and low volumetric refrigerating capacity at low temperatures compared to CFC-12.

The most important change in application of HFC-134 is the requirement for new synthetic lubricants. HFC-134a is immiscible with conventional lubricants used with CFC-12, such as mineral oils and alkylbenzenes. Nearly all large compressor manufacturers have recommended the use of HFC-134a with polyol ester lubricants(UNEP, 1994b).

Current application and sub-sectors using HFC-134a as a refrigerant are listed in Table 4.5. By 1995 there were no reported consumption of HFC-134a. The estimated share of HFC-134a in each sub-sector is given from the refrigerant 'banked'.

Table 4.5: Current Application of and Sub-sectors using with HFC-134a as Refrigerant('banked').

area of application	% out of all refrigerants	remarks
Domestic Refrigeration	0.03%	Used at evaporator temperatures down to -20°C
Commercial Refrigeration	0.07%	Temperature range of -5°C to -20°C

Some physical and thermodynamic data for HFC-134a are listed in Table 4.1

b) Characteristic Properties of HFC-134a

HFC-134a is characterised by the following properties:

- Colourless, almost odourless, non-flammable and extremely low toxicity.

- Compatible to most metals, alloys and sealing materials (as CFC-12).
- Low compressor discharge temperature lower than CFC-12. At evaporating/condensing temperature - 30^0C / +40^0C and a reasonable compressor efficiency, the discharge temperature is approximately 70^0C with HFC-134a and 77% with CFC-12. At high evaporating temperatures and small pressure rations(-5^0C / +40^0C), the compressor efficiency and COP of refrigerants system will be almost the same as CFC-12. At low evaporating temperatures (-30°C) HFC-134a will be less efficient than CFC-12. This is due to increased throttling losses and steeper saturation pressure curve which cause increased pressure ratio at lower compressor efficiency(Table 4.2).

To improve the COP, it is advisable to reduce the temperature difference over the throttling valve by installing a suction gas heat exchanger and an additional air or water cooled heat exchanger, to subcool the condensate from the condenser. In some new plants, heat exchanger surfaces in evaporators and condensers are been designed (Prestcold, 1993).

- High molar mass makes HFC-134a suitable for centrifugal compressors
- For low temperature purposes(below -20^0C), 2-stage compression can be used to a larger extent with the HFC-134a. Energy efficiency will be improved, typically 20-3-%, but the initial costs may increase 10-20%.
- The volumetric refrigerating capacity (kJ/m^3) of HFC-134a is typically 2-3% lower than for CFC-12 at +10^0C evaporating temperature and 15-20% lower at -30^0C, i.e. higher compressor capacity is needed, especially in the low temperature range. This is due to lower saturation pressure and vapour density at temperatures below +20^0C. The difference in saturation pressure between HFC-134a and CFC-12 is rapidly increased with decreasing temperatures. In addition, higher pressure ratio than CFC-12, especially at low temperatures, gives reduced volumetric compressor efficiency.
- The properties of HFC-134a makes it more suitable in medium-to high temperature(above -15^0C) cooling purposes than for low temperature(below -20^0C) applications.

4.4 Performance of Natural Refrigerants

Natural refrigerants are substances present naturally in the biosphere, and which are harmless to the global environment (zero ODP and very low GWP). Examples of natural refrigerants are air, water, carbon dioxide, nitrogen, the noble gases (helium and argon), hydrocarbons and ammonia. Some of the natural refrigerants have local environmental effects such as flammability and toxicity, but this are aspects which can be satisfactory handled by applying proper system design and suitable operating and servicing routines.

The following natural refrigerants used in Kenya are discussed:-

•Ammonia(NH_3)

•Hydrocarbons (propane, iso-butane, butane)

4.4.1 Performance of Ammonia (R-717)

a) General Aspects and Current Applications of R-717

Ammonia (NH_3) has been successfully applied world-wide as a refrigerant for more than a century. In some countries, ammonia has been the leading refrigerant within medium and large chilling, freezing and cold storage plants(UNEP 1993(ii)). Codes, regulations and laws have been developed mainly to deal with the toxic, and to some extent flammable characteristics of ammonia, which if followed provides a high degree of safety.
Due to safety considerations (toxicity and flammability) the use of ammonia has now been limited to large industrial applications. Today, however, increased research and development activities in many countries, focus on smaller Ammonia systems and improved safety. Work is also being initiated in the fields of hermetic compressor design, reduced refrigerant charge, insulation features, indirect systems and leakage detection(Brendeng, 1990, Haua, 1990, Nesje, 1994, Moller, 1994).

Recommended practices limit the use of ammonia in public buildings to systems that utilises a secondary heat transfer fluid (brine system). This will confine the ammonia to the machine room where alarm and ventilating devices can ensure the necessary safety.

Current applications and sub-sectors with ammonia as refrigerant in Kenya are listed in Table 4.6.

Table 4.6 Current Applications of and Sub-sectors using Ammonia as a Refrigerant('banked')

area of application	% out of all refrigerants	remarks
Domestic Refrigeration	≈0.3%	In places where there is no electricity Ammonia is used in the absorption cycle domestic refrigerators.
Industrial Refrigeration	66%	Ammonia together with HCFC-22 are the leading refrigerant in industrial refrigeration.

Some physical and thermodynamic data for ammonia are listed in Table 4.1 .

b) Characteristic Properties of Ammonia

Ammonia is characterised by the following properties:

- Proven, long term refrigerant without global environmental drawbacks (zero ODP and GWP of zero).
- Refrigerant price approximately 1/4 of the current price(1995) of HFC-134a.

- Excellent thermodynamic properties. More efficient than halocarbons with respect to theoretical COP and component efficiencies(Table 4.1). At evaporating / condensing temperature -30^{0}C/40^{0}C the theoretical ammonia cycle is approximately 2% better than CFC-12 and 6% better than HFC-134a. The difference in COP increases with increasing condensing temperature.
- Volumetric refrigerating capacity (kJ/m^3) is approximately the same as HCFC-22 and 40% higher than with CFC-12 and HFC-134a(Table 4.1).
- Superior transport properties compared to the halocarbons.
- High compression discharge temperature and pressure ratio (compared to CFC-12). At low evaporating temperatures two-stage compression is necessary.
- Non-compatible with copper and copper alloys when moisture is present. Therefore all pipes, valves, fittings etc. have to be made of compatible materials. Ammonia retrofitting is limited to systems made of steel and possibly with aluminium parts. Because of incompatibility to motor windings only open compressors are used in vapour compression ammonia cycle. However hermetic compressors compatible with ammonia have been introduced recently(UNEP 1994).
- Non-miscible with mineral oil. Requires efficient oil separator and oil return system. It can be used together with normal lubricating oils (inexpensive mineral oils). Lubricants that are soluble in ammonia are available, however.
- Less suitable in centrifugal compressors because of relatively low molar mass.
- Toxic with a strong, pungent odour. A TLV of 25 ppm is common, while the lowest reported fatal concentration is about 5,000 ppm. The characteristic odour, which is recognisable at very low concentrations (less than 10 ppm), can provide excellent opportunities for timely repair of leaks and will force the personnel to leave the plant before damaging or threatening concentration are reached.
- As ammonia is expected to be an even more important refrigerant in the future, it is required to further improve quality in design, installation and operation of systems (authorisation of installer firms, certification of operational personnel), and public information.

System safety requires that equipment and machine room is designed according to national and international recommended standards. Details on such design criteria are given in (ASHRAE, 1983, 1985, 1987b , IIAR, 1984,). Refrigerant change, application area etc. will determine the necessary safeguards to ensure safety. Examples of such safeguards are:

1. Different kinds of personal protective equipment.
2. To maintain system security in case of power failure, an additional passive ventilating system should be used. Since ammonia is much lighter than air, an ordinary ventilation duct which leads to the atmosphere may be sufficient.
3. For some applications, e.g. air conditioning or retail refrigeration system design may be necessary to prevent ammonia leakage to public places which could cause panic and dangerous situations. Examples of such design are:
    - enclose the plant in a reasonable gas tight room or casing

- design aggregates for low refrigerant charge, for example by using hermetic compressors and plate heat exchangers as evaporator and condenser.
- Indirect distribution system (brine system)

- Gas detectors which activate:
  - Internal/external alarm systems
  - emergency shutdown system for compressor etc.
  - Sectioning of different parts of the system by automatic valves to limit refrigerant leak.
  - Water vessel connected to the ammonia pipe line system for absorption of refrigerant in case of serious leak.

- Flammable and explosive. Because of strong odour it is unlikely that such high concentration can build up to explode and very few accidents due to fire have actually been reported (IIAR,1984).

4.4.2 Performance Of Hydrocarbons

a) General Aspect and Current Applications of Hydrocarbons

Hydrocarbons are considered to be important refrigerants for the future, replacing R-502, HCFC-22 and in some cases also CFC-12. The hydrocarbons may be used as pure refrigerants (one component) or as components in binary and ternary blends. Some important hydrocarbon refrigerants are presented in Table 4.7 .

Table 4.7 Hydrocarbons in Current End Use as Refrigerants.

refrigerant	chemical formula	denotation	possible replacement for:
Propane	C_3H_8	HC-290	CFC-12 and R-502
Iso-butane	$CH(CH_3)_3$	HC-600a	CFC-12 (higher temp. region, above -10°C)
Butane	C_4H_{10}	HC-600	CFC-144 (low temp. region, below -20°C)

Hydrocarbons (HCs), are long term well known refrigerants, and in Kenya are used within industries handling flammables, such as the petrochemicals. Both iso-butane and butane are used as components in binary blends (propane/iso-butane). Hydrocarbons are long term refrigerants without global environmental drawbacks (ODP and GWP are zero), and they are available.

Propane, iso-butane, butane and other hydrocarbons, which are flammable, have excellent thermodynamic properties. Propane is widely used in larger refrigerating plants within the petrochemical, oil and gas industry. Except for this application, due to their flammability ,the hydrocarbons should only be used in smaller hermetic units with low refrigerant charge, such as domestic and commercial refrigerators and freezers. There are in developed countries some refrigerators on the market, using pure iso-butane or mixtures of hydrocarbons (propane/butane and propane/iso-butane) as refrigerants. Hydrocarbons are being introduced in other application areas as well(Friends of the earth, 1993. Granryd, 1993, Haukas, 1992 a,b, James, 1992, Treadwell, 1991, Proceedings from IIR in Hanover, 1994).

Some physical and thermodynamic data for propane, iso-butane, and butane are listed in Table 4.1.

b) **Characteristic Properties of Hydrocarbons**

Hydrocarbons are characterised by the following properties:

- Highly flammable. Maximum explosion pressure for all three is 7.1 bar. The LFL by volume in dry ambient air and the ignition temperatures are shown in Table 4.8.

Table 4.8: LFL by Volume in Dry Air and the Ignition Temperature of Propane, Iso-butane and Butane

Refrigerant	LFL	Ignition temperature
Propane	2.1%	470^0C
Iso-butane	1.8%	460^0C
Butane	1.5%	365^0C

- Colourless, almost odourless and non-toxic (simple asphyxiates).
- Compatible with most metals, alloys and sealing materials.
- High solubility in normal mineral lubrication oils at all temperatures.
- Propane, iso-butane and butane have similar liquid density and thermal conductivity, which means that the size of liquid pipes, heat exchanger surfaces (evaporator/condenser) etc. will be similar.
- Transport properties are better than for CFCs, but not as good as for ammonia. Due to low molar mass and high thermal conductivity, heat exchanger surface and dimensions on piping and other components can be reduced compared to plants working on CFC-12.
- Propane has low compressor discharge temperature than CFC-12. This may positively affect the compressor reliability. At evaporating/condensing temperature -30^0C/+40^0C, the discharge temperature is about 70^0C for propane and 77^0C for CFC-12.
- For propane the volumetric refrigerating capacity (kJ/m^3) is approximately 35-50% higher than CFC-12, depending on the operating conditions. Iso-butane and butane have approximately 50% and 30% the volumetric refrigerating capacity of CFC-12, respectively.
- In a practical process propane will give approximately the same COP as CFC-12.
- Propane is an excellent refrigerant for centrifugal compressor because of its near ideal molar mass.

CHAPTER FIVE

EQUIPMENT AND TECHNOLOGY IN CURRENT END USER

5.1 General Introduction

In Kenya the present industrial infrastructure and manufacture /assembly /installation of refrigeration equipment is entirely dependent on import of components as well as imports of the refrigerants as was seen in Chapter Three. Hence the substitution of CFC-based equipment with non-CFC based equipment would take place in line with the events occurring in developed countries. However economic pressures would motivate extended use of existing CFC-based equipment resulting in continued requirement of CFCs for servicing.

The total consumption of CFCs includes substantial quantities used for flushing, cleaning and leak detection during assembly and servicing of the refrigeration and air-conditioning equipment. Charging , recharging and topping up of systems involves atmospheric emission of CFCs and wastage of as much as 3 times the ideal amount of CFCs required. This is due to poor charging and servicing methods.

From Table 3.15 and Table 3.16 the total quantity of CFC-12 used for recharging and topping up is 71%(48.1 MT) of the total consumption of CFC-12 in 1995. Out of the total amount consumed 61% (41.5 MT) is the quantity of CFC-12 wasted during servicing in 1995. This quantity can be substantially reduced by introduction of better practices that would reduce wastage and by introduction of refrigerant conservation measures.

The present Chapter therefore presents:-

- An overview of refrigeration and air conditioning equipment in current end user
- Feasible refrigerant wastage reduction measures

Economics of collection, recovery and recycling is dealt with in Chapter Six.

The types of refrigerants used in Kenya as identified in Chapter Three and the sub-sectors they are used in are summarised in Table 5.1.

Table 5.1 : Types of Refrigerants and Sub-sectors Using the Refrigerants in Kenya(1995).

Refrigerant	Sub-sector using
CFC-12	• domestic refrigeration • retail and commercial refrigeration • cold storage & cold rooms • comfort air-conditioning • transport refrigeration • mobile air-conditioning
HCFC-22	• retail and commercial refrigeration • cold storage & cold rooms • comfort air-conditioning • transport refrigeration • industrial refrigeration
CFC-500 and CFC-502	• retail and commercial refrigeration
HFC-134a	• domestic refrigeration • retail and commercial refrigeration
Ammonia	• domestic refrigeration • industrial refrigeration
Hydrocarbons	• industrial refrigeration
Liquid carbon dioxide	• industrial refrigeration

Evaporative cooling adopting absorption processes makes only a small part of the existing equipment as shown from Table 3.12. Most applications use CFCs and HCFCs with vapour compression cycle which provides the most energy efficient processes.

Equipment and technology in current end user is represented herein per sub-sector. Refrigerant waste reduction measures in each of the sub-sector is described, where appropriate, under the following period of the equipment:-

- during manufacture/assembly/installation
- during usage
- during servicing
- during disposal

5.2 Domestic Refrigeration

5.2.1 General Introduction

Many domestic refrigerator users have little or no knowledge of how a refrigerator works. Technicians, both skilled and unskilled, tend to exploit this ignorance by the general public in that even if the problem in a unit does not warrant recharging, they go round the problem to create situation whereby they will recharge the unit since this will be more paying. This leads to unnecessary usage of refrigerant that would have otherwise been conserved for a needy case.

Publicity campaigns, to increase the awareness of Montreal Protocol with its implications and how to correctly use refrigerators, and installation of proper protection devices such as voltage stabilisers, correctly sized fuses etc., on domestic refrigerators would reduce the number of refrigerators recharged per year. This would result in a decline of CFC-12 demand for recharge even with the existing recharge wastage level of 3 times the optimum amount of CFC-12 required per charge.

Improvement of charging, vacuuming and better servicing practice techniques will reduce the wastage level, thus further reducing the demand for CFC-12 for charging and recharging.

The small number of users who do not heed the call to install voltage fluctuation stabilisers, correctly sized fuses, eliminate vibration(see Section 2.7 herein) and correctly use refrigerators will find themselves paying higher cost for recharging with either recycled CFC-12 or retrofit with HFC- 134a once CFC-12 is not readily available.

It is therefore considered that the domestic refrigeration end user benefits from the CFCs consumption reduction measures would be :

- improvement of the global environment
- improvement in quality of refrigerators, servicing etc.
- reduced frequency of refrigerator breakdown and cost of repairs/replacement
- consumer education
- consumer protection
- reduction in transport costs associated with repair of refrigerators
- improved living standards

The Objectives of the proposed remedial measures will be to :

a) Reduce demand of CFC-12 for recharging
b) Increase life-span of refrigerators
c) Provide general education to general public
d) Provide general awareness of environmental issues and in particular CFCs and their effect on social-economics affairs of individuals and the Nation.

e) Provide training and technology transfer
f) Improve manufacturing/assembling standards, quality control .
g) Improve living standards of the public

5.2.2 Current Equipment Technology

Domestic refrigeration includes households freezers and refrigerators and is described as small units, with an average charge of 120 grams. The vapour compression cycle is used in most units and operate with CFC-12 as a refrigerant. There also exist a few absorption refrigeration cycle domestic refrigerators operated with ammonia as a refrigerant.

