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UNIDO PROGRAMME TO ASSIST THE DEVELOPING COUNTRIES MEET THE REQUIREMENTS OF INTERNATIONAL AGREEMENTS TO PROTECT THE OZONE LAYER

US/RAF/90/173

AFRICA REGION

Technical report: Techno-economic assessment of the financial viability of the collection and safe disposal of refrigerant gases and related material - background analysis**

Prepared for the Governments of the Africa region

Based on the work of John Horberry, environmental expert

Backstopping officer: Paul Wiedemann Feasibility Studies Branch

* Reissued for technical reasons.

** This document has not been edited.

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1. INTRODUCTION

1.1. INVENTION OF CFCs

CFCs were invented to serve the refrigeration sector and first applied commercially in ice cream storage units. [1] Because of their relative chemical inertness and general low toxicity, CFCs have since found a wide range of industrial utilizations, ranging from cooling through solvents to aerosol propellants.

1.2. CONCERN OVER THEIR ENVIRONMENTAL IMPACT

In the 1970s electron capture gas chromatography measurements showed that these components were accumulating in the atmosphere, where the radiation from the sun then released reactive chlorine atoms from these modules. This, in turn, could reduce stratospheric ozone through a series of rapid chemical reactions in which the chlorine atoms were continually regenerated. In this way the stratospheric ozone's ability to screen out harmful ultraviolet solar radiation before it reaches the earth.

In addition to this, CFCs are also generally held to be responsible for some one fifth of global warming.

Accumulating international concern culminated in the Vienna Convention to the Protection of the Ozone Layer in 1985, and subsequently the Montreal Protocol on Substances that Deplete the Ozone Layer signed in 1987. The Protocol entered into force in 1989 and was strengthened in London in 1990.

1.3. UNIDO's PROPOSED DRAFT PROGRAMME

As a contribution to these efforts, UNIDO has attempted to identify those general areas of assistance to developing countries which fall within the Organization's capability and mandate, and which they require if they are to comply with the Montreal Protocol. These

1. This chapter draws on UNIDO, 1990.

programmes could cover, inter-alia: technical assistance; technology transfer and development; industrial human resource development; pre-investment analysis; institutional building; information collection, processing and dissemination; technical and economic conversion and rehabilitation of existing industrial enterprises; activities in internal environmental assessment focusing on UNIDO itself; and other supporting activities.

As a hallmark of any such proposals, UNIDO would follow the first principle of a general agreement proposed by the Executive Director of UNEP as the basis for the development of a financial mechanism to enable the developing countries to meet the requirements of the Montreal Protocol: "first and foremost, in order to ensure global co-operation, a new funding mechanism must be established and its funds must be additional to existing development assistance". UNIDO's development of this present, proposed programme also follows from another principle of the UNEP Executive Director in his presentation to the February/March 1990 second session of the second meeting of the Open-ended Working Group of the Parties to the Montreal Protocol in which he argued that "the mandate and experience of various organizations should be utilized in a joint venture".

For this reason UNIDO makes every effort to co-operate and discuss its programme of work with UNEP, the Environmental Division of the World Bank, the US Environmental Protection Agency and other environmental organizations.

With this background, UNIDO has designed a draft programme based on the strategy of appraising the short-, medium- and long-term costs and benefits for the developing countries related to complying with the requirements of the Montreal Protocol. The outputs of the programme have been conceived so as to demonstrate to the governments that the nature of the assistance being delivered and proposed would be supplementary to existing assistance and act as a catalyst to further, sustainable industrialization.

This programme has been very carefully designed so as to guarantee the maximum degree of flexibility to potential donors. This allows them to develop precisely that package of assistance which most closely corresponds to their priorities and preferences, while at the same time ensuring that the developing countries receive the greatest possible access to alternative sources of financing for their development. For this reason the global programme has a matrix structure, allowing - as the accompanying diagramme shows - twelve different potential packages of assistance.

The matrix - based, UNIDO draft programme is presented below:

UNIDO PROGRAMME AND ITS SUB-PROGRAMME

	Collection, Recycling and/or safe Disposal Analyses	Incremental Cost Analysis		*Design Engineering*	*Supporting Activities*
		Cooling	*Other sub-sectors*		
AFRICA	„a"				
ASIA					
LATIN AMERICA					

In implementing this programme full utilization will be made both of the experience of UNIDO in investment analysis as well as in assessing technological opportunities and in evaluating environmental technologies.

1.4. *SUB-PROGRAMME FOR COOLING IN AFRICA*

While CFCs can be used as blowing agents for foams, as coolants, solvents, propellants in aerosols, and sterilants. Of these, it is as coolant fluids in refrigeration and air conditioning equipment that CFCs are most present in Africa. This sub-sector was therefore chosen as the subject for this pilot programme.

From within this draft programme, the initial pilot programme under implementation is "a" of the above diagram of the draft programme, of which this report is the first output. On the following flow chart, this is stage 2, stage 1, having already been carried out in a number of countries and presently underway in others in cooperation between the national environmental agencies and various international agencies.

TABLE 1.1.

SUB-PROGRAMMES FOR APPRAISING REPLACEMENT TECHNOLOGIES IN COOLING EQUIPMENT IN AFRICA

STAGE

1. *Industrial Country Studies for the Signature to the Protocol*

   Overall picture of CFC situation in individual countries.

   ↓

2. *Industrial Sub-sector Background Analyses*

   Detailed analyses of the sector where the greatest impact could be made. In Africa, this is the cooling sector and in particular the gases utilized in this cooling equipment.

   ↓

3. Techno-economic Appraisal

   Analysis of the financial and technical viability of collecting, recycling and/or safely disposing of cooling gases.

   ↓

4. *Identification of Industrial Enterprises producing/assembling CFC-based Products.*

   Identified assemblers of refrigeration, interviewed the companies, selected candidates for later stages.

   ↓

5. ***Development of Methodology to Appraise Techno-economic Viability and Costs of Substituting Technology:***

Based on existing feasibility analyses methodology and software for feasibility analyses, create modified method for assessing viability of substituting non-CFC-based technology in existing cooling equipment plant.

↓

6. ***Test Methodology***

Carry out replacement feasibility study in 2 of the enterprises identified earlier to determine cost of replacement.

↓

7. ***Revise Methodology and Computer Software***

On the basis of the field tests, revise the methodology for appraising the viability and cost of substituting non-CFC-based technologies.

↓

8. ***Determine the Cost of Substituting Technologies***

Analyse the cost of substituting the technologies.

↓

9. ***Funding the Technology Substitution:***

Provide above results to funding bodies for calculating and determining funding of substitution of CFC substitute technologies.

Stage 3 of the sub-programme is presently being initiated and will generate Stage 4 as one of its outputs.