Domestic refrigerators fall in four categories namely:-

- One door refrigerators, which contain a very small freezer compartment and ranges on size from 370 litres (4 cuft) to 930 litres (10cuft) capacity. The stabilised air temperature in the small freezer compartment ranges between -8°C and - 12°C while in the fridge compartment temperature ranges between 2°C and 12°C.

- Larder refrigerators which contain no freezer compartment and whose stabilised air temperature within the compartment ranges between 0°C to 10°C. Larder refrigerators range from 550 litres (6 cuft) to 1100 litres (12 cuft).

- Two door fridge/ freezer with the fridge compartment ranging from 6 cuft to 10cuft and the freezer compartment ranging from 2 cuft to 6 cuft. The stabilised air temperatures in this units are 2°C to 12°C for the fridge compartment and -18°C to -24°C for the freezer compartment.

- Freezer, either upright or chest type ranging from 5 cuft to 25 cuft and whose stabilised air temperature ranges from -18°C to -24°C.

5 2 3 Refrigerant Conservation Technology

a) During Manufacture/Assembly

CFCs and other refrigerants emissions can be minimised in this sub-sector during manufacture/assembly through the adoption of various remedial procedures as shown in Table 5.2.

Table 5.2: Proposed Remedial Measures to CFCs Emissions During Manufacture/assembly of Domestic Refrigerators and Freezers.

process	present scenario	proposed remedy
Storage	Due to poor storage the outlet valves of CFC-containing cylinders are not well closed after use and the gas leaks out slowly into the atmosphere undetected	Technical improvement of quality control and Montreal Protocol awareness compaign.
Leak testing	CFC-12 is used by majority of assembling plants visited during the present study for flushing and leak testing. This gas is thereafter released to the atmosphere; Out of the 6 major assemblers of domestic refrigerators only three use nitrogen for flushing and leak testing extensively.	Elimination of CFC-12 for leak testing and instead use nitrogen for flushing and leak testing
Charging	Due to lack of proper charging facilities, there is a lot of reworking on units and in some cases releasing the gas into the atmosphere in situation where the unit had being overcharged	Adoption of better charging procedures and use of proper charging equipment.

b) During Use

Domestic refrigeration units are hermetically sealed with fewer than 10% ever requiring servicing throughout their 12 - 15 years life for the case of developed countries(AFFEAS 1989c). However in Kenya there is quite a high level of domestic refrigerator breakdowns. The domestic refrigerator breakdowns leading to CFC-12 emissions into the atmosphere while on use are identified as per Table 5.3:

c) During Servicing

The major problems contributing to wastage of refrigerants during servicing are identified as:

- lack of quality control
- servicing and installation by untrained technicians
- lack of appropriate charging and vacuuming systems
- lack of awareness of environmental matters
- lack of professional and government bodies to set standards

The domestic refrigerator breakdowns leading to CFC-12 emission by servicing agents are identified as per Table 5.4;

Table 5.3: Domestic Refrigeration Breakdowns Leading to CFC-12 Emission During Use and Proposed Remedies.

present scenario	proposed remedies
Puncturing of evaporators. This happens at the homes and institutions when sharp metal objects or undue force is used to dislodge food-stuff and ice from the refrigerator. The formation of excessive ice in the refrigerator (both fridge and freezer compartments) is due to: 1. Malfunctioning of control (thermostat, wiring, etc.) due to poor quality, misuse or poor repairs. 2. Unnecessary frequent opening of refrigerator doors. 3. Placing steaming or hot food-stuffs in the refrigerator. 4. Absence of automatic defrost control mechanisms	Education and publicity to masses on; 1. Basics of refrigeration and refrigerators 2. What-to-do and what-not-to-do to a refrigerator. How to use a refrigerator. 3. Basics of installations of refrigerators. 4. Basics of manufacturing standards
Puncturing of condensers	Education and publicity to masses on; refrigerators/freezers handling ; though virtually all refrigerators and freezers are fitted with instruction manual very few people care to read and follow the instructions given in the manual.
Vibration-induced breaking of refrigerant tubing due to vibration originating from the poor mounting of hermetic compressors and other components.	Technical improvement of brazing at the joints and compressor mounting to reduce or eliminate leakage at the joints.
Leakage due to improper joints.	1. Technical improvement of brazing at the joints to reduce or eliminate leakage at the joints. 2. Elimination of swaged lock joints 3. Information on who can service refrigerators.

Table 5.4: Domestic Refrigerator Breakdowns leading to CFC-12 Emission by Servicing Agents and the Proposed Remedial Measures

present scenario	proposed remedies
Failure of compressor motor due to voltage fluctuations. In this case in an attempt to change the compressor, the refrigerant is vented in the atmosphere by the technicians.	• Installation of voltage stabilisers and correctly sized fuses to domestic refrigerators and freezers • Education to servicing agents on the economics of recovery and how to recover • Public compaign on Montreal Protocol awareness and its implications.
Repair of refrigerators by unqualified technician who spoil parts of the refrigerator.	Education, registration and certification of technicians and servicing firms to curb untrained and unskilled technicians.
Improper vacuuming: almost all the repair workshops do not have vacuuming pump and the vacuuming is done using the refrigerator's own compressor. In this kind of vacuuming the degree of vacuuming is only 20-30%. This leads to the refrigerant retaining moisture and thereafter choking as the dryer is contaminated with air and water.	• Use of proper vacuuming pump • Education to servicing technicians on the need, and how, to achieve better vacuum prior to charging.
Incorrect charge: Almost all servicing agents use a manifold pipe only in charging and the quantity charged is by feeling the suction line of the compressor. This kind of charging always leads to overcharging and as the compressor is running this excess gas is slowly released .	Use of correct charging equipment that will charge the correct charge into a unit
Contamination : majority of small workshops are full of dirt which find their way into the system during servicing. For brazing of joints some technicians use kerosene blow lamps and due to their low temperatures compared to oxy-acetylene flames the joints are improperly brazed and since this kind of a flame produces carbon dust, this dust finds its way into the system and as such contaminates the refrigerant and leads to choking.	• Good house keeping and using oxy-acetylene flame for brazing the joints • Education , registration and certification of technician and servicing workshops.

The reduction in emission by service agents should have the following refrigerant conservation measures:

- Reduce wastage of refrigerants during charging
- Protect existing CFC-12 systems from failure and/or leakage
- Institute CFC-12 recovery and recycle programme

- Create lasting improvement in manufacture, assembly, servicing and use of refrigeration equipment
- Increase public awareness in environmental matters, the use of refrigeration systems etc.

The proper charging of refrigeration systems constitute a refrigerant conservation measure and will result in:

- Reduction in emission of CFCs into the atmosphere
- Continuation of use of CFC-operated refrigeration systems to their full life-spans
- Reduction in servicing costs
- Reduction in the quantities and cost of CFC stockpiled, recycled and/or reclaimed.

d) During Disposal

In Kenya refrigeration equipment are retained by the owners as long as they can be kept running and discarded only after all possible measures to salvage the equipment fail. At this point the equipment is often sold to dealers who cannibalise it, repair and sell as used equipment or sell it as scrap.

Before cannibalising or selling the equipment as scrap, CFC-12, if still in the system, can be recovered for recycling (see Chapter Six)

5.3 Commercial and Retail Refrigeration

5.3.1 Current Equipment Technology

The majority of commercial and retail refrigerating systems in Kenya are used in food merchandising and food service applications such as supermarkets, food stores, restaurants, cafeterias, commercial and institutional kitchens. The design of commercial refrigeration systems and the type of refrigerants used depend on the required operating temperatures as shown in Table 5.5

Table 5.5: Temperature Range for Various Commercial and Retail Design Application

Area of application	Compartment air temperature
Fresh fruits and vegetables	4°C to about 13°C
Fresh meat and dairy products	-2°C to 2°C
Frozen meat and frozen food	-18°C to -30°C
Ice cream	-18°C to -24°C
Cold drinks	4°C to 10°C

Table 5.6. shows the most commonly used refrigerants in commercial refrigeration. An estimation of percentage distribution between the refrigerants in these applications in 1995 is also given.

Table 5.6: The Most Commonly Used Refrigerants Within Commercial Refrigeration Sub-sector

Refrigerant	HFC-134a	CFC-12	HCFC-22	CFC-502
Operating temperature	-15°C to 15°C	-15°C to 15°C	down -37°C	down to -45°C
Percentage Distribution	0.07%	98.27%	1.60%	0.06%

source Table 3.12

5.3.2 Refrigerant Conservation Technology

The CFC-12 refrigerant conservation measures for domestic refrigeration are also will be applicable to small commercial and retail refrigeration units(bottle coolers, ice cream cabinets, ice makers) .

Reduction for refrigerant emission for larger systems are described below in sections a), b), c), d) below.

a) During Manufacture/Assembly and Installation

Larger systems, which have a central refrigeration plant, are installed at the customer's site to form a refrigeration system with its refrigerant flowing through pipe-work which connects individual refrigeration cabinets into a complete system. The refrigeration system is charged with refrigerant after installation at the client's site. Self contained retail refrigeration units have their own refrigeration system delivered to the customer with a refrigerant already charged

Method for reducing CFC-12 emissions during installation includes using alternatives to CFCs for leak testing for example:-

- Use of N_2 or CO_2 gas to 'bubble' test the system for large leaks.
- Use of HCFC-22 to test small leakage within the system. The HCFC-22 can be recovered to prevent it from being released to the atmosphere;

b) **<u>During Use</u>**

As has been seen from the CFC consumption audit for commercial and retail refrigeration(see section 3.3.2), the major losses of CFCs from this sub-sector is through leakage in normal use. About 80% of leaks occur at compressor drive shaft seals and from system valves for open type compressors and at joints for hermetically sealed units. Leakage from the system in use can be reduced by improved leak testing at the manufacture and installation stages. Present scenario and proposed remedies are tabulated in Table 5.7

Therefore reduction in CFC emissions from retail and commercial refrigeration whilst in use can be achieved through two approaches:-

- To make the equipment as leak proof as possible at the manufacturing stage;
- To detect any leakage of refrigerant as early as possible. Automatic leak detection equipment can be fitted in the refrigeration plant. This equipment ensures that any leakage that does occur will be detected as early as possible and the service technician notified quickly and told where in the system the leak has occurred. The technician can close to isolate the portion that has a leak.

Table 5.7: Present Scenario and Proposed Remedies for Large Commercial and Retail Plants While in Use.

Present scenario	Proposed remedies
leakage through compressor drive shaft seals	Use of hermetically sealed compressor units and factory pre-assembled units to give more reliable units with lower leakage problem.
leakage through system valves	Use of brazed connections within the refrigeration system instead of flanged, screwed or swaged lock fittings.
large amount of refrigerant used for topping up	Use of smaller refrigeration charge. This can be achieved through the use of central systems and secondary fluid such as brine to cool the refrigeration cabinets.

c) **During Service**

CFCs emission during service can be reduced by following proper codes of practice, which includes:

- collection of CFCs during service rather than venting them into the atmosphere.
- prompt isolation and repair of leaks , thereby limiting the loss of CFCs and
- using alternatives to CFCs to clean and flush the system.

As an example, Farmer's Choice Company of Nairobi is reported to have reduced its use of CFC-12 by up to 30% in 1995 by following good maintenance procedures(present study). This indicates the level of improvement that can be attained.

Some commercial enterprises such as large supermarkets have service contracts requiring their systems to be inspected monthly. The average service interval; however; is 6 months and is generally carried out by specialist service companies. Some larger users carry out their own servicing.

d) **During Disposal**

The emission of CFCs during disposal of retail and commercial refrigeration can be greatly reduced through collection of the CFCs prior to destruction and decommissioning of the refrigeration system. This can be achieved through the use of portable reclaimer units which are capable of removing the refrigerant safely from the refrigeration system(see Chapter Six).

5.4 Cold Storage and Cold Rooms

The annual demand for CFC-12 for this sub-sector was 27.6 metric tonnes in 1995. The refrigeration equipment involved in this sub-sector are stationary and can therefore benefit from the remedial measures applied to domestic and commercial sub-sectors. This sub-sector has the highest demand for CFC-12 due to the large charging capacity required per unit. A major campaign to effect good house-keeping, better charging ,recharging and topping up methods will therefore reduce the national demand for CFC-12 by a big margin.

Future consumption of CFC and HCFC refrigerants will be substantially reduced through improved maintenance and refrigerant recovery measures when systems are serviced, retrofitted or disposed off. About 57.7% of current refrigerant consumption in cold storage and cold rooms is used for servicing purposes (Table 3.15). Reclaimed refrigerant available for reuse may considerably extend the operational life of many CFC systems in this sub-sector.

5.4.1 Current Equipment Characteristics

The cold storage and cold rooms includes a variety of applications within storage, chilling and freezing of food and perishable products. The temperature level may vary from 10 to 15°C to below -60°C(superfreezing).

Refrigeration systems for cold storage and cold rooms are in general large, and have large refrigerant charge in relation to refrigeration effect. Typical specific charge may be up to 5 - 10 kg/kW cooling effect.

Most large scale chilling, freezing and cold storage plants in Kenya utilise CFC-12 and HCFC-22. Table 5.8 gives a rough estimate for the refrigerant consumption for cold storage and cold rooms in Kenya.

Table 5.8 Estimated Consumption of Refrigerants for Cold Storage and Cold Rooms(1995)

Refrigerant	Estimated consumption (MT)
CFC-12	27.63
HCFC-22	27.36

5.4.2 Refrigerant Conservation Technology

a) During Installation

Cold storage and cold room equipment are supplied without charge . The refrigerant equipment is assembled and installed at the client's site, and only then is the equipment charged with refrigerant.

Most refrigerant emissions occur through leakage of the refrigerant during normal usage. This can be reduced by thorough leak testing of the system at the installation stages. Reduction in the refrigerant emissions during leak testing can be achieved by:

- testing with gases other than the controlled CFCs, for example HCFC-22/ N_2 mixtures can be used.
- Use of other refrigerants such as HCFC-22 in new installations and in total replacement of obsolete CFC-12 systems

b) During Use

Reduction of refrigerant emissions during use of cold storage and cold rooms equipment can be achieved through a reduction of the frequency and size of the leaks which occur by :

- ensuring that the equipment is as leak proof as possible by thorough leak testing
- installing automatic leak detection equipment which will identify leaks immediately and enable the service technician to locate, isolate and repair the leak quickly. This will reduce the amount used for topping up.
- Use of hermetic or semi-hermetic compressors as far as possible. This will reduce the frequent leakage from shaft seals.
- Use of brazed connections instead of flare connections, flanges and threaded joints.
- Excellent quality control at all stages
- Use of vibration reduction features to avoid rupture of piping and dislocation of joints
- Use of trained operators and servicing technicians

c) <u>During Service</u>

Reduction of refrigerant emission in cold storage and cold rooms equipment during service can be achieved by:

- recovery of the refrigeration from the system prior to service and maintenance. This prevents unnecessary venting of refrigerants to the atmosphere
- prompt repair of any leaks
- good house keeping

d) <u>During Disposal</u>

A reduction of refrigerant emissions from this sub-sector during disposal and destruction can be achieved by the use of portable reclamation units. During recovery of the refrigerant from the system some of the CFC remains dissolved in the compressor oil. This can be recovered either, by heating the compressor oil to 25 - 30°C or by collecting the oil and sending it for reclamation along with the CFC. Highly contaminated CFCs or CFC mixtures can be recovered from the equipment, but cannot be reclaimed. These mixtures need therefore to be destroyed to prevent the release of the CFC to the atmosphere(see Chapter Seven).

5.5 Comfort Air-Conditioning

The demand for CFC-12 for this sub-sector is small compared to the other sub-sectors. This is partly because all small air conditioners operate on HCFC-22 and the use of air-conditioning is not so common in Kenya (except along the Indian Ocean Coast) due to the favourable weather. Damage to refrigeration systems in this sub-sector is also low because operators do not have access to the system except for the on/off adjustment switches.

The remedies proposed for the cold storage sub-sector will also be applicable in the comfort air-conditioning sub-sector.

5.5.1 Current equipment Characteristics

Air cooled air conditioners ranging from about 2kW to 420 kW cooling capacity comprise a vast majority of the comfort air-conditioning market in Kenya. The units are operated to cool air or to cool and dehumidify air in small rooms to large commercial structures. All the units are electrically driven vapour compression systems.

Air cooled comfort air conditioners can be divided into four categories, based primarily on capacity:-

- Unitary room air conditioners
- Duct-free split systems
- Ducted split systems
- Commercial unitary systems

a) Unitary Room Air Conditioners

Unitary room air conditioners range in capacity from about 2 kW to 10kW. They all use hermetic rotary, reciprocating or scroll compressors. The units are applied in small shops, offices as well as apartments. They can be mounted in the window, through a wall, or on a free standing mobile unit.

b) Duct-free Split Systems

The duct free split systems range in capacity from about 2kW to 20kW (6,800 to 34,000 Btu/hr). The system consists of an outdoor unit (compressor and condenser) and one or several indoor units (evaporators). The indoor and outdoor units are connected by refrigerant piping and power and control cables. For small capacities hermetic rotary compressors are used while larger models use hermetic scroll or reciprocating compressors. Duct-free split systems are applied in commercial buildings, Schools, free standing residences etc.

c) Ducted Split Systems

The ducted split air conditioning systems range in capacity from 5 kW to 20kW. They are applied in central, forced air cooling systems. A compressor/ condenser unit outside the space to be cooled is connected to a single or several indoor heat exchangers installed within the duct system. The cooled air flowing over heat exchanger is forced into the air-conditioned space.

d)Commercial Unitary Systems

Commercial unitary systems range in capacity from about 20kW to 420 kW. These units are applied in many different ways. Some of the smaller units are mounted on the roofs of individual offices, shops or restaurants. Multiple units with one or more compressors are used to cool entire shopping centres, schools, hospitals, exhibition halls or other commercial structures.

5.5.2 Refrigerant Conservation Technology

a) During Installation

Leak testing of air conditioning equipment at the installation stage is important as it reduces refrigerant losses during use of system. However , a reduction in refrigerant emission from this leak testing process is possible by following correct handling procedures, which include:

- reduction of the use of CFC-12/air mixtures for leak testing;
- increase in the use of HCFC-22/N_2 mixtures for leak testing. N_2 has to be used as HCFC-22/air mixtures are flammable at high pressures;
- recovery of any CFCs or HCFCs used for leak detection.

b) During Use

A reduction in leakage rate of refrigerants during equipment usage can be achieved by thorough leak testing during manufacture and installation. Other methods for reducing emission during usage include:

- automatic leak detection, which detects leaks quickly and helps the service technician to locate the leak. Any leaks which do occur are dealt with quickly, thereby reducing the amount of refrigerant lost;
- improved efficiency of the purge units on CFC-12 systems to reduce refrigerant loss.

c) During Service

Reduction in emissions during service can be achieved through following codes of good practice which include recovery of the refrigerant from the system prior to servicing' instead of the old practise of venting into the air. Large air-conditioning appliances are typically serviced once every six months, generally by specialist companies.

d) During Disposal

Refrigerant emissions from the decommissioning of air conditioning equipment can be reduced through recovery of refrigerant prior to dismantling the system. The recovered refrigerant can then be reclaimed or destroyed.

5.6 Transport Refrigeration

5.6.1 Current Equipment characteristics

The transport refrigeration equipment includes road transport, railcars, ships and intermodal containers for the transport of refrigerated cargoes, and also refrigeration on board of all types of ships.

Transport refrigeration is an international business, not only in trade but also in terms of equipment supply. Hence there is really no distinction between different countries.

i) **Railcars**

There are usually two refrigerating units per refrigerated railcar, each of 10 kW nominal capacity input and each containing about 7 kg of CFC-12

ii) **Sea Freight Containers**

refrigeration units contain about 12 kg of CFC-12 per container

iii) **Trucks**

The trailer units typically have a refrigerating capacity of 6 kg refrigerant charge. This is valid if the system is designed for a cargo space temperature -18°C and 38°C ambient temperature. Truck units have a refrigerating capacity of 1.5 to 5 kW and contains about 6 kg refrigerant charge, the smaller units may have 3 kg charge. CFC-12 is used extensively in refrigerated containers.

5.6.2 Refrigerant Conservation Technology

The wastage of CFCs in this sub-sector are due to:
-leakage induced by vibrations due to poor roads and railways
-wastage during charging and recharging processes.

The existing transport refrigeration systems use standard components used in stationary plants. Wastage due to induced vibration may not be significantly reduced in the near future since it is unlikely that Kenyan roads and railways will be significantly improved in the near future. However using components that can withstand the levels of vibration the equipment is subjected to may result to a slight reduction in refrigerant consumption. This will be achieved at a penalty of increased capital cost. Wastage due to use of inappropriate charging techniques and equipment may be reduced by following good codes of practise. Emissions can be reduced by following good service procedures and not venting refrigerants into the air and recovering the refrigerant for reuse or reclamation.

5.7 Mobile Air-Conditioning

5.7.1 Current Equipment Characteristics

The main area of mobile air conditioning is climatization of the passenger compartment in motor cars and personnel zones in trains, trucks, buses and ships. As a means to increase comfort and safety of driving, climate cooling is necessary in temperate and hot climates. In Kenya there is no climate cooling for passengers in trains and trucks. Ships with comfort air-conditioning for passengers operate through many countries and as such the consumption of CFCs here can be viewed internationally which is beyond the scope of this report. Mobile air-conditioning in Kenya is primarily for saloons and coaches.

Air conditioning systems are normally installed at the assembly line at the car manufacturers but add-on kits are also available.

CFC-12 vapour compression cycle, with the compressor belt driven from the car engine, i.e. open compressor with shaft seal, and refrigerant-to-air heat exchanger is often employed. Both reciprocating (axial piston) and sliding vane compressors are commonly used, and some car models use scroll machines. Flexible hose connection are necessary between the compressor and the rest of the system, both to allow relative movement of the engine and to limit noise transmission. The condenser is placed infront of the radiator and cooled by the ambient air flow. The evaporator is placed within the climate control unit infront of the passenger compartment. This unit also comprises the heater core, fans, dampers and duct system for ventilating, heating and cooling the passenger compartment. Both recirculating air and flesh air are cooled by the evaporator. The refrigerating capacity is usually in the range of 3 to 5 kW at 40°C ambient air temperature.

A receiver with filter/drier element is usually installed on the liquid line close to the condenser. The expansion valve is of a thermostatic type, or an orifice or capillary tube . In some cases the system also comprises of an accumulator between the evaporator and the compressor. The compressor is normally regulated on/off by a magnetic clutch, which is controlled by an evaporator thermostat that limits the minimum temperature to about 0°C to avoid frost formation.

The cooling capacity of a typical 30 seater bus system is in the order of 25kW, and the system comprises of as much as 120 m of refrigerant lines (split system). In buses the climate control unit is normally at the rear on the roof or below the floor (information provided by Vehicle Assembling Plants).

5.7.2 Refrigerant Conservation Technology

The elimination of the use of CFC-12 in mobile air conditioning is one of the most important aspects the automobile industry is committed to. This will be accomplished via a combination of conservation, recycling and reclamation measures during servicing and disposal, and replacing CFC-12 with HFC-134a in new equipment.

It appears that, whether or not a retrofit solution is found to service existing CFC-12 vehicles, the cost to society(or to individual consumer) to eliminate CFC-12 will be significant.

All new cars will use HFC-134a as coolant(Kanyua, 1993). Since leakage of CFC-12 to the atmosphere cannot be eliminated due to the poor state of the roads, it is strongly recommended that all recharging be met by HFC-134a. This would eliminate the CFC-12 demand for this sub-sector.

5.8 Industrial Refrigeration

5.8.1 Current equipment Characteristics

Industrial refrigeration corresponds to a wide range of application and operating conditions, within chemical, pharmaceutical and petrochemical industries, the oil and gas industries, civil engineering, the metallurgical industry etc.

Industrial refrigeration units are in general large, ranging from 100 - 200 kW up to several MW refrigeration capacity. The industrial refrigeration sub-sector is characterised by:

- Relatively large refrigerant charge
- No public access to areas where equipment containing refrigerant is located.
- Operation and maintenance performed by well qualified personnel.
- Refrigeration system often linked to production system.

In this sub-sector the importance of energy efficiency, refrigerant prices, and system availability is stronger than concerns regarding toxicity and flammability. The temperature range in this sub-sector varies from 10°C down to the boiling point of nitrogen (-196°C) and even lower, but major part of applications operates from -20°C and above.

The most common refrigerants in this sub-sector are listed in Table 5.9

Table 5.9 Refrigerants for Industrial Refrigeration and their Estimated Consumption in 1995

Refrigerant	Ammonia	HCFC-22	Hydrocarbons	Liquid CO_2	Total (MT)
estimated consumption (MT)	0.38	0.16	0.0177	0.02	0.57
Percentage	66.2	27.9	3.1	2.8	100

5.8.2 Refrigerant Conservation Technology

This sub-sector uses HCFC-22, Ammonia and hydrocarbons. CFC-12, the controlled refrigerant, is not used in this sub-sector. Loss of refrigerants in this sub-sector is very low due to proper management, operation and maintenance. Wastage reduction measures applied to cold storage and cold rooms can be applied for this sub-sector.

CHAPTER SIX

ECONOMICS OF COLLECTION, RECOVERY AND RECYCLING OF REFRIGERANTS

6.1 General Introduction

When the use of Chlorofluorocarbons(CFCs) began after the second world war(SCBR, 1989a) the focus was first and foremost on the practical applications and the long term damage of the ozone layer caused by these CFCs were undreamed of. The current drop-in alternatives, like HFC-134a, are very stable compounds and the question as to what will happen when these substances are not broken down by nature's own purifying mechanism is still unanswered. Questions such as: Where do these substances go after being released in the atmosphere ? What kind of damage will they probably cause in future? Are yet to be considered.

Collection, recovery and recycling of all refrigerants is therefore an ecological requirement as well as an economic necessity. The two main reasons for collection, recovery and recycling of CFCs are :-

- The protection of the environment
- Ensurance of a reserve of refrigerants for the existing CFC-12 based refrigeration systems

Collection, recovery and recycling will indeed enable the industry to keep its CFC-12 based equipment running when production of CFC-12 has stopped. Presently there are no collection/recovery or recycling procedures being followed in Kenya during servicing or repair of air-conditioning and refrigeration equipment. Hence as a normal practice the refrigerant is simply vented into the atmosphere as seen in Chapter Three. This is inspite of the prediction /recommendations and efforts by the Montreal Protocol and associated agencies (see previous reports on ODS in Kenya namely UNEP, 1989, UNIDO, 1992 and Kanyua, 1993).

Recovery and re-use of refrigerants has been an established practice in some developed countries (Coppers and Lybrand, 1992a). The focus in the present chapter will be mainly on equipment where CFC-12 are used. In the medium to long-term planning, the recovery and recycle operations will be extended to cover the recovery and recycle of HCFC-22, HFC-134a and any other refrigerant introduced in the market. At present HFC-134a costs at least 8-12 times as much as CFC-12(Table 4.3) and therefore the economic incentive for recovery and recycle of HFC-134a is much higher than that for CFC-12. HFC-134a and CFC-12 are similar in many ways and therefore they will be recovered and recycled using the same type of equipment .

6.1.1 Summary of the Results of Venture Level Economic Analysis

Venture level economic analysis in the present study yielded 32 portable recovery units and six stationary recycling centres. The number of these ventures has been based on the eligibility of agents to set them up, geographical distribution of servicing agents, manufacturers/assemblers and commercial installations. In the computation of the economic viability of recovery and recycling ventures it was suggested there be a portable recovery unit for every 5 stations that service refrigeration and air conditioning equipment and a recycling plant for every 30 stations.

Table 6.1 gives the summary of the results of the analysis. The Table is intended to give a summary of the results of the analysis and more detailed information and supporting arguments are contained in the rest of the section. The project life is taken to extend upto the year 2010 which is the terminal year for use of CFC-12 in the developing countries. Recovery and recycling equipment life span is taken as equal to the project life (14 years).

Table 6.1: Summary of the Results of the Venture Level Analysis (1995).

	VENTURE TYPE	
	Recovery	Recycling
No. of ventures	32	6
Equipment cost (Ksh.)	81,125	190,644
Total equipment cost (Ksh.)	2,596,000	1,143,864
Feasible quantity of CFC handled over project life (kg.)	2,258,000	2,258,000
Annualised operational cost (Ksh.)	1,114,950	4,457,875
Annualised revenues(value of CFC saved) (Ksh.)	3,210,000	7,490,000
Operational cost/kg. of CFC processed (av. annual) (Ksh.)	74.33	297.2
Break even quantity (kg)	2300	1230
annualised operating profit (Ksh.)	1,000,000	1,000,000
payback period for venture (Months)	30	13

6.2 Elements of Collection, Recovery and Recycling of Refrigerants

The main elements of collection, recovery and recycling of refrigerants as used in this text are:-

- Collection;
- Recovery;
- Recycling;

6.2.1 Collection

The collection process is essentially confined to picking up the equipment containing the refrigerants as shown in Figure 6.1 This may involve a van or a lorry with 1 or 2 manual workers. It is essential that the product/equipment is not damaged during handling and transportation as this may cause the release of the refrigerant from sealed systems. In the case of collected refrigerators, secure storage is important in order to prevent the scavenging of copper wire or other components which could break the seal and cause the loss of the refrigerant to the atmosphere.

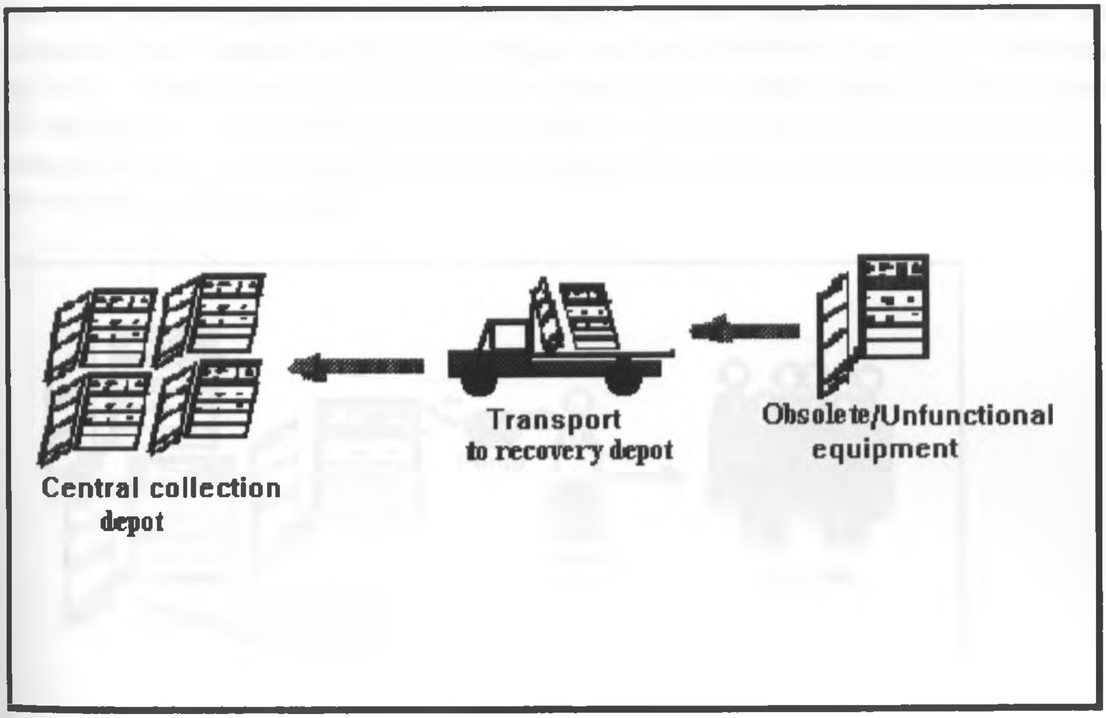


Figure 6.1: Refrigerant Collection Process.

6.2.2 Recovery

The recovery process involves the extraction and storage of the refrigerant within a purpose built container prior to recycling as shown in Figure 6.2. Equipment used in recovery can either be developed and constructed in-house, or designed and constructed primarily as a portable unit.

The recovery of CFCs often involves the handling of equipment containing liquid gases under pressure. Consequently, appropriate health and safety precautions need to be observed as direct contact with liquid CFCs could degrease the skin and cause a strong chilling effect. Gloves and eye protection equipment need to be worn during recovery procedure.

Recovery equipment for refrigerants typically consists of the following basic items:-

- Sunction equipment, usually a portable pump which will vaporise and condense all refrigerants and can be powered from a standard power supply, an air compressor or operated manually.
- Suitably labelled storage container usually a cylinder capable of holding CFCs under pressure.
- Flexible hose pipes (refrigerant resistant) with shut off valves at the connection points.
- Special piercing tool or a tap valve (which opens a pipe and seals it at the same time).
- Weighing scale or a pressure gauge.
  (PIR; 1993a, SCBR; 1989b, Cheserem; 1993a)

The basic recovery process involves connecting a pump via a flexible hose pipe to the system containing the refrigerant and also to a storage container as shown in Figure 6.2. This requires the use of a special piercing tool for easy evacuation of the sealed system without leakage of the refrigerant to the atmosphere. The refrigerant is then pumped from the system into the storage container. The storage container is normally a purpose built cylinder capable of holding the refrigerant under pressure.