These outputs are all financed under project *US/RAF/90/173 by the Government of Sweden.*

Stages 5 through 8 are part of the outputs of a new project entitled *"The Methodological Development, Design and Pilot Implementation of a Programme of Conversion Investment Analyses to Assist the Developing Countries Meet the Requirements of the Montreal Protocol new project document US/GLO/91/xxx"* presently being submitted for financing. Copies of the proposal are available from the UNIDO Secretariat. (UNIDO, IO/OS/FEAS, P.O. Box 300, Vienna, A-1400, Austria, Telephone: 21131 extn. 3396, Fax: 232156)

In calculating the cost of substituting technologies,(stages 8 and 9 UNIDO will follow closely the work on calculating incremental cost of the World Bank (World Bank 1991), and other co-operating parties in the Multilateral Fund of the Montreal Fund.

1.5. CONCLUSION

UNIDO hopes that the present "Background Analysis" will make a contribution to the efforts of the international community to assist the developing countries to meet the requirements of the Montreal Protocol.

2. CFCs, THE MONTREAL PROTOCOL

2.1. OBJECTIVE

- To provide an outline for a national audit of CFC utilization in African countries, guidelines regarding data collection on national CFC utilization, and to suggest a structure of a regional policy-making oriented data bank on CFC utilization in Africa.

- To outline the structure of the techno-economic assessment needed and provide generalized policy guidelines for the implementation of programmes to collect and recycle or dispose safely of CFCs used in the refrigeration industry in the countries of Africa as a whole.

The report is structured in the following way:

- Section 1
    - Background to the report, the Montreal Protocol and CFC consumption in Africa.

- Section 2
  - An outline of a national economic audit of CFC consumption and utilization in an African country.
  - Sources and collection of data and information for the analysis of CFC utilization in Africa.
  - The structure of a regional, policy-making oriented data bank on CFC utilization in African countries.
- Section 3
  - A proposed analytical structure for the techno-economic analysis necessary to assess the viability of programmes for the collection, recycling and/or safe disposal of refrigerant gases and allied materials containing CFCs.
  - Identification of types of guidelines and policy measures necessary for the successful introduction of collection, recycling and/or disposal systems.

2.2. BACKGROUND: THE MONTREAL PROTOCOL AS IT APPLIES TO REDUCING CFC CONSUMPTION IN AFRICAN COUNTRIES

The Montreal Protocol defines CFC consumption in terms of the quantity available to a country for utilization; this definition assumes that all available CFCs will eventually be vented to the atmosphere, and their consumption therefore threatens to deplete stratospheric ozone. Consumption is defined as:

Production + (Imports - Exports) - Destruction by approved means.

The Montreal Protocol controls the consumption of two groups of chemicals, CFCs and Halons, to which carbon tetrachloride and methyl chloroform were added in 1990. Consumption is measured in tonnes multiplied by the relative ozone depleting potential (ODP) of the chemical in question.

Group I Substances	**Chlorofluorocarbons**	**ODP relative to CFC-11**
CFC-11	Trichlorofluoromethane	1.0
CFC-12	Dichlorodifluoromethane	1.0
CFC-13	Chlorotrifluoromethane	1.0
CFC-111	Pentachlorofluoroethane	1.0
CFC-112	Tetrachlorodifluoroethane	1.0
CFC-113	Trichlorotrifluoroethane	0.82
CFC-114	Dichlorotetrafluoroethane	0.76
CFC-115	Chloropentalfluoroethane	0.43
CFC-211,)		
CFC-212,)		
CFC-217)		1.0
Group II Substances	**Halons**	**ODP relative to CFC-11**
Halon-1211	Bromochlorodifluoromethane	3.0
Halon-1301	Bromotrifluoromethane	10.0
Halon-2402	Dibromotetrafluoroethane	6.0
Group III		**ODP relative to CFC-11**
Carbon tetrachloride		1.1
Methyl chloroform	1,1,1-tetrachloroethane	0.1

The Protocol requires each Party that is a developing country where CFC consumption per capita is less than 0.3 kg/year, and remains so until 1999, to phase out CFC consumption according to the following schedule (taking average consumption over the period 1995 to 1997 inclusive as the baseline level for complying with the Protocol):

1999	*freeze CFC consumption at baseline level of consumption*
2003	*reduce CFC consumption to 80% of baseline level*
2005	*reduce CFC consumption to half of baseline level*
2010	*zero CFC consumption*

All Parties are required from 1990 to ban CFC imports from non-parties and by 1993 to ban CFC exports to non-Parties. Parties are also obliged to provide data on national CFC production, imports and exports to UNEP in Nairobi within three months of ratifying the Protocol.

By 15 March 1991 the following African countries had ratified the Montreal Protocol:

♦ *Burkina Faso*	♦ *Kenya*	♦ Ghana
♦ *Cameroon*	♦ *Libya*	♦ *Tunisia*
♦ *Egypt*	♦ *Malawi*	♦ *Uganda*
♦ *The Gambia*	♦ *Nigeria*	♦ *Zambia*

Table 2.1. shows approximate CFC consumption per capita and CFC emissions to the atmosphere for African countries for which data is available.

TABLE 2.1.

CFC Utilization in Selected African Countries, 1986 Estimates

Country	Party to Montreal Protocol	CFC Consumption per capita in 1986 (kilograms)	Atmospheric CFC Emissions: Net Increase in 1986 (thousand tonnes)
Algeria		0.1	2.3
Congo		0.0	
Cote d'Ivoire		0.1	1.1
Egypt	Yes	0.1	2.9
Gabon		0.0	
Ghana	Yes	0.1	1.4
Kenya	Yes	0.0	
Liberia		0.1	0.2
Morocco		0.0	
Nigeria	Yes	0.1	10.2
Senegal		0.1	0.7
Togo		0.0	
Tunisia	Yes	0.1	0.8
Zaire		0.0	
Zimbabwe		0.1	0.9

Source: World Resources Institute, 1991

In addition to the above data, recent reconnaissance undertaken by the World Bank indicates that annual CFC consumption in Cameroon, Ghana, Kenya and Nigeria is currently in the range 0.1-02 kg per capita. Nigeria uses approximately 3,000 tonnes/year while the other three countries use 150-300 tonnes/year each. Egypt's consumption of

CFCs was 2,375 tonnes in 1989. By comparison with developing countries outside Africa, Mexico's CFC consumption was 8,128 tonnes in 1989 and India's was around 10,000 tonnes in 1990. Table 2.2 shows approximate CFC consumption per capita in selected non-African countries.

Table 2.2.