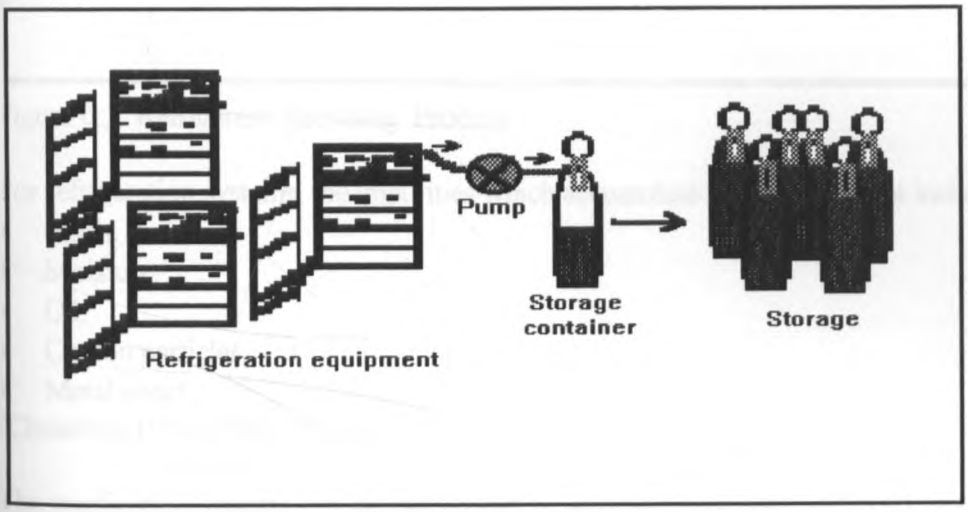


Figure 6.2: Refrigerant Recovery Process

Some refrigerants, such as CFC-12, are miscible with the compressor oil in the refrigerator at low temperature, and it is necessary to warm the compressor to 25°C - 30°C using a hot air blower while vibrating it in order to release the CFC from the oil as gas(Cheserem; 1993b). In normal circumstances, less than 10% of refrigerant is likely to be in the oil. A separate collection vessel is required if the oil is to be disposed off or recycled. Recovered refrigerants can sometimes be re used (after minor system repairs) without further treatment but it should usually be recycled.

6.1.3 **Recycling**

The recycling process involves cleaning the recovered refrigerant to remove any impurities which have accumulated during use as shown in Figure 6.3.

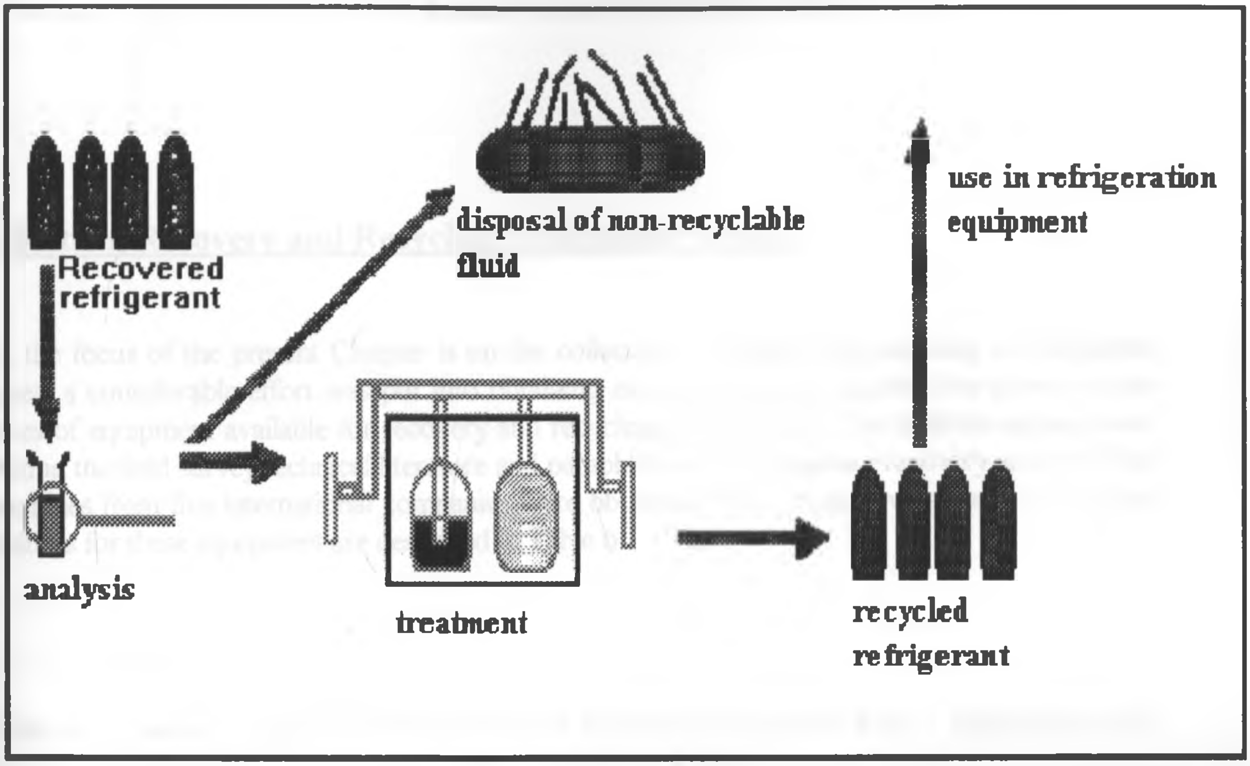


Figure 6.3: Refrigerant Recycling Process

For refrigeration systems, the impurities which accumulate in the refrigerant include:-

- Acids.
- Moisture.
- Oil.
- Carbon particles.
- Metal swarf.

(Cheserem;1993c, PIR; 1993b)

The purification process can be carried out by appropriately designed machines. The recycling equipment is much more complex than that required for recovery and includes :-

- A dryer.
- Filter.
- Heater.
- condenser.
- Cooler.
- Oil separator.

(PIR; 1993c)

There are three stages in the recycling process namely:-

1. Filtration using special sieve to remove carbon particles and metal swarf.
2. Pumping the refrigerant through special dryer and oil separator to remove moisture and oil respectively.
3. Chemical reprocessing to remove other chemical impurities (such as acids) within the refrigerant.

The purity of the recycled material depends upon the recycling process.

6.3 Collection, Recovery and Recycling Equipment Details.

As the focus of the present Chapter is on the collection , recovery and recycling of refrigerant gases, a considerable effort was put into obtaining maximum current information about various types of equipment available for recovery and recycling of refrigerants for different applications. During the field survey technical literature and pamphlets of 14 refrigerant recovery and recycling machines from five international companies were obtained. The comparative summary of salient features for these equipment are described in Table 6.1 - Table 6.6.

Table 6.2 : Salient Features for Recovery and Recycling Equipment from : REFRIGERANT RECOVERY SYSTEMS INC., FLORIDA, USA

Model	Rejuvenator		Model RC-1
	ST-1000	ST-100	
refrigerant handled	CFC-12, CFC-500, CFC-502, HCFC-22		
Application Area	commercial air-conditioning		domestic/ commercial contractors
size (mm)	760 x 710 x 430	740 x 810 x 360	410 x 300 x 460
weight (kg.)	61	48	27
recovery rate (kg./hr)	80-160	50-80	14
recycling rate (kg./hr)	-	-	-
features	recovery unit only		
Indicative price (Ksh. 1995)	285,000	145,000	52,500

Table 6.3 : Salient Features for Recovery and Recycling Equipment from : SPX CORPORATION, (OTC division), USA

Model	OEM 1396	OEM 1397	OEM 1380
refrigerant handled	CFC-12		
Application Area	mobile air conditioning and domestic refrigeration		
size (mm)	1140 x 535 x 610	380 x 510 x 360	1140 x 590 635
weight (kg.)	156	24	200
recovery rate (kg./hr)	14	10	14
recycling rate (kg./hr)	14	-	68
features	recovery/ recycling	recovery only	recovery/ recycling
Indicative price (Ksh. 1995)	250,000	50,000	200,000

Table 6.4 : Salient Features for Recovery and Recycling Equipment from : ENVIRONMENTAL PRODUCT AMALGAMATED PTY LTD., AUSTRALIA

Model	EP-3	EP-4	EP-4HC	EP-5
refrigerant handled	CFC-12, CFC-500, CFC-502, HCFC-22			
Application Area	Mobile , commercial air-conditioning, domestic			
size (mm)	400 x 500 x 1000	400 x 500 x 1000	4350 x 220 x 440	400 x 350x 400
weight (kg)	156	20	20	124
recovery rate (kg/hr)	25	25	35	20
recycling rate (kg/hr)	25	-	-	22
features	portable model (Filter and distillation), Recovery and recycling unit	hand carry, recovery unit		hand carry, recovery and recycling
Indicative price (Ksh. 1995)	206,944	58,333	54,444	266,111

Table 6.5 : Salient Features for Recovery and Recycling Equipment from: JAVAC, RECO, AUSTRALIA

Model	RECO-1	RECO-12s	RECO-134s
refrigerant handled	CFC-12, HCFC-22, CFC-502	CFC-12	CFC-12/ HFC-134a
Application Area	commercial air-conditioner	domestic/automobile	
size (mm)	390 x 440 x 600	390 x 440 x 600	390 x 440 x 600
weight (kg)	48	135	105
recovery rate (kg/hr)	60	33	-
recycling rate (kg/hr)	-	10	12
features	recovery unit	vapour form refrigerant recovery and recycling	recycling unit only
Indicative price (Ksh.1995)	142,500	99,500	117,500

Table 6.6 : Salient Features for Recovery and Recycling Equipment from :TECHNICAL CHEMICAL COMPANY, USA

Model	SERCON 9000	SERCON 8000	SERCON 5000
refrigerant handled	CFC-12, CFC-500, CFC-502, HCFC-22		
Application Area	high volume air-conditioning/ refrigeration units		-low volume air-conditioners -small volume domestic refrigeration
size (mm)	510 x 510 x 1150	510 x 510 x 1150	230 x 490 x 610
weight (kg.)	175	160	70
recovery rate (kg./hr)	600	6000	600
recycling rate (kg./hr)	70	70	-
features	recovery and recycling unit		recovery only
Indicative price (Ksh.1995)	250,000	210,000	62,500

The equipment details given above are representative of the range available for recovery and recycling equipment in terms of technology as well as prices which can be used for considering the economic viability of recovery and recycling. These equipment have been successfully used in Australia and USA. It should be noted that the prices of this equipment have been lowered internationally (UNEP 1994c) to enable developing countries purchase them at affordable prices.

The features incorporated in the recovery and recycling equipment are such that they can be easily operated and maintained by local technicians after initial training input of 1 to 2 weeks. The important average operating parameters for these equipment are summarised in Table 6.7.

Table 6.7: Average Operating Parameters for Recovery and Recycling Equipment.

	Recovery equipment	Recycling equipment
Spares and consumable (Ksh/kg)	15.5	20.5
Energy consumption (per kg)	0.1 kWh	0.1 kWh

6.4 Technical Options for Collection, Recovery and Recycling of CFCs in Various Groups

Based on the study of recovery and recycling equipment details in section 6.3 and preliminary data collected from the field survey, various technical options (group-wise) have been proposed for collection, recovery and recycling of refrigerant gases.

Recycling plants and recovery/recycling plants are heavy and the process also requires stationary plants. Recovery only equipment are light and can be portable or stationary.

Collection, recovery and recycling system has to be appropriate for a sub-sector. For example, small hermetically sealed refrigerant units are not fitted with charging or isolating valves and are movable, while larger refrigeration systems are fitted with valves so that component can be isolated for repair, charging and emptying and are mostly stationary.

Air-Conditioning and refrigeration industry, from the point of view of collection, recovery and recycling can be divided into three groups namely :-

a)Small Movable Equipment

These are movable equipment with small refrigerant charge (below 500 grams) and will include:-

- Domestic refrigeration units such as; domestic refrigerators and freezers
- Small retail and commercial refrigeration units such as; bottle coolers, food display cabinets, ice makers and ice-cream cabinets
- Small comfort air conditioning units such as; unitary room air conditioners, duct free split systems and ducted split systems

b)Mobile Equipment

These are mobile equipment and includes;

- Mobile air conditioning ;Comfort air-conditioning units for cars and vans.
- Transport refrigeration; refrigerated trucks, sea freight containers and railway wagons.

c)Large Stationary Installations

These includes stationary equipment with large refrigerant charge (above 500 grams) such as:

- Cold rooms.
- Large air conditioning plants such as commercial unitary systems.
- Industrial refrigeration.

The following technical options for each of the above groups were considered:

6.4.1 **Small Movable Equipment.**

For refrigeration and air-conditioning units containing a small amount of refrigerant two technical option are feasible.

A) Repair Done at Site Itself as Shown in Figure 6.4.

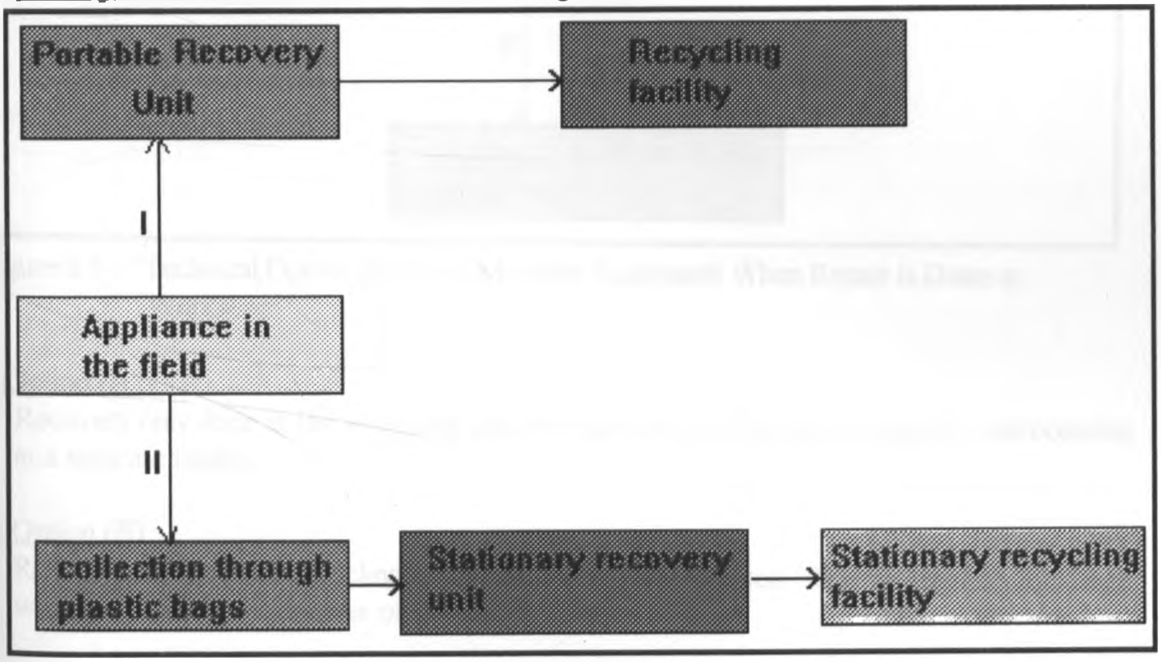


Figure 6.4: Technical Option for Small Movable Equipment When Repair is Done at Site.

(i)Option (I):

The portable recovery equipment is carried to the site and the refrigerant gas is recovered in an empty cylinder under vacuum. The refrigerant is then taken to a stationary recycling plant for reprocessing.

(ii) option (II):

When the servicing agent does not own a portable recovery equipment, or it is not feasible to transport the same to the site, the technician simply collects the refrigerant gas into a special plastic bag. These bags are then taken to a facility with a stationary recovery machine for condensing and storing into cylinders. The refrigerant is then taken to a stationary recycling plant for reprocessing.