CFC Utilization in Selected Non-African Countries, 1986 Estimates

Country	CFC Consumption per Capita in 1986 (kilograms)	Atmospheric CFC Emissions: Net Increase in 1986 (thousand tonnes)
Argentina	0.1	3.1
Australia	0.8	12.0
Brazil	0.1	8.9
China	0.0	18.0
Czechoslovakia	0.1	1.6
Germany, Federal Rep.	0.9	42.9
India	0.0	0.4
Japan	0.5	57.5
Mexico	0.1	5.2
Singapore	0.8	2.1
Trinidad and Tobago	0.3	0.4
Turkey	0.1	5.3
United Arab Emirates	0.9	1.3
United Kingdom	0.9	40.3
United States	0.8	197.4
USSR	0.4	101.0

Source: **World Resources Institute, 1991**

2.2.1. WORLD SECTORAL CFC CONSUMPTION

CFCs are multipurpose chemical,s utilized in a number of sectors, their principal applications being in refrigeration and air conditioning, aerosols, foam blowing and as solvents in the electronics and metal cleaning industries. The proportion of world CFC consumption by region and by sector for the year 1986 is shown in Table 2.3. It can be seen that refrigerants, aerosol propellants and foam-blowing agents each account for about a quarter of the global consumption of CFCs. It should be noted that in Eastern Europe ammonia is the primary refrigerant rather than CFCs.

TABLE 2.3.

1986 Global Consumption of CFCs

Region	Percentage	Sector	Percentage
Africa	1%	Refrigeration/AC	14%
Asia/Pacific	18%	Mobile AC	11%
Latin America	3%	Aerosols	26%
North America	35%	Plastic Foams	26%
Eastern Europe	11%	Solvents	16%
Western Europe	32%	Miscellaneous	7%
Source:	UNEP, 1989		

The global production of domestic fridges and freezers in 1987 was estimated to be over 58 million units, and the corresponding consumption of CFC-12, the commonest domestic refrigerant, to be in excess of 8,400 tonnes, or about 2% of world production. Table 2.4 shows these figures broken down by region.

TABLE 2.4

1987 GLOBAL PRODUCTION OF DOMESTIC REFRIGERATORS AND FREEZERS AND ASSOCIATED CFC-12 CONSUMPTION

Region	Number of Units	CFC-12 Consumption (tonnes)
Africa	1,335,000	210
Asia (except China)	13,644,000	1910
China	3,980,000	600
Eastern Europe	11,251,000	1570
Western Europe	14,200,000	1990
Oceania	550,000	80
South America	2,937,000	500
USA and Canada	9,085,000	1550
World	58,076,000	8410

Source:UNEP, 1989

The worldwide number of air-conditioned cars and light trucks in 1987 was about 41.5 million, and the estimated usage of CFC-12 in mobile air conditioning systems (MAC) was about 120,000 tonnes, or 28% of world production (approximately 30,000 tonnes in original equipment manufacture and approximately 90,000 tonnes in servicing existing vehicles). Table 2.5 shows the regional breakdown of demand within the MAC sector.

TABLE 2.5

1987 Mobile Air Conditioning Demand

Region	Number of Vehicles	Number of MAC Units
Africa	500,000	300,000(60%)
Asia (except Japan)	2,400,000	1,300,000(54%
Japan	5,600,000	4,300,000(78%)
Europe	13,900,000	1,300,000(9%)
Middle East	600,000	40,000(60%)
Latin America	1,500,000	900,000(60%)
USA and Canada	17,000,000	11,300,000(66%)
World	41,500,000	19,800,000(48%)

Source: UNEP, 1989

2.3 SECTORAL CFC UTILIZATION IN AFRICA

CFC-11 and CFC-12 comprise the bulk of the refrigerants used in Africa. HCFC-22 is also used as a refrigerant in a number of air conditioning applications but is not included in the Montreal Protocol. A sectoral breakdown of CFC consumption in Egypt is shown in Table 2.6

TABLE 2.6

SECTORAL BREAKDOWN OF CFC CONSUMPTION BY CFC TYPE IN EGYPT, 1989 (tonnes)

Sector	CFC-11	CFC-12	CFC-113	CFC-114	ALL CFCs Combined
Refrigeration and A/C	526(37%)	379(44%)		13(21%)	918(39%)
Aerosols	60(4%)	486(56%)		50(79%)	596(25%)
Plastic foams	849(59%)				849(36%)
Solvents			12(100%)		12(1%)
TOTAL	1,435	865	12	63	2,375

Source: Egyptian Environmental Affairs Agency, 1990

Table 2.7 shows sectoral CFC consumption in Kenya for the year 1989 and gives a breakdown of CFC-11 and CFC-12 consumption within the refrigeration and air conditioning subsector.

By way of a comparison with a developing country outside Africa, Table 2.8 shows a sectoral breakdown of CFC consumption in Mexico for the year 1990.

TABLE 2.7

SECTORAL AND SUB SECTORAL BREAKDOWN OF CFC-11 AND CFC-12 CONSUMPTION IN KENYA, 1989 (tonnes)

Sector	CFC-11 and 12 Consumption	Refrigeration subsector	CFC-11 Consumption	CFC-12 Consumption
Refrigeration and A/C	60	Domestic		4
		Commercial		5
Aerosols	150	Cold Storage		28
Plastic Foams	30	Transport		<1
Total	240	Air conditioning		<1
		Mobile Air Conditioning		4
		Flushing Cleaning	10	
		Unallocated		8

Source:UNEP, 1990

TABLE 2.8

SECTORAL BREAKDOWN OF CFC-11 AND CFC-12 CONSUMPTION IN MEXICO, 1990 (tonnes)

SECTOR	CFC-11	CFC-12	TOTAL
Refrigeration and A/C	840(39.9%)	3,912(70.1%)	4,752(61.8%)
Aerosols	207(9.8%)	786(14.1%)	993(12.9%)
Plastic Foams	1,059(50.3%)	570(10.2%)	1,629(21.2%)
Sterilization		310(5.6%)	310(4.0%)
TOTAL	2,106	5,578	7,684

Source: SEDUE, 1990

The key point regarding the background to this study is that CFC consumption in African countries is very low at the present time. principal determinants of the consumption level and its rate of growth over the coming decade will include the following:

- Population growth.
- Income levels and distribution.
- Trends in consumer tastes.
- Access to electricity.
- Technology choice.
- Service and maintenance of CFC-using equipment.
- Quality control in equipment manufacture.
- The introduction and success of programmes to reduce consumption.

An approximate breakdown of typical CFC utilization in developing countries is shown in Table 2.9.

TABLE 2.9

CFC UTILIZATION BY SECTOR

SECTOR	UTILIZATION	SUBSECTOR	UNIT CONSUMPTION AND COMMENTS
Refrigeration and air conditioning	40-60% all CFCs; mainly CFC-12; HCFC-22	Domestic fridges and freezers	0.2-0.3 kg CFC/unit: mainly in a few affluent urban households; very few in rural or less affluent urban households
		Commercial refrigeration	0.5-10 kg CFC/unit, cold stores 1000 kg CFC/unit; cold storage and retail food storage comprise the largest refrigeration subsector

Table 2.9 contd..

	Domestic/room air conditioning	*room air conditioning units; 1-2 kg HCFC-22/unit; window-fitted systems are often used in offices as well as affluent residential properties (a very small proportion of all dwellings)*
	Commercial/building air conditioning	*reciprocating systems: 100-200 kg CFC-12/unit; centrifugal systems: 500-1000 kg CFC-11/unit*
	Mobile air conditioning	*1-2 kg CFC/car, 10-20 kg CFC/bus, 50 kg CFC/train: car, bus and train air conditioning systems account for a very small proportion of demand*

		Recharging	*CFC demand for equipment recharging exceeds the demand for original equipment manufacture in many developing countries*
Aerosols	*10-40% all CFCs; CFC-11, CFC-12*	*Pesticides* *Cosmetics and household products*	*<0.1 kg CFC/unit: CFCs are being replaced by liquid petroleum gas (LPG) as a propellant in Africa as they have been in developed countries over the last ten years; demand for CFCs in this sector is falling, therefore, particularly in the pesticides subsector*
Plastic foams	*10-40% all CFCs; mainly CFC-11*	*Polyurethane* *Polystyrene*	*flexible polyurethane foam is used principally in mattresses and furniture; rigid polyurethane foam is used in insulation and packaging applications* *used in insulation and packaging applications, and in flooring, ceilings and wall linings*

Solvents	*<10% all CFCs; CFC-113; CCI.*	*Degreasing*	*CFC-113 is used as a cleaning agent in the electronics and metal finishing industries; Carbon tetrachloride and methyl chloroform (1,1,1-trichloroethane) are commonly used in this sector as well as CFCs*

Source:case studies on the costs of complying with the Montreal Protocl in Egypt (EEAA, 1990), India (GOI Ministry of Environment and Forests, 1990), Kenya (UNEP, 1990) and Mexico (SUDUE, 1990).

3. SOURCES, COLLECTION AND MANAGEMENT OF NATIONAL CFC UTILIZATION DATA

In this section we develop an outline of a national economic audit for CFC consumption in African countries. This includes information regarding sources of data and its collection and analysis. Lastly we discuss the structure of a regional data base on CFC utilization oriented towards policy-making.

3.1. OUTLINE OF A NATIONAL AUDIT

3.1.1. Introduction

In simple terms, to estimate CFC consumption in any given year, we need to know the amount of CFCs imported or manufactured domestically, less the amount exported or destroyed. This figure is then added to the stock of CFCs to estimate the total consumption for that country. Estimation of these figures can be made from the demand side (measuring quantities of CFCs purchased in the country) or the supply side (measuring quantities of CFCs manufactured or imported). Data must be collected for each CFC and by each sector to be aggregated at the national level. The output of a national audit should provide data in the format shown in Table 3.1.

3.1.2. The Demand Side Approach

Demand within each sector may be estimated by building up subsectoral demand profiles for CFCs by type from manufacturers' and suppliers' information. In general, the refrigeration and air conditioning sector tends to be the largest in African countries and this pattern is likely to be emphasized over the coming decade. Problems in estimating demand in this way arise where different products require different charges of CFCs or require recharging more or less often than other products. A better method of estimation is to audit the number of existing refrigerators and air conditioning units and the use of CFCs in aerosols, foam-blowing and solvent applications by carrying out surveys.

3.1.3. The Supply Side Approach

Demand for CFCs in most African countries is satisfied wholly by import. The importation of chemical products or appliances containing CFCs accounts for a proportion of total CFC imports, the exact proportion varying from country to country depending on the size of the local product assembly industry. Most refrigeration and air conditioning equipment in African countries is assembled from imported knock-down kits. African countries which support an indigenous refrigeration equipment manufacturing or assembly industry still rely on imported CFCs or assemble imported components containing CFCs.

3.2. DATA SOURCES AND COLLECTION

3.2.1. Demand Side Data Sources

Market information may be obtained from local suppliers of imported or locally assembled CFC-using equipment to give an estimation of the demand for CFCs within an African country. Historical growth in demand may be projected to 1977 to given an estimation of the baseline CFC consumption as defined by the Montreal Protocol. This will give an indication of the likely scope and extent required of any programme introduced to collect, reycle and/or dispose of CFCs.

Information on the demand for CFCs within the major sectors of the market may be sought from manufacturers or suppliers of the following equipment or ozone-depleting substances.

- Refrigeration equipment and refrigerants.
- Air conditioning units and refrigerants.
- Aerosols and propellants.
- Plastic foams and foam-blowing agents.
- Solvents and degreasing agents.

The best sources of information regarding CFC market sectors in Africa are the CFC manufacturers such as Du Pont and their subsidiaries in the United States and Europe and ICI in the UK. These major manufacturers are hesitant to release information on CFC markets because of commercial and public relations sensitivities, although they have provided the appropriate data to UNEP under the terms of the Montreal Protocol.

Local commercial enterprises such as assemblers and distributors of CFC-using equipment from knock-down kits may be able to provide country-specific sectoral information. It would be useful to ascertain the market split between locally assembled and foreign-built equipment. Suppliers could also include enterprises such as importers, main agents, wholesales or installers. The suppliers' sector of CFC users may be highly fragmented and disorganised, and information they provide is unlikely to be as complete as data collected from manufacturers.

3.2.1. Supply Side Data Sources

For countries which neither manufacture nor destroy CFCs, consumption is defined as imports minus exports. Data on imports and exports of CFCs and products containing CFCs are not readily available from African government departments, nor wholly reliable. Available supply data can be correlated with information on demand to given an overview of total national CFC utilization. It is necessary to take re-exports into account.

In view of the differences in ozone depleting potential of the five CFCs in Group I of the Montreal Protocol's list of controlled substances, supply information should be sought for each of them. Information regarding imports and exports of CFCs is often held by the following sources:

* Importing country governments

  Where available from African government departments such as departments of trade and commerce or offices of statistics, data and information on CFC supply and consumption are often poor and unreliable.

* Exporting country governments

  The Export Centre within the UK Department of Trade and Industry is a market intelligence unit which provides country by country information on exports of industrial products including CFCs from the UK and other exporting nations. Information regarding African countries however is not always up to date.

* CFC manufacturers

  Major CFC manufacturers also record data on exports to developing countries which they will divulge to UN organizations.

National CFC supply data may be obtained from one or more of these sources and correlated with demand data obtained from equipment manufacturers and CFC suppliers. Such information, however, is not easily sought. Manufacturers such as ICI are unwilling to divulge information to any other than the appropriate national and international authorities for commercial reasons. Manufacturers, exporting and importing country governments that are Parties to the Montreal Protocol are obliged under its terms to collate and make available to the Protocol Secretariat in Nairobi information on national CFC production, import and export.

3.2.2. Surveys

A more accurate estimation of national CFC consumption in an African country will require surveys of both suppliers and consumers to be undertaken. Surveys should be designed to collect the following data relating to CFC consumption by sector.

- The number and CFC type, capacity and recharging requirements of domestic and commercial refrigeration units in use: retail food and drink chillers will comprise the largest subsector within this category.

- The number and CFC type, capacity and recharging requirements of domestic and commercial air conditioning systems in use: commercial units will again comprise the overwhelmingly predominant subsector.

- The number and CFC type, capacity and recharging requirements of mobile air conditioning systems in use: the total number of units would be expected to be extremely small as a proportion of the total number of vehicles (cars, buses and trains).