B) Appliance From the Field Brought to the Workshop for Repair as Shown in Figure 6.5

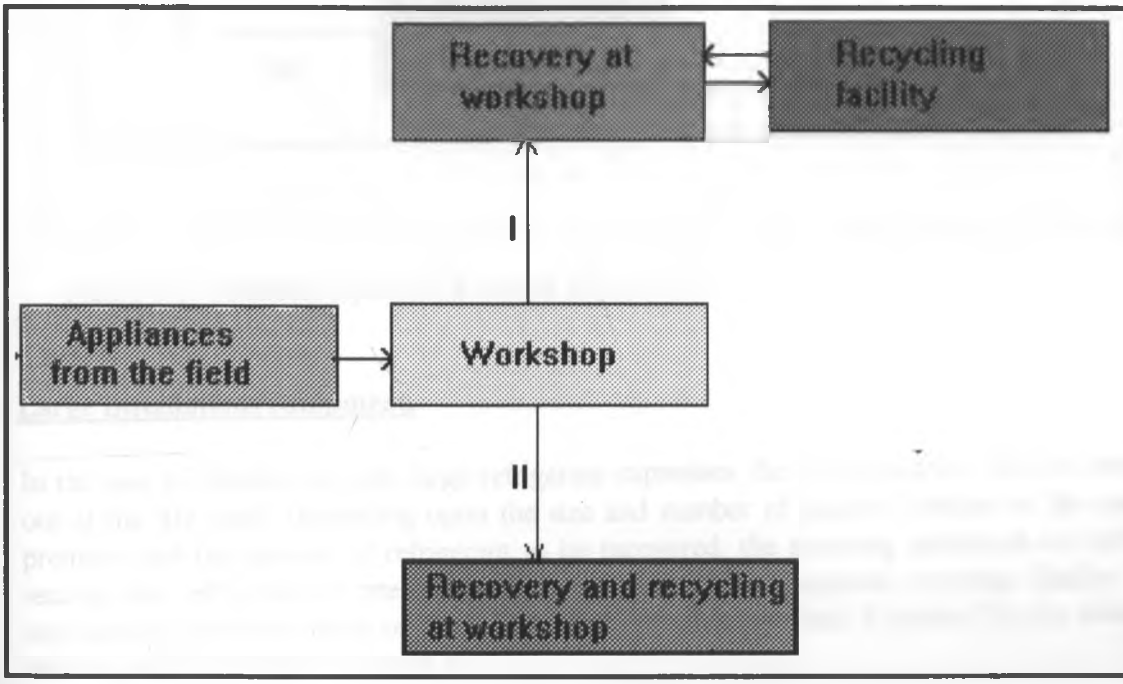


Figure 6.5 : Technical Option for Small Movable Equipment When Repair is Done at Workshop.

(i)Option (I) :

Recovery only done at the workshop and the recovered refrigerant is taken for reprocessing at a separate facility.

(ii)Option (II) :

Recovery as well as recycling done at the workshop itself. This is feasible for large workshops where the number of appliances repaired is high.

6.4.2 Mobile Equipment

In the case of mobile refrigeration and air-conditioning plants , the repair is often done at the servicing workshop. Depending upon the number of automobiles being repaired the workshop can install either only the recovery equipment (option (I)) and the refrigerant is taken to a separate recycling facility for reprocessing or recovery and recycling equipment (option (II)) as shown in Figure 6.6.

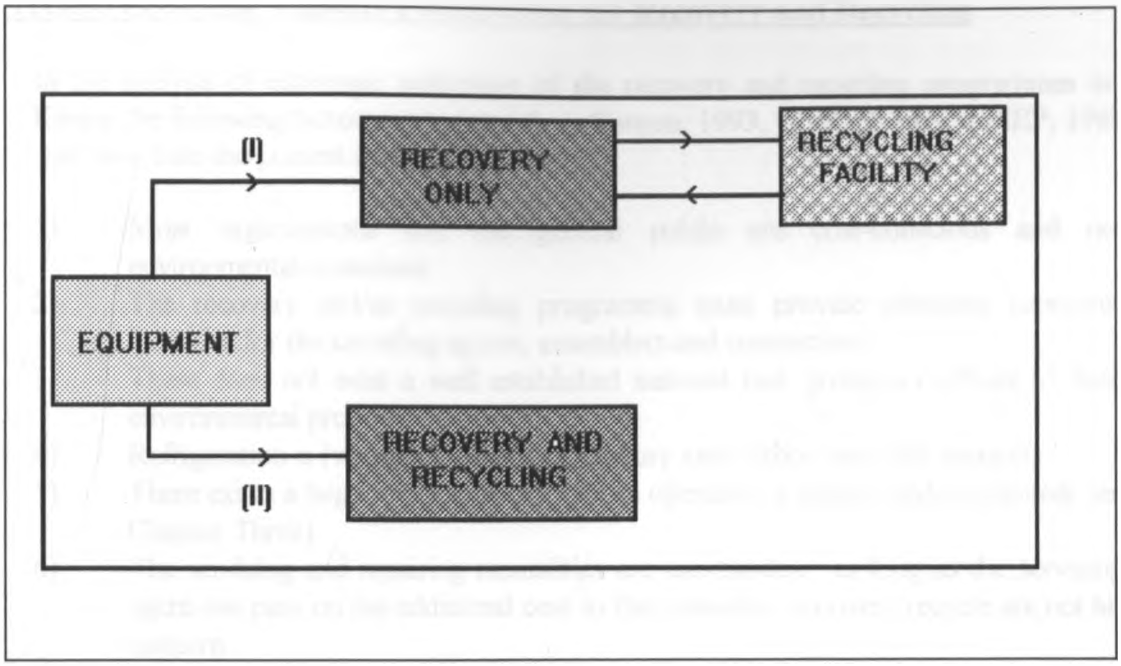


Figure 6.6: Technical Options for Mobile Equipment.

6.4.3 **Large Installations equipment.**

In the case of installations with large refrigerant capacities, the maintenance is always carried out at the site itself. Depending upon the size and number of systems installed at the user's premises and the amount of refrigerant to be recovered, the servicing technician can either recover the refrigerant at site (option (I)) and take it to a separate recycling facility for reprocessing for future reuse or can recover and recycle at site itself (option (II)) for reusing the refrigerant as shown in Figure 6.7.

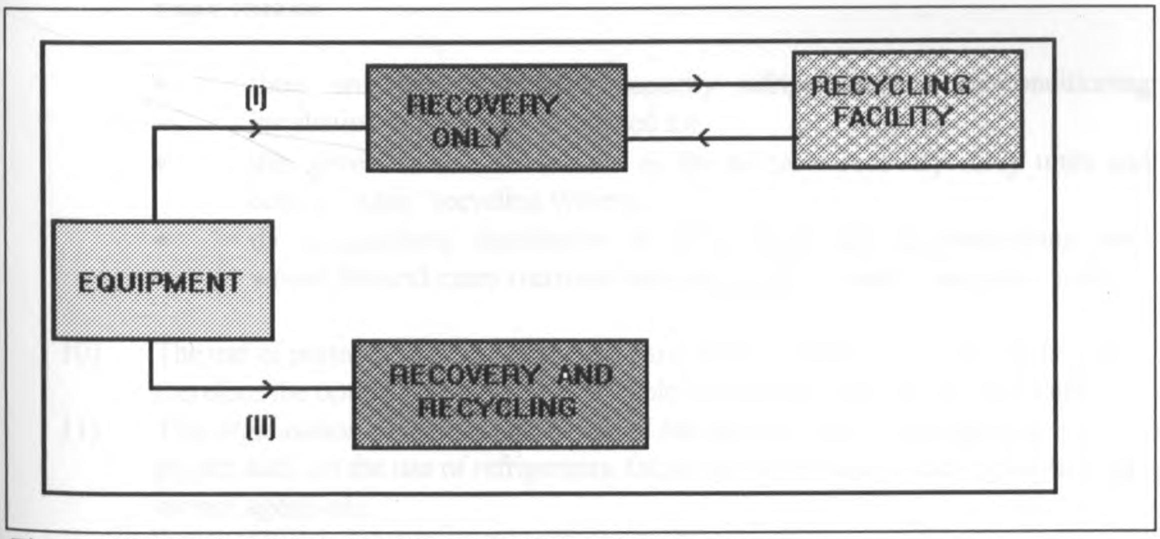


Figure 6.7: Technical Option for Large Stationary Equipment

6.5 Economic Analysis

6.5.1 Techno-Economic Viability Programmes for Recovery and Recycling

In the analysis of economic evaluation of the recovery and recycling programmes in Kenya, the following factors were noted from Kanyua; 1993, UNIDO; 1992, UNEP; 1989 and also from the present study:

1) Most organisations and the general public are cost-conscious and not environmental-conscious.
2) The recovery and/or recycling programme must provide adequate economic incentive for the servicing agents, assemblers and contractors.
3) There does not exist a well established national task groups or offices to push environmental programmes.
4) Refrigeration is (wrongly) viewed as a luxury item rather than vital necessity.
5) There exists a large informal sector whose operation is largely undocumented(see Chapter Three).
6) The servicing and repairing mentalities are unorthodox , as long as the servicing agent can pass on the additional cost to the consumer, recovery/recycle are not his concern.
7) There are no local energy standards.
8) Collection through plastic bags was considered impractical in Kenya for five major reasons:

    - it is not suitable for R-12 and R-22 because these refrigerants are gases at atmospheric pressure.
    - it is unlikely to reduce emission to atmosphere appreciably.
    - transport vehicles for these bags are not available.
    - the refrigeration industry may not accept it,
    - it will cause friction between the collecting and buying agents.

9) Combined recovery/recycling equipment is not justifiable at present for three major reasons:

    - there are very few large capacity refrigeration or air-conditioning installation in Kenya to be catered for.
    - this system is not as versatile as the portable recovery- only units and central "static" recycling systems.
    - the geographical distribution of refrigeration and air-conditioning units would demand many recovery/recycling plants, which is uneconomical

10) The use of portable recovery -only units and central 'static' recycling plants were therefore the option considered to be viable both technically and economically.
11) This organisation of the use and re-use of refrigerants will greatly enhance the proper audit on the use of refrigerants, the proper certification and registration of service agents etc.

6.5.2 Feasible Recovery Quantities Of CFC-12

When proper equipment are used for recovery of refrigerants the net recovery should be between 80% and 90% of the initial charge value(UNIDO; 1992e). The recycling rate will however depend on the extent of contamination of the recovered refrigerant. In this section it is assumed that 100% of the recovered refrigerant is reclaimed during recycling process. A recovery rate of 80% can be assumed for Kenya since this is a new activity.

There are two main situations that leads to recharging the units namely:-

- Leakage: In this case the refrigerant leaks into the atmosphere and cannot be recovered. However as detailed in Chapter Five this can be reduced considerably. In large plants containing shut off valves, some amount can be recovered depending on how quick the system is isolated once a leak is detected.

- Compressor failure: In this situation the refrigerant is intact inside the system and can be recovered.

A considerable amount of refrigerant is used for cleaning, flushing and leak testing. This refrigerant can also be recovered for reuse. A recoverable rate of 85% can be assumed in this case.

Group-wise feasible refrigerant recovery rates and technically feasible quantities which can be recovered are given in Table 6.8 based on 1995 data (see Chapter Three)

The quantities for refrigerant recovery indicated in Table 6.8 are the average quantities which are technically possible to be recovered, assuming that all the service agents engaged in repair and maintenance of all types of refrigeration and air-conditioning equipment are properly trained and equipped with appropriate equipment to collect, recover and recycle the refrigerants.

Also the total quantity of CFCs available for recovery will substantially reduce with the improvement of better working practices as seen in Chapter Five.

Table 6.8 Feasible Recoverable [illegible] of CFC-12 per Year (1995)

Sub-sector		Average initial charge(kg)	Compressor Failure		Flushing and leak testing		Leakage			Total quantity (kg)
group			No. of cases	Recoverable Quantity (80%)(kg)	Total quantity used (kg)	Recoverable Quantity (85%)(kg)	no.of cases	Recoverable %	Recoverable Quantity (kg)	
Small movable equipment	domestic refrigeration	0.12	6000	576.0	9445	8028.3	36000	0	0	8604.3
	small commercial and retail	0.12	3500	336.0	4444	3777.4	6000	0	0	4113.4
	small air-conditioning plants	0.15	2250	180.0	1667	1417	2000	0	0	1597
Large stationary equipment	large commercial and retail equipment	1.50	20	24.0	2222	1888.7	50	40	30.0	1942.7
	cold rooms and cold storage	6.00	60	288.0	2777	2360.5	400	45	1080.0	3728.5
	large air-conditioning equipment	0.45	5	1.8	1111	944.4	10	20	0.9	947.0
	Industrial refrigeration	-	-	-	-	-	-	-	-	-
Mobile equipment	Mobile air-conditioning equipment	1.50	100	120.0	111	94.4	15	0	0	214.4
	Transport refrigeration	8.50	20	136.0	111	94.4	15	25	32.0	262.4
Total				1661.8		18604.8			1142.9	21409.5

6.5.3 Number of Recovery and Recycle Rigs

The number of recovery-only units is based on the population of servicing agents in and around the individual town and the national geophysical distribution of existing refrigeration retailing, servicing or contracting companies with sufficient business to purchase the recovery units and operate at a profit. The number of CFC-12 recovery-only units and the number of recycling units recommended by the present report are 32 and 6 respectively.

A minimum of one portable unit for every 5 stations and one recycling plant for every 30 stations were assumed. The number of recovery and recycle equipment were therefore estimated as shown in Table 6.9 .

Table 6.9 : Portable Recovery-only and Recycling Rigs

LOCATION	Assembling and servicing stations	No. of recovery-only rigs (CFC-12)	No. of recycling rigs (CFC-12)
Nairobi	70	14	3*
Mombasa	60	12	2
Kisumu	15	3	1
Nakuru	10	2	0
Eldoret	6	1	0
Total	161	32	6

NB. Eldoret will be served by the unit in Kisumu and Nakuru will be served by the units in Nairobi.

* In Nairobi, being the Capital City of Kenya, 3 recycling Rigs are recommended to deal with market growth nationally.

The above towns will service the surrounding regions quite adequately. Refrigerants recovered from refrigeration systems installed in the smaller centres will be transported by road or rail to the central recycling plants. Figure 6.8 shows the map of Kenya and the locations of the major towns and their catchment areas.

The recovered and cleaned refrigerants would be carried in pressurised containers. Since ambient temperatures in some of the regions of Kenya may rise to 35°C and above, the storage/delivery cylinders would be exposed to various pressures as shown in Table 6.10.

Table 6.10: Designed Pressures for Recovered/Recycled refrigerant cylinders

REFRIGERANT	SATURATION PRESSURE AT 35°C (Bar)	DESIGN PRESSURE (Bar)
CFC-12	8.500	17.000
HCFC-22	13.500	27.000
HFC-134a	8.865	17.730

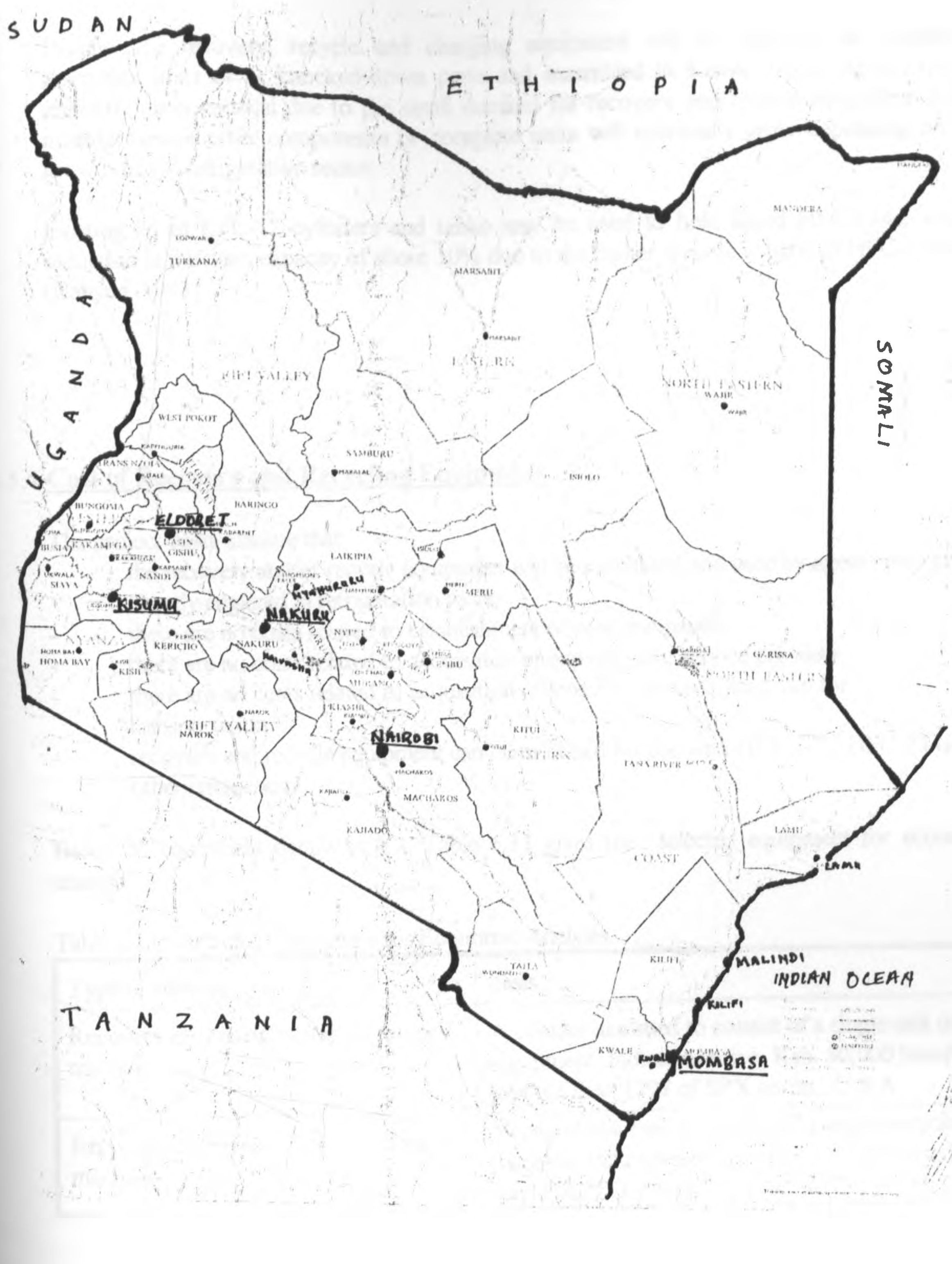


Figure 6.8 : Map of Kenya Showing Location of Major Towns and their Catchment Areas

The facilities and capability for local manufacture of the refrigerant cylinders/tanks are already available in Kenya.