- The number and CFC requirements by type of aerosol manufacturers and importers.

- The number and CFC requirements by type of plastic foam manufacturers and importers.

- The number and CFC requirements by type of enterprises using CFCs as solvents.

Survey methodology must be designed to yield statistics representative of the country as a whole. The survey must consider the following details:

- The degree of accuracy required and most appropriate surveying techniques.
- The sample sizes and areas to be targeted.
- The appropriate balance between urban and rural, domestic and commercial or industrial sectors, and social strata within each sample population.
- Size and representativeness of the sample populations in comparison to the parent population.
- The multipliers employed to convert raw sample data into national data.

3.3. *DATA BANK FOR REGIONAL POLICY ANALYSIS*

Information on CFC utilization in African countries should be collated in order for formulate the most effective regional and local policies to introduce CFC phase out programmes. A regional, policy-making oriented data bank should contain separate data for each country derived from the results of national audits. Table 3.1. outlines the information requirements for a regional data bank to be used in policy-making.

Principal economic and policy parameters should also be included such as population, economic growth and CFC taxes, with summary statistics showing total CFC utilization, percentage change, CFC consumption per capita and CFC consumption per dollar GNP. A data bank of this type can be used as a decision-making tool for policy-makers. The data may be stored on computer and accessed to provide information regarding the likely impacts of potential programmes and policies and forecast CFC consumption under different policy regimes.

TABLE 3.1.

CFC NATIONAL AUDIT AND REGIONAL DATA BANK INFORMATION REQUIREMENTS

	CFC-11	CFC-12	Other CFCs
Refrigerants (inc. air con.)	•annual quantity consumed •annual growth in demand •types and number of refrigeration and air conditioning equipment used •physical distribution of end-users •major equipment manufacturers, importers, suppliers and servicing companies •recharging requirements of equipment	•annual quantity consumed •annual growth in demand •types and number of refrigeration and air conditioning equipment used •physical distribution of end-users •major equipment manufactuers, importers, suppliers and servicing companies •recharging requirements of equipment	•ODP of annual quantity consumed •annual growth in demand •types and number of refrigeration and air conditioning equipment used •physical distribution of end-users •major equipment manufacturers, importers, suppliers and servicing companies •recharging requirements of equipment
Aerosol propellants	•annual quantity consumed •annual growth in demand •availability of hydrocarbon alternatives	•annual quantity consumed •annual growth in demand •availability of hydrocarbon alternatives	•ODP of annual quantity consumed •annual growth in demand •availability of alternatives

Foam blowing agents	•annual quantity assumed •annual growth in demand •breakdown of end-uses and availability of alternatives	•annual quantity consumed •annual growth in demand •breakdown of end-uses and availability of alternatives	•ODP of annual quantity consumed •annual growth in demand •breakdown of end-uses and availability of alternatives
Solvents	•annual quantity consumed •annual growth in demand •physical distribution of end-users •major equipment manufacturers, importers, suppliers and servicing companies	•annual quantity consumed •annual growth in demand •physical distribution of end-users •major equipment manufacturers, importers, suppliers and servicing companies	•ODP of annual quantity consumed •annual growth in demand •physical distribution of end-users •major equipment manufacturers, importers, suppliers and servicing companies

4. ANALYSIS AND IMPLEMENTATION OF PROGRAMMES OF CFC COLLECTION, RECYCLING AND DISPOSAL

4.1. INTRODUCTION

Section 4.2 outlines a proposed structure for a techno-economic analysis to evaluate programmes to collect and recycle or safely dispose of CFCs used as refrigerants. The objective of such an analysis is to identify the most appropriate and cost effective technical option to achieve a significant reduction in CFC consumption. The technical, economic and institutional aspects of CFC collection, recycling and disposal programmes are discussed in turn below. The section concludes with a methodology for carrying out such an analysis.

Section 4.3 presents guidelines and policy measures to assist the implementation of programmes to collect and recycle or dispose safely of CFCs.

4.2. Techno-economic analysis structure

The structure for a techno-economic analysis of CFC collection and recycling or safe disposal should comprise three main steps:

- An assessment of the technical feasibility of alternatives to rule out those options which are not technically feasible, either due to inappropriate requirements of the technology, the immaturity of its development, or other reasons.

- An evaluation of the economic feasibility of a programme to implement possible technical option or options to identify the most cost effective programme.

- An examination of the institutional applicability of a new technology or technical programme, and the constraints upon its effective implementation.

An evaluation of the economic feasibility of a project or programme to implement a new technology will determine its cost to the economy. A comparative evaluation of technical options will indicate the least cost alternative. it is possible that although a programme is of net benefit to the economy it still represents a cost to somebody or to some institution and is therefore never implemented. It is necessary therefore to identify any constraints upon the applicability of proposed programmes.

It is widely accepted that there is potential for environmental improvements in both the developing and the developed world which would bring positive financial returns but are not implemented. Energy efficiency measures are such a case. It may be for example that there are options that potentially result in a net benefit to the economy, but have never arisen before due to local institutional or other non-economic constraints: these must also be examined.

4.2.1. CFC Collection

Technical Considerations

Used CFCs can be collected by a refrigeration or air conditioning service company and returned to the distributor or importer. The practical logistics of collection may be simple when servicing equipment using large volumes of CFC such as reciprocating air conditioners, but the collection of waste refrigerant in small quantities (less than 10 kg) from domestic equipment and small commercial units can be problematic. In such cases the used CFCs must be transported to a central collection point before being sent for reprocessing in larger batches. The exception is the recovery of small volumes of used CFCs in mobile air conditioning systems which may be collected at a service station.

Any collection programme should satisfy a number of technical standards of operation. Leakage of refrigerant gases can occur during the transfer of CFCs from equipment to container or between containers. Most CFC emissions in fact occur during use, servicing and disposal of equipment rather than during manufacture, and it is in these stages that there is the greatest scope for measures to prevent refrigerants venting to the atmosphere. Gas bottles should be leak-proof, should not be over-filled and, as used CFCs may be contaminated with acid, must be constructed from a suitable material of sufficient thickness. Equipment which ensures that containers are emptied completely should be used.

Economic Considerations

This section lays out the steps for estimating economic costs of recovery and transfer of CFCs. The cost of collection in free markets where a recycling industry operates viably without government subvention comprises one or more of three elements:

- The price paid to the waste generator, in this case the CFC user.
- The collector's costs, including transportation cost.
- The collector's profit.

Where the refrigeration servicing company or engineer acts as the collector, the first of these costs need not necessarily arise. Indeed, the removal of used CFCs, hitherto of little or no value, may be seen as part of the service provided and paid for by the customer.

Transport costs are often the largest component of collection costs. These may be high where:

- The source of used products is diffuse, as for example domestic fridge refrigerant.
- The recycling or disposal plant is separated from the source by a large distance.
- In congested urban areas.