Initially, the recovery, recycle and charging equipment will be imported as completely assembled units or as knocked-down parts and assembled in Kenya. Local manufacture is presently uneconomical due to the small demand for recovery and recycle equipment. Local manufacture of other components or complete units will eventually grow depending on the growth of the refrigeration sector.

Existing liquid CFC-12 cylinders and tanks may be used to hold liquid HFC-134a, with a reduction in the mass capacity of about 10% due to the higher specific volume of HFC-134a. (Kanyua, 1993)

6.5.4 Cost of Recovery and Recycling Equipment

The project costs assume that:

- the recovery and/or recycle equipment will be purchased and used by agents who are already engaged in refrigeration work.
- there are no costs related to establishment of new companies.
- there are no costs related to acquisition or expansion of service premises
- there are no costs related to acquisition of a new or second- hand van for transportation.
- recovery and recycle equipment can be modified for use with HCFC-22, HFC-134a and other refrigerants.

Based on equipment details in 6.2, Table 6.11 gives the selected equipment for economic analysis.

Table 6.11 : Selected Equipment for Economic Analysis.

Type of venture	basis
Recovery only using portable recovery machine	A venture assumed to consist of a single unit of equipment. Indicative price- Ksh. 50,000 based on model OEM 1397 of SPX corpn., U.S.A
Recycling only using static recycling machine	Ventures assumed to consist of a single recycling machine. Indicative price: - Ksh.117,500 based on model RECO 134s of JAVAC RECO AUSTRALIA.

The costs of the ventures are given in Table 6.12

Table 6.12: Cost of Recovery and Recycle Venture (Ksh. Dec. 1995)

	RECOVERY	RECYCLE
Basic cost of equipment	50,000	117,500
Freight and insurance (10%)	5,000	11,750
Customs Duty (25%)	13,750	32,313
VAT (18%)	12,375	29,081
Equipment cost without Duty and VAT	55,000	129,250
Equipment cost with Duty and VAT	81,125	190,644
Delivery Van	Nil	Nil
Number of firms involved	32	6
Total Cost (With Duty and VAT)	2,596,000	1,143,864

NOTES

Delivery van: it is assumed that all registered major servicing agents and contractors who are likely to handle the ventures already have delivery vans.

Exchange rate at time of present study 1USD = 55.5Ksh

6.6 Economic Analysis of Collection, Recovery and Recycling

6.6.1 General Introduction

An important aspect for the success of collection, recovery and recycling programme is that it must provide adequate economic incentive for the personnel/agents involved to motivate them to carry out the programme.

The technology and equipment for recovery and recycling of CFCs in developing countries are now fully developed and brought to a state where the operation and maintenance of these is quite simple. Hence in view of the technical service and expertise available in Kenya, the technology and equipment available for recovery and recycling are appropriate for adoption. This will however require initial training of technical personnel to ensure proper usage and maintenance of the equipment.

The attainable level of reduction in CFC consumption in Kenya in the air-conditioning and refrigeration sector is of the order 41.5 MT(Table 3.16) per annum in 1995. The maximum reduction attainable through recycling would be about 21.4 MT (Table 6.9). This amounts to 49.3% of recharging demand or about 51.2% of attainable level. However with improvement of wastage reduction measures 21.4 MT of CFC-12 attainable is possible.

However the practical and feasible collection rate will depend upon several factors of which the major ones are:-

- Geographical distribution of the equipment from which the refrigerant is to be collected(CFC-12 based equipment are widely dispersed).
- Economic viability of the activity, so that it is self motivating for the service agents to adopt.
- Legislative and other measures introduced by the government of Kenya to induce compliance with the requirement of collection of refrigerant during servicing of equipment.
- Logistics of collection for on site recovery and central recycling

6.6.2 Estimated Cost and Means of Financing the Project

The methodology adopted for economic analysis in this section consist of the viability analysis and will involve the following considerations:-

- The cost for each type of project has been worked out in the local currency and on the basis of latest exchange rates for imports in foreign currency.

- The project life is taken to extend till the year 2010 which is the terminal year for elimination of CFC consumption as defined under the Montreal Protocol.

- It has also been assumed that the recycling equipment and the portable recovery equipment will have a life equal to the project life.

- Operating revenues are computed on the basis of quantity of CFC processed. (i.e. recovered or recycled) and the price to be realised for recovered CFC liquid and recycled CFC in cylinders.

- The typical scale of activity per venture has been based on the present level of activity of the typical service agent who will adopt the venture.

- Further, the level of activity in subsequent years is assumed to follow the same pattern as the aggregate quantity of CFC available for recycling which will of course decline over the years. This has been done to assess the viability of the venture over the first six years of the total project life.

- Operating costs include costs of raw material (in this case CFC collected gas, or CFC collected and condensed). Consumable and spares, power, labour, interest and selling and administrative overheads.

Table 6.13 and Table 6.14 shows the results of the economic viability analysis for recovery and recycling ventures.

It is assumed that the project will be operated at a loan payable within 5 years and at an interest rate of 20% per annum. The loan will involve the cost of equipment plus the first year operation cost. i.e.

recovery venture
loan(Ksh.) = 1,093,800 (operational cost) + 2,596,000 (cost of equipment) = 3,689,800

recycling venture
loan(Ksh.) = 4,457,875 (operational cost) + 1,143,864 (equipment cost) = 5,601,739

Table 6.13: Economic Viability Analysis for Recovery Using Portable Equipment

Description of item	Year					
	1996	1997	1998	1999	2000	2001
quantity of CFC-12 recovered (kg per annum)	21400	21400	21000	20000	18000	16000
Raw material cost						
1) recovered CFC at 0 Ksh per kg	0	0	0	0	0	0
2) spares and consumable						
rate Ksh/Kg	15.5	15.5	17.0	18.5	20.0	21.5
Total Ksh	331700	331700	357000	370000	360000	344000
Total Raw material cost (A)	331700	331700	357000	370000	360000	344000
power						
rate Ksh/kWh	2.5	2.6	2.7	2.8	2.9	3.0
Total cost at 0.1KWh/ kg) (B)	5350	55645	5670	5600	5220	4800
labour						
1)wages						
a) man-hours/ kg	0.3	0.29	0.28	0.27	0.26	0.25
b)wage rate (ksh/man-hour)	50	55	60	65	70	75
c)total wages (Ksh)	321000	353100	352800	351000	327000	300000
2)supervision salaries						
a)man-hours/kg	0.1	0.1	0.09	0.08	0.07	0.06
b)rate (Ksh/man-hour)	100	105	110	115	120	125
c) Total salaries (Ksh)	214000	224700	207900	184000	151200	120000
Total labour cost (Ksh) (C)	535000	577800	560700	535000	478800	420000
overheads						
1)repairs and maintenance (initially at 5% of equipment cost the 10% increment)	88000	95800	106480	117128	128841	141725
2)administrative and selling expenses (20% labour)	107000	11560	112140	107000	95760	84000
3) contingencies (at 5% Labour)	26750	28890	28035	26750	23940	21000
total overhead (D)	221750	241250	246655	250878	248541	246725
estimate cost of operation (A+B+C+D) (E)	1093800	1156314	1170025	1161478	1092561	1015525
expected sales						
rate Ksh/kg	150	150	160	170	180	190
Total sales (F)	3210000	3210000	3360000	3400000	3240000	3040000
gross profit before interest , tax and loan repayment (F-E) (G)	2116200	2053686	2189975	2238522	2147439	2024475
loan repayment (H)	737960	708360	708360	708360	708360	0
Interest 20% (I)	737960	590368	442776	295184	147592	0
tax 2% of sales (K)	64200	64200	67200	68000	84800	60800
operating profit (G-H-I-K) (J)	596080	661158	942039	1137378	1177087	1963675

Table 6.14:. Economic Viability Analysis for Central Recycling Unit

Description of item	Year					
	1996	1997	1998	1999	2000	2001
quantity of CFC-12 recovered (kg per annum)	21400	21400	21000	20000	18000	16000
Raw material cost 1) recovered CFC 2) spares and consumable rate Ksh per kg Total cost	 3210000 25 535000	 3210000 25 535000	 3360000 27.5 577500	 3400000 30.0 600000	 3240000 32.5 585000	 3040000 35.0 560000
Total Raw material cost (A)	3745000	3745000	3937500	4000000	3825000	3600000
power rate Ksh/ kWh Total power cost at 0.1KWh/Kg(B)	 2.5 5350	 2.5 5350	 2.75 5775	 3.0 6000	 3.25 5850	 3.5 5600
labour 1)wages a) man-hours/ kg b)wage rate (Ksh/man-hour) c)total wages(Ksh) 2)supervision salaries a)man-hours/kg b)rate (Ksh/man-hour) c) Total salaries (Ksh) Total labour cost (Ksh) (C)	 0.3 50 321000 0.1 100 2140000 535000	 0.3 55 353100 0.1 105 224700 577800	 0.28 60 352800 0.09 110 207900 560700	 0.27 65 351000 0.08 115 184000 535000	 0.26 70 327600 0.07 120 151200 478800	 0.25 75 300000 0.06 125 120000 420000
overheads 1)repairs and maintenance (initially 5% of equipment cost then 10% increment annually) 2)administrative and selling expenses(20% labour cost) 3) contingencies at 5% labour total overhead (D)	 38775 107000 26750 172525	 42653 115560 28890 187103	 46918 112140 28035 187093	 51610 107000 26750 185360	 56770 95760 23940 176470	 62448 84000 21000 167448
estimate cost of operation (A+B+C+D) (E)	4457875	4515253	4691068	4726360	4486120	4193048
expected sales rate (Ksh/kg) expected total sales(F)	 350 7490000	 350 7490000	 360 7560000	 370 7400000	 380 6840000	 390 6240000
gross profit before interest, tax and loan repayment (F-E) (G)	3032125	2974747	2868932	2673640	2353880	2046952
Loan repayment (H)	1120348	1120348	1120348	1120348	1120348	0
Interest (20%) (I)	1120348	896278	672207	448139	224069	0
tax (2% sales) (K)	149800	149800	151200	148000	136800	124800
operating profit (G-H-I-K) (J)	641629	818754	925177	957153	872663	1922152

5.6.3 Conclusions

The findings of the analysis indicate that given adequate support and with appropriate legislation and institutional strengthening for implementation , viable programmes for recovery and recycling of refrigerant gases can be set up in Kenya. The analysis shows that recovery and recycling in Kenya will be economically viable at the venture level. However the following financial incentive will promote the implementation.

- Exemption of import duty on recovery and recycling equipment.
- Subsidy on equipment cost
- Funding the cost of training programmes on operation
- Funding the public awareness campaign
- Provision for loans at subsidised rates

Based on the venture level viability analysis, the net national economic benefit for adopting a recovery and recycling programme includes:-

- Savings in imports of refrigerants (CFCs)
- Increase in employment measured in terms of increased private investment
- Increased government revenues on duties and taxes

In the context of the findings of the analysis, it is desirable and necessary to introduce regulatory legislative measure regarding various aspects of CFC consumption such as sales, purchasing and conservation, through recovery and recycling. These legislative and regulatory measures would be aimed at achieving the following:-

- Identification of users of CFCs.
- Imposing an obligation on sellers and users to report consumption or utilisation of CFCs.
- Establishing codes of practice for repair/servicing agents.
- Accreditation of service technicians and agents.
- Ensuring proper disposal of equipment containing CFCs.
- Ensuring adoption of recovery and/or recycling equipment.

In order to initiate and implement the above scheme, it is necessary to strengthen the institutional framework in Kenya(see Chapter Seven). This would involve creating proper awareness about the harmful effects of ozone layer depletion and the repercussions of the Montreal Protocol to Kenyan Refrigeration Industry.

CHAPTER SEVEN
FRAMEWORK FOR IMPLEMENTATION.

7.1 Institutional Considerations

All CFCs used in Kenya are imported by about 4 main chemical importers as outlined in Chapter Three. The importers may promote the campaigns on conservation of CFCs but it is unlikely that they would feel obligated to buy back recovered CFCs or financially promote ventures involved in recovery and recycling.

The major promoters of recovery and recycle ventures will be:
- Government of Kenya
- Refrigeration Contractors
- Assemblers of Refrigerators and Freezers
- Retail and Service Agents
- Chemical Importers

For the number of recovery and recycling equipment proposed in chapter six, Kenya has the capacity for developing recovery and recycling programmes and providing technical, financial and managerial support.

7.2 Institutional Framework

This section briefly describes the responsibilities, organisation, functions and capabilities of institutions which are considered to be potential players in the successful implementation of a national policy on CFCs conservation measures such as recovery and recycling programmes.

7.2.1 Ministry Of Finance

The Ministry of Finance is the major Government body controlling, directing, initiating, etc. the economy policies and has a say in the running of all other ministries. The Ministry of Finance has legislative powers with respect to taxes, tariffs, etc. and must be involved if any financial incentives/disincentives are envisaged concerning introduction of refrigerant recovery, recycling and waste reduction measures. The Ministry of Finance has the power of prohibiting importation of certain items and commodities.

The Customs and Excise Department is under the Ministry of Finance. The Customs Department is responsible for enforcing duties and taxes, preventing illegal importation of goods. The recovery and recycling programmes will greatly depend on the ability of the Customs Department providing proper copies of all importation declarations concerning refrigeration equipment and refrigerants to the National Environmental Secretariat. At present the documentation of imported chemicals and machinery/equipment is vague in terms of type, function, capacity and origin of equipment and chemicals.

7.2.2 **Ministry of Agriculture**

The Ministry of Agriculture is responsible for production of food (crops, animals, creameries, etc.), research, extension services etc., which are highly dependent on the use of cold storage facilities and fumigants (e.g. methyl bromide). The following organisations under the Ministry of agriculture will play a big role in the implementation of recovery and recycling programmes:-

- Horticultural Crops Development Authority
- Kenya Agricultural Research Institute
- Kenya Co-operative Creameries

7.2.3 **Ministry of Works**

The Ministry of Works (MoW) is responsible for design, installation and construction, maintenance and servicing of practically all Government premises including the following:

- Hospitals and clinics
- Schools, colleges and training centres
- Offices, hostels and residential premises.

The Ministry of Works is thus responsible for all refrigeration and air-conditioning plants, fire protection equipment, etc. operated by the Government.

7.2.4 **Ministry of Information**

The Ministry of Information has the Department of Information and the Kenya Broadcasting Corporation (KBC) under it. KBC operates television and radio stations which will be essential for Montreal Protocol awareness campaigns on the implications of the CFCs phase-out programme and on the proper use of refrigeration equipment.

7.2.5 **Ministry Of Technical Training And Applied Technology**

The Directorate of Industrial Training which is under this ministry is empowered by the Industrial Training Act Cap. 237 - Laws of Industrial Training Scheme to:

- Collect training levies from industries
- Organise training courses and certification
- Reimburse training fee to firms accepting/providing industrial training

This organisation will play a pivotal role in training of technicians in relation to recovery and recycling equipment.

7.2.6 **The National Environmental Secretariat (NES)**

The NES was created in the mid-70s under the Ministry of Natural Resources and Environment. The functions of NES are:

- to advise the Government on all environmental matters
- to enlighten the public on environmental issues and create awareness on environmental problems

- to advice the Government and industries on the best ways of disposing wastes likely to create environmental hazards
- to undertake and promote research in environmental issues
- to undertake and approve environmental impact assessment of new and old industrial projects before project implementation is permitted
- to represent Kenya on environmental matters in international programmes.

The NES has no enforcement powers itself but can act by giving advice and recommendations to other Government Ministries and Agencies.

A National Committee on ODS was formed under NES. This committee serves the following purposes:
- advises NES and the Government on ODS related matters
- advises Government on policy requirements, legislation, programmes of action, research, institutional strengthening and awareness campaigns

The Committee monitors ODS consumption data and co-ordinates the ODS phase out programmes between the Government, UN organisations, industry, etc.