If the responsibility for CFC recovery is left entirely to the service company or engineer, used CFC collection is likely to develop only in certain subsectors of the market. The percentage of used CFCs recovered will inevitably depend upon their market price, which in turn will depend on the value of recycled CFCs.

Constraints upon Implementation

The costs or inconvenience of transportation to the end-user or distributor has prevented the realization of past waste recovery proposals that would have shown an overall profit. In order to overcome such barriers, the losing parties need to be compensated or the cost otherwise removed. The cost or inconvenience arises where there is no existing system for the separation and collection of a particular waste. The introduction of a waste collection system can itself affect the economics of recovery, as happened when public attitudes to wastepaper recycling in the UK underwent a dramatic change over the year 1989-90, leading to an increase in the number of collection schemes, a jump in the wastepaper recovery rate, and a consequent fall in the price of wastepaper.

4.2.2. *CFC Recycling*

Technical Considerations

The recycling of used refrigerants potentially represents a technically feasible way in which to achieve two ends:

- To reduce emissions of CFCs to the atmosphere while CFCs are still in use.

- To prolong the life of existing refrigeration and air conditioning equipment or to avoid the cost of retrofitting equipment to use HCFC-22 or another non ozone-depleting chemical after CFCs are no longer imported or manufactured.

The recycling of CFCs can bring about a significant reduction in the demand for imported refrigerants, particularly in countries where equipment is frequently recharged with CFCs. The need to recharge fridges and air conditioning units in developing countries tends to be higher than in developed countries for two reasons:

- Where equipment in developed countries is often replaced before it has reached the end of its expected lifetime, measures to prolong equipment lifetimes are often undertaken in the developing countries.

- Lack of quality control during equipment manufacture in developing countries, the use of non-hermetically sealed units, poor maintenance and heavy usage frequently result in a greater reliance upon the repair and replacement of parts.

Refrigerant recycling, therefore, in combination with improvements in the quality of equipment manufacture and assembly, potentially represents an effective way in which to reduce national CFC consumption.

The reprocessing of CFCs essentially relies upon the purification of the chemical by the same process as was employed in its manufacture, and can therefore be carried out by the manufacturer or in an appropriately equipped decontamination plant.

Alternatively, CFCs may be recovered and recycled on-site. Such systems tend to be less viable economically but offer the technical advantage of greater recycling efficiency with fewer CFC emissions to the atmosphere. A number of both on-site and off-site CFC recycling systems are currently employed:

- <u>Off-site systems:</u>

  - Built-in receiver tanks which recover refrigerant from commercial systems for transfer to a recycling facility.

  - Plastic recovery bags with capacity to collect refrigerant from two or three small-scale systems.

- <u>On-site systems:</u>

  - Dedicated recycling systems for large-scale commercial air conditioning applications which decontaminate recovered refrigerant and recharge the air conditioning equipment, either during servicing or operation.

  - Mobile units which may recover and recycle CFCs from multiple large-scale air conditioning or refrigeration systems.

  - Portable recycling machines suitable for domestic air conditioning and small-scale commercial applications.

  - Stationary recovery and recycling systems for mobile air conditioning units.

Economic Considerations

Assessment of the viability of a programme to collect and recycle refrigerant gases and allied materials containing CFCs may be carried out as steps to evaluate the following information:

- Baseline CFC demand
- Level of CFC consumption reduction attainable.
- Per kilogram cost of reduction in CFC consumption.

Assuming the national baseline demand can be estimated, the actual attainable reduction in national CFC consumption will depend on local conditions in the country in question. The number of units of a particular type of plant or piece of equipment required in order to implement a national programme will have to allow for logistical difficulties in recovering CFCs from rural areas and small-scale end-users, sub-optimal plant utilization and inevitable losses. A practicable upper limit achievable by any recovery and recycle programme might be 50% of national consumption.

The cost of a recycling programme (not including collection costs) per kilogram of reduction in CFC consumption can be calculated on the basis of capital cost plus operating cost minus value of CFC saving. Assuming the unit capital and operating costs of the plant or technology under consideration are known, as well as its likely annual output of recycled CFCs, the unit cost to the economy per kilogram of CFC reduced will be equal to:

$$\frac{\text{annualized capital cost}^{(1)} + \text{annual operating cost} - \text{value of CFCs saved}^{(2)}}{\text{annual CFC saving (unit output}^{(3)})}$$

The cost of a national recycling programme will incorporate the costs of training and institutional development as well as the costs fo the recycling technology and used CFC recovery.

Constraints upon Implementation

Potential economic benefits of recycling are often never realised because of non-economic factors. Where schemes have proved successful it has often been as a result of government intervention to overcome these barriers. Recycling in developing countries has tended to develop rarely and only where there is a clear path to an economic benefit. The repair and reuse of used or waste materials on the other hand is very much more common as the benefits are immediate and accrue directly to the user or waste generator.

(1) Annualized capital cost estimates use discounting to render present and future costs comparable within a growing economy. The effect of discounting is to reduce the cost of future actions and the value of future resources in relation to the cost of present actions and today's resources. The validity of discounting has been questioned by environmental economists for this reason, and it is therefore suggested that low discount rates are considered in evaluations of capital investments in this area. The USEPA used a 2% discount rate in their evaluation of the costs to Egypt of complying with the Montreal Protocol (USEPA, 1990).

(2) The value of CFCs saved will be equivalent to the annual plant output of recycled CFCs in kilograms multiplied by the local cost of imported CFC per kilogram.

(3) The annual output of recycled CFCs will depend on the capacity of the plant or technology in question, its percentage utilization rate over a year and its recycling efficiency.

Barriers to the successful development of recycling schemes could include the following:

- Lack of awareness of the potential benefits of recycling on the part of responsible authorities.
- Lack of recycling infrastructure such as recovery and redistribution systems.
- Lack of technical expertise to manage recycling programmes.
- Preference to invest in expanding production at the expense of less attractive recycling programmes.

4.2.3. CFC Disposal

Technical Considerations

Waste CFCs are not classified as hazardous, but should be treated as such in view of their ozone depleting potential. The safe disposal of used CFCs is technically more difficult than recycling and the service exists only in very few countries. Any disposal programme in Africa should be the subject of strict guidelines of operation, covering the avoidance of leakage and atmospheric emissions.

Economic Considerations

To evaluate the viability of a programme to dispose safely of refrigerants gases and allied materials containing CFCs it is necessary to evaluate the following information:

- Baseline used-CFC arisings.
- Level of CFC disposal attainable.
- Cost per kilogram CFC disposal.

The cost per kilogram of CFC safely disposed can be calculated on the basis of annualized capital cost plus operating cost divided by annual plant capacity times percentage utilization. Economies of scale are likely to be of critical importance. The low volume of waste CFCs in African countries may not justify the capital investment in disposal plant.

The cost of a national disposal programme will incorporate the costs of training and institutional development as well as the costs of the disposal technology and used CFC recovery.