7.2.7 Directorate of Occupational Health And Safety Services

The Directorate was created in the early 1990's and took over the functions of the former Inspectorate of Factories. The Directorate is established under the Ministry of Labour by an Act of Parliament. The Directorate has offices in all provinces of Kenya and is manned by engineers, chemists, physicists, doctors, etc. The main functions of this Directorate are:
- to implement and enforce the Factories Act
- to inspect factories and other places of work to ensure the premises comply with the applicable laws and standards
- to approve the design and installation of industrial projects
- to advise the Government and industries on the best ways of storage and disposal of chemicals, etc.

The Directorate of Occupational Health and Safety has powers to regulate the use and handling of Controlled Substances.

7.2.8 Other Important Government Institutions

This category includes training and teaching institutions involved in training engineers and technicians.

These institutions should play an important part in the implementation of the proposed recovery and recycling programmes and waste reduction measures through training for the refrigeration and air-conditioning sector. Lack of qualified refrigeration technicians is a major cause of high wastage of refrigerants in Kenya.

7.2.9 Kenya Association of Manufacturers (KAM)

KAM membership embraces all sectors of manufacturing and all sizes of firms. The officials of KAM are elected from among candidates whose firms are members of KAM. KAM has a secretariat in Nairobi.

KAM offers the following services to its members:
- Dissemination of information
- Training of employees of member companies
- Liaison (or lobby) with Government of Kenya departments regarding matters affecting KAM members e.g. tariffs, licensing of businesses, licensing of imports and exports, allocation of foreign currencies, industrial standards, labour laws and relations, etc.
- Liaison with workers unions
- Export promotion
- Others

The local major and medium assemblers of refrigerators and freezers and some of the local refrigeration contractors are members of KAM. KAM has long experience in training which may be used to train refrigeration technicians. KAM is also well-suited to advise on the best way of setting up Association for Refrigeration and Air-Conditioning.

KAM publishes a monthly journal which may be used for disseminating information on trends in the refrigeration and air-conditioning industry.

7.2.10 **Kenya National Chamber of Commerce and Industry**

The National Chamber of Commerce and Industry looks after the welfare of all sectors of business and therefore embraces many firms which will be affected by the changes caused by phasing out CFCs.

The Chamber of Commerce and Industry normally deals with business executives. The Chamber operates a secretariat in Nairobi and have branches in all provinces of Kenya. The Chamber publishes a monthly journal.

The Chamber may therefore be used to reach the management cadre on matters relating to trends in the phase-out of CFCs and their effect on business activities.

Most assemblers of refrigerators, refrigeration contractors, importers of chemicals, exporters of agricultural produce, etc. are members of the Chamber of Commerce and Industry.

7.2.11 **Institution of Engineers of Kenya (IEK)**

IEK embraces all the engineering disciplines in Kenya. The major functions of IEK are:
-Dissemination of information on projects, products, technical knowledge, etc.
-Setting training and professional standards
-Certification/Registration of professional engineers
-etc.

IEK publishes a bi-monthly journal called the Kenya Engineer which covers the above activities. IEK also organises seminars, talks, etc. aimed at bringing its members up to date on engineering topics.

7.2.12 **Architectural Association of Kenya (AAK)**

AAK functions in the same manner as IEK

7.2.13 **Special Interest Groups**

The following special interest groups who are major users of CFCs will play the role of sensitising and advising their members on trends in the refrigeration and air-conditioning sectors:

-Fresh Horticultural Produce Exporters Association of Kenya
-Kenya Association of Hotel Keepers and Caterers
-Kenya Consumers Organisation
-Kenya Association for Refrigeration and Air-Conditioning (KARA)(proposed in this report)

7.2.14 **Kenya Association for Refrigeration and Air-Conditioning (KARA) (Proposed)**

The absence of an organisation bringing together all parties interested in refrigeration and air-conditioning has been identified as a major constrain in setting standards, certification and registration procedures; auditing CFCs consumption; training technicians and dissemination of information. UNEP consultants(UNEP; 1990(i)), UNIDO consultants(UNIDO; 1992) and University of Nairobi (Kanyua; 1993) have strongly recommended the establishment of KARA. The participants of the UNEP Training Workshop held in Nairobi in December 1992 strongly supported the formation of KARA. Most refrigeration contractors, retailers and assemblers have also expressed their willingness to join such an association. This organisation as by 1995 had not been launched.

It is envisaged that KARA would draw its membership from the following areas:
-servicing agents
-refrigeration and air-conditioning contractors
-assemblers/manufacturers of refrigerators
-practising engineers and technicians
-educators and trainers
-institutional members

3 Policy Framework

Existing legislation related to licensing, control and standards for importation, local manufacture and use of chemicals and equipment is considered adequate for implementation of the refrigerant conservation programmes. The relevant sections of legislation and their applications are as follows:

(a) Customs and Excise Act may be used to:
- Restrict importation of CFCs and CFC-operated equipment (restricted substances)
- Keep proper records of chemical and/or trade names of CFCs and other chemicals.

- Raise tariffs on CFCs and CFC-operated equipment as a disincentive for their importation.
- Exempt from duty refrigerant recovery, recycle and charging equipment , voltage stabilisers etc.

(b) The Kenya Bureau of Standards Act may be used to:
- Improve quality control of imported and locally assembled refrigerators and refrigeration systems.
- Set standards for retrofitting technologies.

(c) The Occupational Health and Safety Act may be used to:
- Regulate the quality of refrigeration installations by approval of design and regular inspection.
- Licensing refrigeration inspectors as is done with boiler, compressed air, etc. inspectors.
- Regulate use of fire fighting equipment and degreasing systems based on CFCs.
- Formulate codes of practice for industries using CFCs.

(d) The Ministry of Commerce and Industry in conjunction with other Government Ministries may contribute to refrigerant conservation measures by:-
- Restricting the licensing of refrigeration contractors and service agents to trained and registered technicians.
- Restrict the retail of CFCs to registered suppliers and contractors and service agents only.

Apart from the above legislative acts, the Government of Kenya has already established NES (and the ODS Committee) whose duties are spelt out in the Institutional Framework.

The various personnel, materials policies and modalities for the implementation of conservation programme and long term regulation of use of CFCs already exists and only needs to be put into practice.

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APPENDIX A

ASSESSMENT OF RECOVERY AND RECYCLING OF CFCs IN THE REFRIGERATION INDUSTRY IN KENYA.

Socio-economic survey questionnaire for users, manufacturers/ assemblers, Retailers of domestic refrigerators, retailers of refrigeration equipment, importers of refrigerants, service agents, commercial installations, Government departments and professional bodies

The Department of Mechanical Engineering of the University of Nairobi is carrying out research on the utilisation of Chlorofluorocarbons (CFCs) used as refrigerants in Kenya. CFCs will be phased out as per the Montreal Protocol Schedule, or earlier. The study is intended to facilitate the launching of appropriate legislation and institutional strengthening on efficient systems of recovery, recycling and waste reduction measures of refrigerants in Kenya. Please assist us in our data collection exercise by answering the questions asked in this questionnaire. Strict confidentiality will be observed in using information provided by your organisation.

BASIC

1)Sample number________________________________

2)Name of your organisation __________________________________

3)Physical Location of the organisation________________________
____

4)Town (please tick appropriately)
a)Nairobi
b)Mombasa
c)Kisumu
d)Nakuru
e)Eldoret
f)Other (please specify)__________________________

5)Out of the following which one best describes the nature of your organisation in relationship to CFCs:
a)service agent
b)commercial installation
c)importer
d)user (please specify)
e)Retailer of domestic refrigerators
f)Retailer of refrigeration equipment
g)Government department
h)Professional / Institutional body
i) other (please specify)____________________________

6)How many employees does this organisation have?______________

7) Out of the following sub-sectors which one best describes your organisation.

a) Domestic refrigeration
b) commercial & retail refrigeration
c) cold storage & cold rooms
d) comfort air-conditioning
e) Transport refrigeration
f) Mobile air conditioning
g) Industrial refrigeration
h) Institutional body

8) Name of refrigerants involved with, their sources and purchase/import order quantity (Please tick and fill appropriately).

	Source Company	Source Town	Source Country	Purchase/import order quantity
R12				
R22				
R502				
R500				
R134a				
Ammonia				
Propane				
Methane				
others				

9) Average usage/production/level of imports of refrigerants.

		Current usage			Past usage/import levels		
	Current cost Ksh/kg	Initial charge kg/year	Topping up kg/year	servicing kg/year	1992	1993	1994
R12							
R22							
R502							
R500							
R134a							
Ammonia							
Propane							
Methane							
others							

10) Name of brands of refrigeration dealt with and their sources.

brand	Sub-sector	source	refrigerant used	charging norm	production/ import level

11) How frequent do you get refrigerant shortages which forces you to consume less than you usually do when sufficient refrigerant is available?.

a) About twice every month
b) Once a month
c) Once a year
d) No shortage

12) What type of service equipment do you use for the following service processes?.

	type of service equipment	Model	Make
brazing of the joints			
leak testing			
vacuuming			
Charging			
Temperature sensors			
Flaring process			
Pressure testing			
Performance testing			
Others			

14) List rate in order of merit what you consider as the main causes for most breakdowns of refrigeration plants.

_____Compressor failure due to voltage instability
_____Compressor failure due to ageing
_____Leakage due to punctured evaporator
_____Leakage due to punctured condenser
_____Leakage due to improper brazing/tightening of nuts
_____Malfunctioning of controls (thermostat, wiring etc.)
_____Induced vibrations resulting in breakage of refrigerant tubing
_____Misuse of the unit
_____Others____
____
____

Recovery and recycling

15) In general, would recycling/recovery programs be of

i)Technical/substantive value to you (yes/No)
ii)Relevant to you (yes/No)
iii)of use to you (yes/No)

16)Is your organisation currently involved in the recovery and recycling of refrigerants________________________

If yes please elaborate____

17)Other Comments____

____

____
____

18)The following data would be useful for statistical analysis

Your name ____
Professional background____________________________
Position/function/occupation __________________________

How long have you been in operation___________________
Address/telephone___________________________________
date ____

Thank you for completing this questionnaire

APPENDIX B

ASSESSMENT OF RECOVERY AND RECYCLING OF CFCs IN THE REFRIGERATION INDUSTRY IN KENYA.

Socio-economic survey Checklist for users, manufacturers/ assemblers, Retailers of domestic refrigerators, retailers of refrigeration equipment, importers of refrigerants, service agents, commercial installations, Government departments and professional bodies

The Department of Mechanical Engineering of the University of Nairobi is carrying out research on the utilisation of Chlorofluorocarbons (CFCs) used as refrigerants in Kenya. CFCs will be phased out as per the Montreal Protocol Schedule, or earlier. The study is intended to facilitate the launching of appropriate technical, legislation and institutional strengthening on efficient systems of recovery, reclaim and recycling of refrigerants in Kenya. Please assist us in our data collection exercise by answering the questions asked in this questionnaire.

Basic

1) Sample number ______________________________

2) Name of your organisation ______________________________

3) Physical Location of the organisation ______________________________

____

4) Nature of your organisation in relationship to CFCs: _______

____

_____

Montreal Protocol

5) Have you ever heard of any international controls to protect the Ozone layer?
   - ◊ yes
   - ◊ Unsure
   - ◊ No

6) What do international controls to protect the ozone layer state concerning the use of CFCs?
   - ◊No knowledge
   - ◊Reduction in CFCs
   - ◊Specific Reduction
   - ◊Sudden Phase-out

7) What impact will Montreal Protocol have on your business?
   - ◊ Unsure
   - ◊ No impact
   - ◊ Downturn in business

8) Will Montreal Protocol require you to change working practices

- ◊ yes
- ◊ unsure
- ◊ No

9) How specifically will the Montreal Protocol Controls affect your business?

- ◊ Don't know
- ◊ Modify manufacturing process
- ◊ Use of alternative refrigerants
- ◊ Change production design
- ◊ Discontinue Manufacturing

10) What kind of changes have you already made?

- ◊ Modified manufacturing process
- ◊ Use alternatives
- ◊ Change production design
- ◊ Discontinue manufacturing

11) What happens to the refrigerant to necessitate topping-up?

- ◊ 'Consumed'
- ◊ Leaked out
- ◊ No knowledge

12) How do you dispose of obsolete equipment?____________________

____

_____

13) Is your organisation licensed?______________________________

14) Other Comments____

____

15) The following data would be useful for statistical analysis

Your name ____

Professional background_____________________________

Position/function/occupation ________________________

How long have you been in operation___________________

Address/telephone___________________________________

date ____

Appendix C

List of organisation/persons that answered the questionnaires and checklists.

	Organisation/person contacted	Town located
1.	Premier Refrigeration and Engineering Works limited (Factory)	Nakuru
2.	Premier Refrigeration and Engineering Works limited (Sales office)	Nairobi
3.	Sanyo Armco	Nairobi
4.	Kemco Engineering limited	Nairobi
5.	Integrated cooling equipment	Mombasa
6.	Nairobi Afrigas	Nairobi
7.	Abdulrasal mulla	Malindi
8.	Victoria Contractors	Kisumu
9.	APV hall equatorial	Nairobi
10.	APV hall equatorial	Mombasa
11.	Frametree Refrigeration Contractors	Nairobi
12.	Ezmak refrigeration contractors	Nairobi
13.	Raerex refrigeration contractors	Nairobi
14.	Refrigeration contractors	Nairobi
15.	Refrigeration centre	Nairobi
16.	Gilfillian technical services	Nairobi
17.	Gilfillian technical services	Mombasa
18.	Frigitech limited	Mombasa
19.	Aircotech limited	Mombasa
20.	Elco limited	Mombasa
21.	Newfield refrigeration systems	Nairobi
22.	Refrigeration plumbing and electrical services	Nairobi
23.	Snowpix refrigeration and general contractors	Nairobi
24.	Clean air systems	Nairobi
25.	Hot point appliance	Nairobi
26.	Nairobi technical suppliers	Nairobi
27.	Airflow engineering	Nairobi
28.	City refrigeration and air conditioning services	Nairobi
29.	Electro air flow systems limited	Nairobi
30.	Kooltech engineering company limited	Nairobi
31.	Hotpoint air-conditioners	Nairobi
32.	British Overseas Company (BOC) limited	Nairobi
33.	British Overseas Company (BOC) limited	Mombasa
34.	Hoechst East Africa limited	Nairobi
35.	Twiga chemicals	Nairobi
36.	Twiga chemicals	Mombasa
37.	Refrigeration Contractors	Nairobi
38.	Premier Refrigeration and engineering works limited	Nairobi
39.	Integrated cooling equipment	Nairobi
40.	XYZ cooling equipment	Nairobi
41.	United Nations Industrial Development Organisation (UNIDO)	Nairobi
42.	United Nations Environmental Programme (UNEP)	Nairobi
43.	United Nations Development Programme (UNDP)	Nairobi
44.	United Nations Education Scientific and Cultural Organisation (UNESCO)	Nairobi

45.	United Nations International Children Educational Fund (UNICEF)	Nairobi
46.	Kenya Consumers Organisations (KCO)	Nairobi
47.	Kenya Association of Manufacturers (KAM)	Nairobi
48.	Institute of engineers of Kenya (IEK)	Nairobi
49.	Kenya National Chamber of commerce and industry	Nairobi
50.	Kenya motor industries association	Nairobi
51.	Kenya associations of hotels and caterers	Nairobi
52.	World view international	Nairobi
53.	Agriculture development corporation	Nairobi
54.	Kenya grain growers co-operative union	Nairobi
55.	Kenya Industrial Research Development Institute (KIRDI)	Nairobi
56.	Kenya Bureau of Standards (KBS)	Nairobi
57.	National Environmental Secretariat (NES)	Nairobi
58.	Kenya Agricultural Research Institute (KARI)	Nairobi
59.	Kenya energy and environmental organisation	Nairobi
60.	Kenya meteorological department	Nairobi
61.	Ministry of works - Superintendent Engineer	Nairobi
62.	Ministry of works - Chief Chemist	Nairobi
63.	Ministry of research science and technology- Senior research officer (Chemist)	Nairobi
64.	Ministry of industry - Registrar of industries	Nairobi
65.	Ministry of industry - Director of industries	Nairobi
66.	Ministry of Agriculture-Horticulture crops development authority	Nairobi
67.	Ministry of agriculture - Kenya co-operative Creameries (KCC)	Nairobi
68.	Ministry of finance - Customs and exercise department	Nairobi
69.	Ministry of finance - Customs and exercise department	Nairobi
70.	Kenya Broadcasting Corporation (KBC)- marketing department	Nairobi
71.	Kenya ports authority	Nairobi
72.	Central Bureau of Statistics (CBS)	Nairobi
73.	Directorate of industrial training	Nairobi
74.	Directorate of occupational health and safety services	Nairobi
75.	Kenya Navy - Mombasa	Nairobi
76.	Maline refrigeration company limited	Nairobi
77.	Alphonso refrigeration enterprises	Nairobi
78.	Daikin Kenya limited	Nairobi
79.	Kingsway radio and refrigeration	Nairobi
80.	Qualitrade air technical services	Nairobi
81.	Hermetic refrigeration	Nakuru
82.	ABBA refrigeration	Nakuru
83.	Refrigeration electrical services	Nakuru
84.	Mobile refrigeration services	Nakuru
85.	Donline refrigeration	Nakuru
86.	Alltech services	Nakuru
87.	Colltech services	Mombasa
88.	Kenya Cold storage	Nairobi
89.	refrigeration distributors limited	Nairobi
90.	refrigeration distributors limited	Nairobi
91.	Deep refrigeration Delta refrigeration GR services	Nairobi
92.	Gram Africa limited	Nairobi
93.	John's refrigeration	Nairobi