Constraints upon Implementation

A successful safe disposal programme will probably rely on government intervention and enforced compliance. As with hazardous chemicals, this may necessitate a cradle-to-grave monitoring system which could involve complex chemical auditing procedures. The success of a CFC destruction programme could depend upon international cooperation to share the costs of a plant that disposes of used CFCs between a group of neighbouring countries.

4.2.4. Methodology

1. Information Requirements

The matrix (Table 4.1.) below suggests information requirements for the comparative evaluation of alternative options. It outlines the basic data required to conduct the techno-economic and institutional assessment.

2. Determination of Evaluation Criteria

The analysis of the techno-economic viability of proposed programmes to collect, recycle or dispose safely of used CFCs must determine whether or not a number of criteria are satisfied.

Potential programmes to collect and recycle or dispose of used CFCs must be evaluated against criteria established by the implementing agency. Evaluation criteria should be developed to measure and compare the likely impacts, cost-effectiveness and institutional applicability of such programmes. Key measures in programme determination will include the following (not necessarily in order of priority):

Technical Criteria	*Economic Criteria*	*Institutional Criteria*
•Recovery rate.	• Per kg CFC cost.	• Technical/ managerial support capability.

- Consumption reduction.
- Appropriateness
- User incentives.
- Intervention facility
- Financial support system

Information known about a programme must be evaluated against chosen criteria to determine its likely efficacy.

3. Comparative Assessment

The object of the comparative assessment is to rank options in their ability to meet evaluation criteria. The key techno-economic measure is the cost-effectiveness of a programme against its potential attainable reduction in consumption. Plotting these two variables for each option is likely to produce a curve showing diminishing returns for increasing investment. A low-cost programme such as improving the quality of refrigerator manufacture, for example, may bring about significant reductions in national CFC consumption. The introduction of CFC banks and recycling may resutl in yet a greater overall reduction at a higher per kilogram cost. A programme which disposes of the last ten percent of CFC consumption would probably be prohibitively expensive. The policy-maker must decide upon the appropriate level of expenditure to achieve the desired reduction in CFC consumption.

TABLE 4.1

TECHNO-ECONOMIC FEASIBILITY ASSESSMENT MATRIX

	collection	Recycling	Safe Disposal
Technical Feasibility	•what proportion of used CFC arisings is it technicallly possible to collect • will the collection procedure minimise CFC losses to the atomsphere? • what is the feasible recovery rate?	• what is the demand for refrigerant recharging? • do the logistics of collection justify the introduction of more complex on-site recycling systems? •what level of reduction in CFC consumption is attainable? •is the technology appropriate to the availability of technical services and expertise in the country?	• what level of CFC destruction will be attainable as a proportion of utilization? • will disposal make a significant contribution towards reducing consumption? • will there be a sufficient technical expertise to manage a safe disposal system whilst minimising atmospheric emissions?

Economic Feasibility	*• will used CFCs be of sufficient value to justify their recovery by a private collector?* *• what are the costs of recovery?* *• what are the transportation costs?*	*• what is the capital investment required?* *• what are the operating costs?* *• what is the value of CFC savings?* *• what is the per kilogram cost of CFC recycling?*	*• what is the capital investment required?* *• what are the operating costs?* *• what is the per kilogram cost of safe CFC disposal?*
Institutional Constraints	*• will any individual along the recovery chain incur an overall cost?* *• will institutional mechanisms exist to support the price of used CFCs where necessary?*	*• will the institutional capability exist to develop recycling systems and provide technical, financial or managerial support where required?*	*• does the institutional capability exist to implement cradle-to-grave CFC monitoring?* *• will the disposal system be able to serve neighbouring countries?*

A critical economic consideration will be the scale of operation (size of plant) in relation the density of used CFC arisings. This determines the catchment area for a plant and hence collection costs. Collection cost as a proportion of total cost of a programme will be of key importance.

4.2.5. The Costs of Recycling Compared with Substitution

A number of studies have been carried out, notably in Egypt and Mexico by the USEPA in association with local institutions, to evaluate the costs of reducing the consumption of CFCs and other ozone depleting substances. The data in Tables 4.2 and 4.3 give an indication of the comparative costs of substituting CFCs with safe alternatives and some of the other methods discussed in this section. It should be noted that the data, however, are not entirely comparable as they relate to costs spread over differing periods of time, and with differing environmental impacts. The Chinese data are based on a discount rate of 8% whereas the Egyptian and Mexican data are based on a 2% discount rate. it can be clearly seen, nevertheless, that costs per kilogram of CFC reduction are considerably less for recylcing then substitution.

TABLE 4.2

COMPARATIVE RECOVERY AND RECYCLING COSTS IN EGYPT, CHINA AND MEXICO

Country	Sector	Programme	Cost per kg (US$)	Total Cost (US$)
Egypt	Industrial Commercial Refrigeration	Recycle CFC-11	1.49	60,000
	Domestic Refrigeration	Reduce CFC-12 Charge	Negligible	350,000
	Mobile Refrigeration	Ice Plants for Transport of Perishables		1,200,000
	Mobile Air Conditioning	Recycle CFC-12		
		Recovery only	4.88	2,600,000
China	Mobile Air Conditioning	Recovery only		2,600,000

Mexico	Industrial Commercial Refrigeration	Recycle CFC-11	1.49	2,810,000-5,260,000
	Domestic Refrigeration	Recycle CFC-12	0.75	9,590,000-14,020,000
		Reduce CFC-12 Charge	Negligible	Negligible
	Mobile Air Conditioning	Recycle CFC-12	4.88	2,250,000-4,060,000

Sources: EEAA, 1990, NEPA, 1990, SEDUE, 1990

TABLE 4.2.(b)

COMPARATIVE SUBSTITUTION COSTS IN EGYPT, CHINA, AND MEXICO

Country	Sector	Substitute	Cost/kg(US$)	Total Cost (US$)
Egypt	Industrial/ Commercial Refrigeration	hcfc-123 FOR cfc-11	6.55	
	Mobile Air Conditioning	hcfc-134A	7.40	
	Aerosols	Hydrocarbons	0.00	negligible
	Plastic Foams	Water for CFC-11		2,000,000-3,000,000
	Solvents	Water for CFC-113	0.75	10,000

China	*Domestic Refrigeration*	*HCFC-152a*		*1,600,000*
	Industrial Refrigeration	*Ammonia*		*10,200,000*
	Aerosols	*LPG, Propane and Butane*		*5,700,000*
	Plastic Foams	*Water and HCFC-22*		*300,000*
	Solvents	*Deionised Water, Methanol and Ether*		*6,000,000*
Mexico	*Industrial/ Commercial Refrigeration*	*HCFC-123 for CFC-11*	*6.55*	*5,110,000-11,150,000*
	Domestic Refrigeration	*Ternery Blend or HFC-152a for CFC-12*	*3.20*	*13,240,000-29,890,000*
	Mobile Air Conditioning	*Ternery Blend or HFC-152a for CFC-12*	*0.00* *7.40*	*negligible* *2,040,000-5,940,000*
	Aerosols	*Compressed Gas (CO_2 or air)*	*0.00*	*negligible*