94.	Liquid air services	Nairobi
95.	Mandannis refrigeration electrical works	Nairobi
96.	McGeorge electrical and refrigeration services	Nairobi
97.	Mountain dew electrical and refrigeration systems	Nairobi
98.	Refrigeration components	Nairobi
99.	SVR electrical services	Nairobi
100.	Spring valley refrigeration and electrical services	Nairobi
101.	Sub zero systems	Nairobi
102.	Caravel refrigeration services	Nairobi
103.	Tech refrigeration	Nairobi
104.	Thomsons engineering company limited	Nakuru
105.	Universal engineering systems limited	Eldoret
106.	AL;s refrigeration company	Eldoret
107.	East end refrigeration services	Eldoret
108.	Factory refrigeration and power controls	Nairobi
109.	Fast refrigeration and electrical engineers	Nairobi
110.	Kenya refrigeration and air-conditioning company limited	Nairobi
111.	No-frost refrigeration services	Nairobi
112.	Phoneway (K) limited	Nairobi
113.	Ponty pool enterprises	Nairobi
114.	R and G electric limited	Nairobi
115.	Ref cold refrigeration	Nairobi
116.	Refrigeration systems limited silver refrigeration services	Nairobi
117.	Ngei estate electronics and refrigeration	Nairobi
118.	Aircon Electro services	Nairobi
119.	Bhamber refrigeration and electrical limited	Kisumu
120.	Ezemak electronics refrigeration	Kisumu
121.	Joemak refrigeration services	Kisumu
122.	Principal refrigeration and electrical services	Kisumu
123.	Wishborne refrigeration and electrical suppliers	Kisumu
124.	Nyanza refrigeration services	Kisumu
125.	New field refrigeration and contractors	Nairobi
126.	Amar engineering works	Nairobi
127.	Alltech services	Nairobi
128.	housewife choice refrigeration service	Nairobi
129.	Nyali refrigeration services	Mombasa
130.	And cool services	Mombasa
131.	Sincere refrigeration	Mombasa
132.	Mtwapa refrigeration services	Mombasa
133.	Make cool services	Mombasa
134.	Hamid electrical services	Mombasa
135.	likoni refrigeration services	Mombasa
136.	Bamburi ice makers	Mombasa
137.	Heshima refrigeration services	Mombasa
138.	Jadini electrical services	Mombasa
139.	Kilifi refrigeration services	Mombasa
140.	Malindi electrical and refrigeration services	Mombasa
141.	Abdube electrical services	Kisumu
142.	Victorial electrical services	Kisumu
143.	Huruma refrigeration services	Eldoret

144.	Bluefish refrigeration services	Kisumu
145.	Shah electronics	Kisumu
146.	G.J Patel cooling services	Kisumu
147.	Oginga electronics	Kisumu
148.	African Maline and mala engineering	Mombasa
149.	Abdulrasal refrigeration	Mombasa
150.	Habib air-conditioners	Nakuru
151.	Nyali air conditioners	Nairobi
152.	Herald engineering enterprise	Nairobi
153.	Refrigeration people	Nairobi
154.	Central refrigeration services	Mombasa
155.	Sodomite refrigeration	Nairobi
156.	Brilliant refrigeration	Malindi
157.	Fast cool services	Kisumu
158.	Visions electronics	Nairobi
159.	Namecoll services	Mombasa
160.	Gachari refrigeration services	Nairobi
161.	Refrigeration services	Nairobi
162.	Baking electroservices	Nairobi
163.	Bureau Refrigeration and electrical services	Nairobi
164.	G and G electronics	Nairobi
165.	Wachira electrical services	Nairobi
166.	Kims electrical and plumbing services	Mombasa
167.	EN refrigeration	Nakuru
168.	Armaflex refrigeration	Mombasa
169.	Kagemi refrigeration services	Nairobi
170.	Githurai refrigeration and electrical services	Nairobi
171.	Ruiru refrigeration services	Nairobi
172.	Lower valley refrigeration systems	Nairobi
173.	Kariombangi refrigeration services	Nairobi
174.	equal zero services	Nairobi
175.	Recool services	Nairobi
176.	Langalanga refrigeration services	Nairobi
177.	Kibera refrigeration	Nairobi
178.	Line7 services	Nairobi
179.	Uasi Gishu electrical	Eldoret
180.	Sarakwa services	Eldoret
181.	Coolant services	Kisumu
182.	Heat cool services	Mombasa
183.	Kisauni refrigeration	Nairobi
184.	Nyali electrical	Mombasa
185.	real refrigeration services	Mombasa
186.	McZero services	Nairobi
187.	Downtown electrical services	Nairobi
188.	Omondi refrigeration	Nairobi
189.	Parts refrigeration	Nairobi
190.	Oceanic refrigeration	Nairobi
191.	Labcool refrigeration	Nairobi
192.	Tours refrigeration services	Mombasa
193.	Yusuf technical services	Mombasa

194.	Bare electronics	Nairobi
195.	Old chief electrical	Nairobi
196.	Kedowa hermetic	Kisumu
197.	Shankar	Mombasa
198.	Dibeco	Mombasa
199.	Radiocraft	Mombasa
200.	Austin and patners	Mombasa
201.	East Africa electronics	Nairobi
202.	East Africa electronics	Nairobi
203.	Crystal Kitchens	Nairobi
204.	Uchumi Supermarkets	Nairobi
205.	Discovery electronics	Nairobi
206.	P.G Punjabi	Nairobi
207.	A to Z electronics	Nakuru
208.	Bakers Music corner	Nakuru
209.	African retail traders	Nairobi
210.	Kukopesha	Nairobi
211.	Sincere trading company	Nairobi
212.	Kassin Kanji	Nairobi
213.	Mombsa law courts	Mombasa
214.	African tours and travels	Mombasa
215.	Jadini beach hotel	Mombasa
216.	Nairobi Serena hotels	Nairobi
217.	Kenya oil refineries	Nairobi
218.	Farmers choice	Nairobi
219.	East Africa industries	Nairobi
220.	Bidco oil refineries	Nairobi
221.	Pan Africa paper mills (EA) limited	Nairobi
222.	Pyrethrum board of Kenya	Nakuru
223.	Cadbury Kenya Limited	Nairobi
224.	Kenya fruit processors	Nairobi
225.	New Stanley hotel	Nairobi
226.	Ronny's supermarket	Nairobi
227.	elephant soap industries Kamsons limited	Nairobi
228.	Crown cork (Co.) limited	Nairobi
229.	Ebrahim Ali Salim limited	Nairobi
230.	Johnson's wax (EA) limited	Nairobi
231.	Toyota Kenya	Nakuru
232.	General motors	Nairobi
233.	Associated vehicle assemblers	Mombasa
234.	Bobmil industries	Nakuru
235.	Foam plastics	Nakuru
236.	Kenya railways	Mombasa
237.	Fresh produce exporters	Nairobi
238.	Broke board Kenya	Nairobi
239.	Coca cola bottling company	Nairobi
240.	Pepsi bottling company	Nairobi
241.	Flamingo bottlers	Nakuru
242.	Coast bottlers	Mombasa
243.	Kisii bottlers	Kisii

244.	Equator bottlers	Kisumu
245.	Rift valley bottlers	Eldoret
246.	Mt. Kenya bottlers	Nyeri
247.	Kenya breweries limited	Nairobi
248.	Car and general	Nairobi
249.	Uchumi supermarket	Nakuru
250.	Gilani supermarket	Nakuru
251.	Majic superstores	Nakuru
252.	Sita supermarket	Nakuru
253.	Administration office - Sarit shopping centre	Nairobi
254.	Musikland	Eldoret
255.	City breweries limited	Nairobi
256.	African superbutchery	Eldoret
257.	Haji Yusuf bros. company	Nairobi
258.	Hilal butchery	Nairobi
259.	Housewives butcheries	Nairobi
260.	Hurlingham butchery	Nairobi
261.	Jericho butcheries	Nairobi
262.	Mum's choice butchery	Nairobi
263.	Highland canners	Nairobi
264.	Kabazi canners	Nakuru
265.	Kenya orchards limited	Nairobi
266.	Sprinridge foods company limited	Nairobi
267.	Chemigas limited	Nairobi
268.	Beka chemicals	Kisumu
269.	Catalyst chemicals	Kisumu
270.	ICI limited	Nairobi
271.	Henkel chemicals (EA)	Nairobi
272.	KEL Chemicals limited	Kisumu
273.	Lyntons pharmacy limited Dodhia foam limited	Kisumu
274.	Utopia natural foods	Nairobi
275.	Carbacid (CO_2) limited	Nairobi
276.	Procter and Gamble (EA) limited	Nairobi
277.	AAR health services	Nairobi
278.	Lyons maid (EA) limited	Mombasa
279.	Boston industries	Mombasa
280.	Chemicals and solvents (EA) limited	Mombasa
281.	Africana sea lodge	Mombasa
282.	Grand holiday hotel	Mombasa
283.	Nairobi Safari club	Nairobi
284.	Hotel Sirikwa	Eldoret
285.	Polana hotel	Mombasa
286.	Serena beach hotel	Mombasa
287.	Nakumatt holdings	Nairobi
288.	Muthaiga mini market	Nairobi
289.	Across Africa tours	Mombasa
290.	Comfort tours	Mombasa
291.	Simba safaris	Kisumu
292.	Action palace hotel	Eldoret
293.	Alakapa hotel	Kisumu

294.	Bullhead hotel buffallo spring	Kisumu
295.	Hotel kunste	Nakuru
296.	Eldoret valley hotel	Eldoret
297.	Imperial hotel	Eldoret
298.	Tokyo piccannony hotel	Mombasa
299.	Cussons and company limited	Nakuru
300.	East Kenya bottlers	Machakos
301.	New colen mini market	Nakuru
302.	Chartur electronics	Nairobi
303.	Electroworks	Mombasa
304.	Sangyong motors	Nairobi
305.	Esmail abdullahi and sons	Malindi
306.	Habib African bank limited	Kisumu
307.	Chandaria paper mills	Nairobi
308.	Alibhai shariff and sons	Mombasa
309.	Kenya polytechnic	Nairobi
310.	Mombasa polytechnic	Nairobi
311.	Kenyatta university	Nairobi
312.	Jomo kenyatta university of Agriculture and technology	Nairobi
313.	Student welfare authority - Nairobi university	Nairobi
314.	Tropical environment consultants	Nairobi
315.	pullman international hotels	Mombasa
316.	Goro consulting engineers	Nairobi
317.	Naciti engineers	Nairobi
318.	National youth service	Mombasa
319.	Nairobi city Council	Nairobi
320.	Municipal council of Mombasa	Mombasa
321.	Municipal council of Kisumu	Kisumu
322.	Municipal council of Nakuru	Nakuru
323.	Municipal council of Eldoret	Eldoret
324.	Municipal council of Thika	Thika
325.	Southern engineering company	Mombasa
326.	Maritime engineers	Mombasa
327.	Bark chemist	Nairobi
328.	Joseph Wandaka	Nairobi
329.	James wahome	Nairobi
330.	G. Gachoka	Nairobi
331.	Abdul Rahim	Mombasa
332.	S.sivaraj	Nairobi
333.	S.J. Shah	Nairobi
334.	Leonard Njau	Mombasa
335.	Eliud Kimaro	Nairobi
336.	Njiraini Njoroge	Nairobi
337.	Naushad A. Tejani	Nairobi
338.	Dr. David Okioga	Nairobi
339.	Mr.Joseph Lelei	Nairobi
340.	J.M. Chege	Nairobi
341.	Peter Kariuki Nyahoro	Nairobi
342.	Peter M Karanja	Nairobi
343.	M Waimiri	Nairobi

344.	Francis P. Gachago	Nairobi
345.	Bernard Oloo	Nairobi
346.	Reuben Mugo	Nairobi
347.	G.H. Olum	Nairobi
348.	Shadrack Amakoye	Nairobi
349.	Dr. Z.A Ogutu	Nairobi
350.	L. Gatumu	Nairobi
351.	Mark kariuki	Nairobi
352.	Moses Mwangi	Nairobi
353.	Peter Njenga Warukira	Nairobi
354.	Wahida Shah Patna	Nairobi
355.	Joice Wangechi	Nairobi
356.	Elizabeth Kunguru	Nairobi
357.	Jesinta Muthoni	Nairobi
358.	James Gachari	Nairobi
359.	Joseph Wachira	Nairobi
360.	Edward Makogha	Nairobi
361.	Joseph Kuria	Nairobi
362.	Paul Ongechi	Nairobi
363.	Leonard Malava	Nairobi
364.	Mohammed Ikotsi	Nairobi
365.	Ali Hassan	Nairobi
366.	Joel Koech	Nairobi
367.	Etta Mmangisu	Nairobi
368.	Davlin Chokazinga	Nairobi
369.	Oladele Oladipupo	Nairobi
370.	Mohammed Moktar	Nairobi
371.	Komla Emoe	Nairobi
372.	Emmanuel Werabe	Nairobi
373.	Mathias Banda	Nairobi
374.	Wilson Ndhovu	Nairobi
375.	Hawinga Hangwele	Nairobi
376.	Lawrence Mwangi	Nairobi
377.	Esphan Nganga	Nairobi
378.	Susan Wachira	Nairobi
379.	Loyce C.M.lema	Nakuru
380.	Christian Carlson	Nakuru
381.	Gilly M Bankobesa	Nakuru
382.	Pro. Mathias Bredesen	Nakuru
383.	Rajedra M. Shende	Nakuru
384.	David wally	Nakuru
385.	Laura B. Campbell	Mombasa
386.	P.S.low	Nairobi
387.	K.Madhava Sarma	Nairobi
388.	Joice Ndoro	Nairobi
389.	Baraza Taabu	Nairobi
390.	Kiarie Charles	Nairobi
391.	Mutua Ndwiga	Nairobi
392.	Kipyegon Tanui	Nairobi
393.	Ronald S Bwoge	Nairobi

394.	John Wakulu	Nairobi
395.	Mboya Mungena	Nairobi
396.	Amadani Aman	Nairobi
397.	Ahmed Bare	Nairobi
398.	Anatol Hemed	Nairobi
399.	Tataq Singh	Nairobi
400.	Matan Kiyondi	Nairobi
401.	Alex Maina	Nairobi
402.	George Mutegi	Nakuru
403.	Mulei Muthiiani	Eldoret
404.	Kimilu J. Riungu	Eldoret
405.	Hilary Chebet	Eldoret
406.	Omar Najib	Nairobi
407.	Martime Omondi	Nairobi
408.	C.J. Mitei	Nairobi
409.	Austin Onyango	Nairobi
410.	J.S. Patel	Nairobi
411.	Najra Singh	Nairobi
412.	Mehed rao	Nairobi
413.	Stephen Kungu	Nairobi
414.	Gregory Milsoi	Nairobi
415.	Michael Odero	Nairobi
416.	Janet Wanja	Nairobi
417.	James Karanja	Kisumu
418.	Monica Waithira	Kisumu
419.	Edward Muge	Kisumu
420.	Jackline Wangui	Kisumu
421.	Thomas Riunda	Kisumu
422.	Hannington Ndui	Kisumu
423.	Bilha Nyokambi	Nairobi
424.	Evans Mawengo	Nairobi
425.	F. Gitonga	Nairobi
426.	Joseph Mwalili	Nairobi
427.	C.J. Shah	Mombasa
428.	Joice Maranga	Mombasa
429.	Pter Rihard Davey	Mombasa
430.	Evans Awori	Mombasa
431.	Michael F. Rex	Mombasa
432.	Rexford Osei	Mombasa
433.	C.Osano	Mombasa
434.	Michael Maina	Mombasa
435.	Isaak Maingi	Mombasa
436.	Clement Gaye	Mombasa
437.	Bulbe A Ouma	Mombasa
438.	Duncan Irungu	Mombasa
439.	Samuel Mutuku	Kisumu
440.	Bernard Kiptoo	Kisumu
441.	Samwel Asanyo	Eldoret
442.	Joel Kibe	Kisumu
443.	Martha Nyokambi	Kisumu

444.	Mary Phoebe	Kisumu
445.	Eliud Muchiri	Kisumu
446.	Rachael Nyambura	Mombasa
447.	Bernard Kiama	Mombasa
448.	Luke Njube	Mombasa