Sources: EEAA, 1990, NEPA, 1990, SEDUE, 1990

4.3. GUIDELINES AND POLICY MEASURES FOR THE INTRODUCTION OF PROGRAMMES OF CFC COLLECTION, RECYCLING AND DISPOSAL

4.3.1. Introduction

This section suggests the types of policy options available to facilitate the implementation of programmes to collect and recycle or to collect and dispose safely of CFCs. This assumes a pre-existing policy framework that imposes constraints on the consumption of CFCs or provides incentives to reduce consumption. The two key policies to reduce CFC consumption in non-producer countries will be those designed to reduce importation:

- **Import Quotas and Transferable Licences**

Restrictions imposed on the importation of CFCs are likely to increase the attractiveness of recycling. Quotas may be voluntary or enforceable by fines imposed on importers for every kilogram of CFC brought into the country over and above their quota, or rewards could be given as quotas are met or exceeded.

Alternatively, quotas may be tradeable between importers in a situation where an upper limit is imposed upon the total quantity of CFC imported by a country. Importers should be required to reduce their quota over time at least in line with the minimum reduction proposed in the Montreal Protocol. Similarly, regional agreements may be drawn up whereby an upper limit is imposed on CFC consumption by a group of countries, and governments are free to trade their quotas within the regional framework.

The implementation of either type of system in African countries may present a number of problems. It is important that the governments of countries which are Party to the Montreal Protocol should be involved from the earliest stages in the formulation of policy in this area in order that it is not perceived to be imposed from the top down.

- **Import Tariffs and CFC Taxes**

Taxes and excise tariffs imposed on CFC imports by national governments are also likely to have the desired effect of increasing the incentive to recover and recycle. In the United States, CFC taxes are on a scale reflecting the ozone depleting potential (ODP) of the CFC in question, and increase over time. Where taxes are applied to imported CFCs, recycled CFCs could be exempt or be subject to a different tax structure.

4.3.2. Policy Options

Legislation

Command and control measures imposed by national governments can provide a framework to introduce programmes to recover and recycle or dispose safely of used CFCs. National legislation may be drafted banning the disposal of CFCs other than by approved means or forbidding the use of new CFCs for particular purposes. It is unlikely however that legislation alone can provide sufficient impetus to ensure the success of newly introduced programmes.

Market Incentives

Even if a legislative framework exists to prevent used CFCs being vented to the atmosphere, the end-user may still be inclined to throw away used CFCs rather than collect them for recycling or disposal. In order to make a CFC collection and recycling or disposal programme work it will be necessary to create a market for used CFCs. In general, users and consumers of resources in developing countries are very responsive to economic incentives. Supporting the price of used CFCs may be required to maintain a recovery rate sufficiently high for a collection programme to be effective.

CFC Banks

CFC banks can provide a focal point through which both economic instruments as well as command and control measures may operate. Establishing a market is most easily done through the establishment of CFC banks created for the purpose. The CFC bank can act as a seed from which a recycling or disposal programme would develop. Its establishment would:

- create a convenient central collection point for recovered CFCs;
- control and direct the recycling and reuse of recovered CFCs towards priority sectors of the market such as refrigerant recharging, or to ensure recovered CFCs are safely disposed;

- control the price of recycled CFCs by government intervention, if necessary, through supporting the price of used CFCs and possibly subsidising the cost of recycled CFCs to make them more attractive to end-users.

It is important to realize that, following the creation of a market, the market be controlled to achieve the objectives of its creation. This implies the need for an enforceable regulatory framework whereby the CFC bank or recovery agency has an obligation to collect used CFCs. CFC banks should also be subject to strict quality assurance and control measures to restrict fugitive emissions to the atmosphere (see next section) as well as to maintain the quality of recycled CFCs.

Financial Support

The establishment of a development fund within African party nations could enable the provision of financial assistance for capital construction costs of recycling facilities such as CFC banks and operating costs of recovery and recycle programmes. The fund could also provide the means of meeting the costs of importing new technology or equipment. Finance for the development fund could be provided in part by CFC taxes and import tariffs. Such funds would initially rely on multilateral or bilateral aid.

4.3.3. Training Measures and Quality Control

The efficiency of recovery and recycling programmes will be an important factory in their success. Programme personnel should be qualified as trained refrigeration engineers as far as possible in order to minimise fugitive emissions during servicing and CFC recovery and minimise waste during the CFC recovery, decontamination and reuse cycle. Collection of used CFCs should be carried out by authorized enterprises as far as possible and recycling should be carried out by qualified personnel and approved facilities only. Improvements in the quality of locally manufactured refrigeration and air conditioning equipment would also help to retain existing CFCs in service for longer periods.

4.3.4. Timing of Actions

The India Case Studies

The Development Alternatives (New Delhi) study of the costs to India in meeting the terms of the Montreal Protocol assumes that no capital costs would be incurred until 1997 and that the vast proportion of the total cost would arise from the early replacement of refrigeration and air conditioning equipment after CFCs are no longer available for recharging [1]. These findings assume no action is taken to meet the demand for CFC through recycling. The timing of a recovery and recycling programme to reduce CFC consumption is likely therefore to have an affect upon the overall cost to a developing economy of the phasing out of CFCs.

The UK Overseas Development Administration (1990) study of the cost to India of complying with the Montreal Protocol recommends that early action be taken to introduce recycling programmes (ie. before 1996, the Protocol baseline year) for two reasons:

- The overall cost to the national economy of phasing out CFC consumption will be less, due to avoidance of the early cost burden of replacing CFC-using capital equipment with non-CFC capital equipment during and after the CFC phase-out period.

- The overall emission of CFCs to the atmosphere will be less as a proportion of the 1996 baseline and subsequent demand for CFCs will be met by recycling.

Table 4.3 illustrates how CFC recycling would make a significant economic contribution towards complying with the Montreal Protocol in India, particularly if action to introduce a recycling programme were undertaken earlier than 1997 rather than later.

TABLE 4.3

ECONOMIC COSTS TO INDIA OF REDUCING CFC CONSUMPTION (L million)

		No recycling	Significant Recycling
Early Action	Low Demand High Demand	265 330	170 220
Late Action	Low Demand High Demand	660 755	400 440
Source:	GOI, 1990		

[1] Markandya A, 1990, The Cost to Developing Countries of Entering the Montreal Protocol, see Ref.9

4.3.5. Implementation Support

The introduction of policies to reduce CFC recycling in African countries is likely to present a number of implementational difficulties. It would probably be of some benefit therefore to strengthen the institutions responsible for programmes to collect, recycle or destroy used CFCs. If lacking the technology and technical skills to implement such programmes effectively, it is likely that the responsible authorities also lack the necessary experience and management skills. A proportion of the aid provided to African governments therefore might usefully be in the form of training and other institutional development exercises.

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